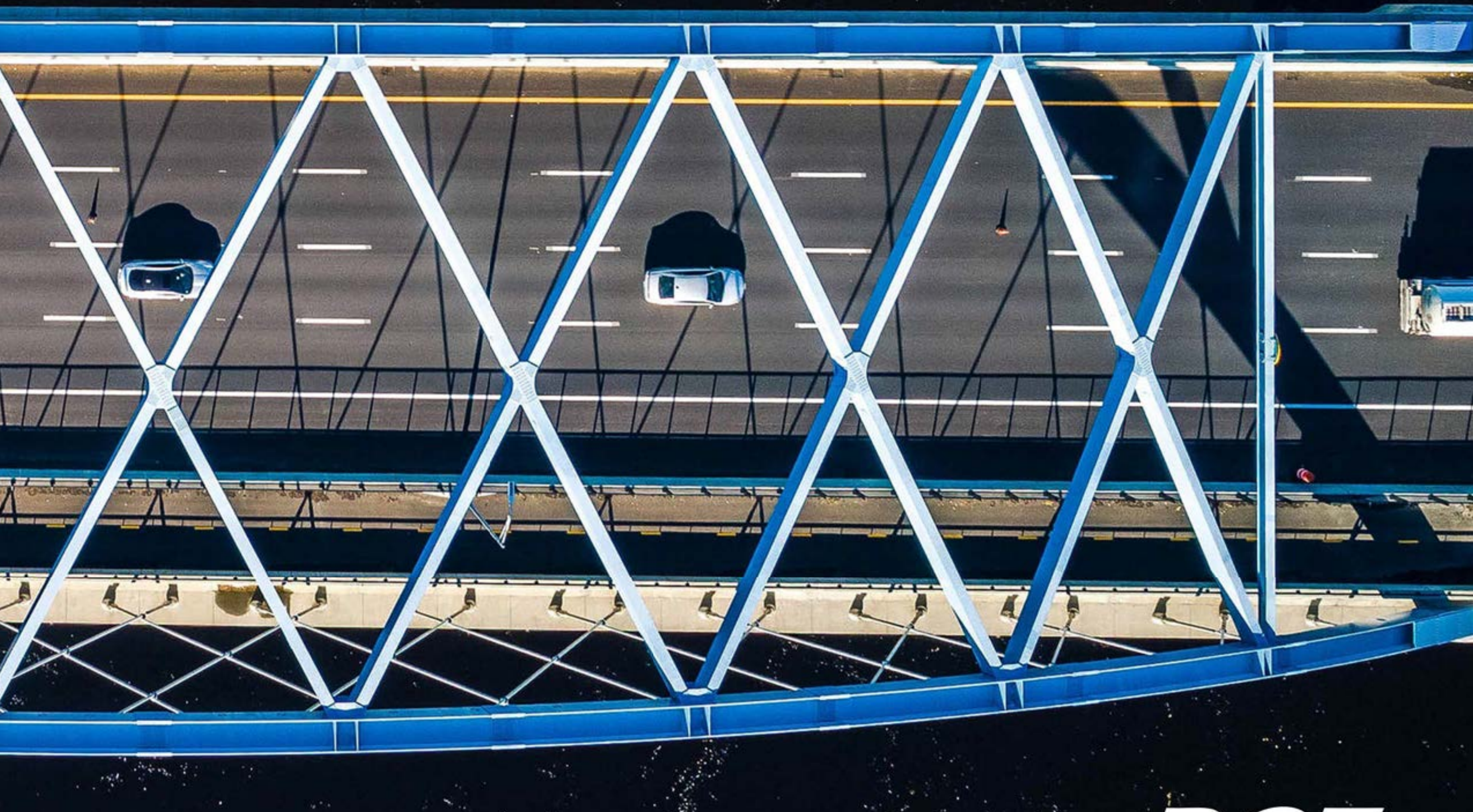
TRANSPORTATION ASSET MANAGEMENT PLAN



September 2019

massDOT
Massachusetts Department of Transportation

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EXHIBITS

1. INTRODUCTION

1.1 Organization of this Plan

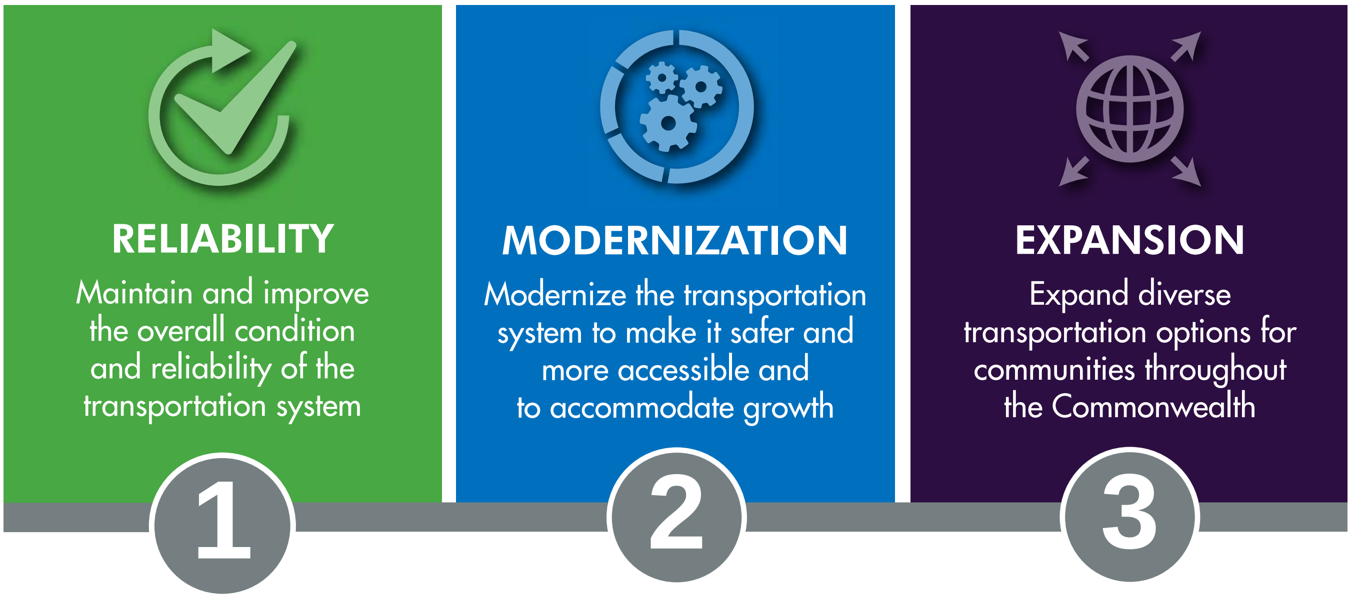
The "Final Rule" that was codified and announced on October 24, 2016 (23 CFR PART 515.7) by the Federal Highway Administration (FHWA) calls for state departments of transportation (DOTs) to develop and implement a **risk-based asset management plan with a 10-year planning horizon** with respect to **all of the bridges and pavement** that are in the **National Highway System** (NHS) inventory. The Final Rule also established the minimum process elements state DOTs must use to develop their asset management plans.

This Transportation Asset Management Plan (TAMP) fulfills these reporting requirements. Chapters 2 and 3 review the condition, life cycle status, investment outcomes, process improvement, and value of NHS **bridges** and **pavement**, respectively. The chapters that follow describe the Massachusetts Department of Transportation (MassDOT)'s **financial plan** and **risk management** strategy, and the final chapter reviews transportation assets that are particularly vulnerable following declared emergencies such as severe weather.

1.2 Goals and Objectives for this Plan

MassDOT was formed in 2009 to oversee and support the movement of people and goods within the Commonwealth. MassDOT's mission is to deliver excellent customer service to people traveling in the Commonwealth by building, maintaining, and managing a transportation network that is safe, reliable, robust, and resilient, and in doing so to provide a transportation system that can strengthen the state's economy and enhance quality of life.

MassDOT's overarching investment strategy is reflected as three planning priorities: **reliability**, **modernization**, and **expansion**.



Reliability and **modernization** investments are forecasted to account for **over 90 percent** of the Highway Division spending in the 2020 to 2024 MassDOT Capital Investment Plan (CIP).

This plan is designed to support and inform Highway Division reliability investments (specifically within the major asset classes of bridges and pavement) by applying asset, performance, and risk management processes. In applying these processes, MassDOT intends to:

- Define Highway Division asset management processes.
- Summarize best available data related to current and future asset condition.
- Analyze current and future performance through our state and Federal performance targets.
- Identify alternative investment strategies to achieve and sustain an asset state of good repair over asset life cycle at minimum practical cost.
- Mitigate risks to performance.

The goals of this plan were developed in the context of the national goals[1] developed by Congress to measure outcomes of the Federal Highway Program. These national goals address seven key transportation considerations:

- **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 National Highway System.

1 https://www.fhwa.dot.gov/tpm/about/goals.cfm.

- **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.

MassDOT's TAMP focuses on infrastructure condition, which impacts performance in other goal areas, such as safety and environmental sustainability. Appropriately managing infrastructure condition, as through the risk-based methods outlined here, is thus likely to simultaneously improve performance across multiple goal areas.

1.3 Relevance of this Plan

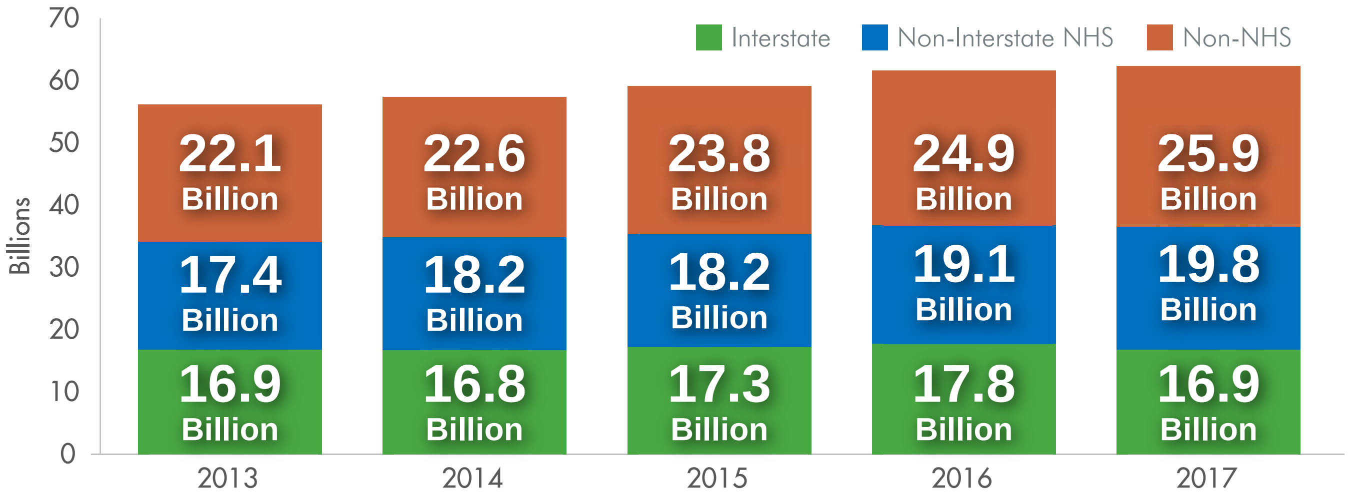
This plan is designed to be responsive to state and federal regulations that require MassDOT to have a performance-driven strategy for the preservation of highway infrastructure. This plan provides strategies for the preservation of bridges and pavements on the NHS and state-owned infrastructure, and is intended to compliment other planning documents, including the Massachusetts Freight Plan[2] and Congestion in the Commonwealth 2019,[3] to inform the investment strategy for overall system performance.

Federal asset management regulations are primarily concerned with the NHS, whereas state responsibility extends beyond it. In order for this document to serve as a **comprehensive reference** for the Federal Highway Administration (FHWA), and transportation stakeholders at the state level, this plan **includes information for bridges and pavement on the NHS and beyond**. The needs and investments identified within this document are intended to inform capital planning at the state level, while simultaneously providing insight of Massachusetts Asset Management to a national audience.

The NHS in Massachusetts accounts for 14 percent of statewide lane mileage and includes the Interstate system as well as major non-Interstate roadways. NHS bridges account for 44 percent of the total statewide bridge inventory by count, but given the geometric character of the NHS, these structures account for 70 percent of overall bridge area.

The most common measure of traffic volume is vehicle miles traveled (VMT). As of 2017, 58.6 percent of VMT takes place on NHS roads, inclusive of interstates and non-interstates. Exhibit 1.1 illustrates VMT on the NHS versus on all roads in Massachusetts since 2013.

Exhibit 1.1 VMT in Massachusetts, *2013-2017*



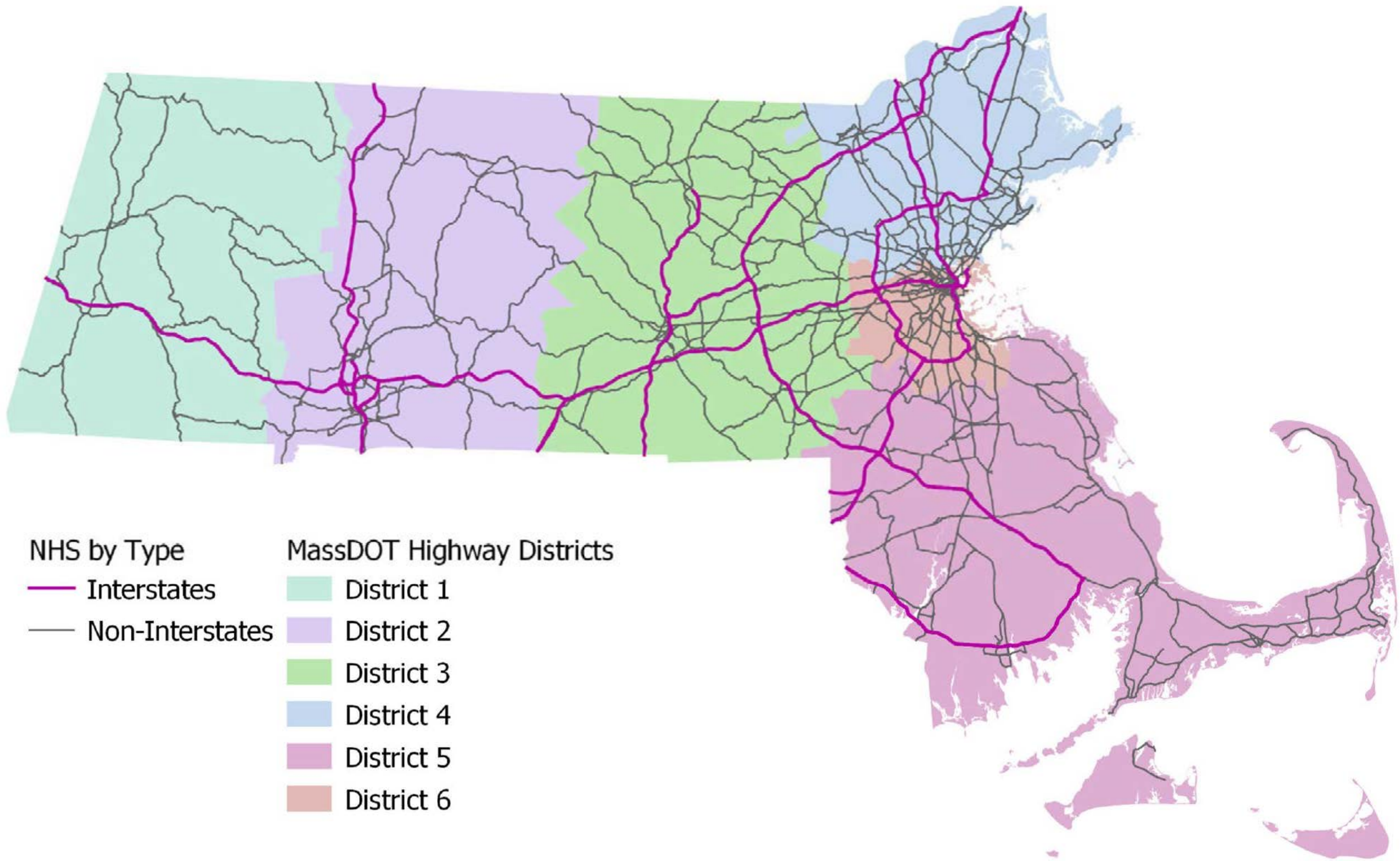
Source: Highway Performance Monitoring System (HPMS), Table VM-3, first available in 2012.

Maps of the NHS in Massachusetts by highway system and by jurisdiction are shown in Exhibits 1.2 and 1.3. A map of MassDOT-owned roadways and bridges which is shown in Exhibit 1.4.

2 https://www.mass.gov/service-details/freight-plan.

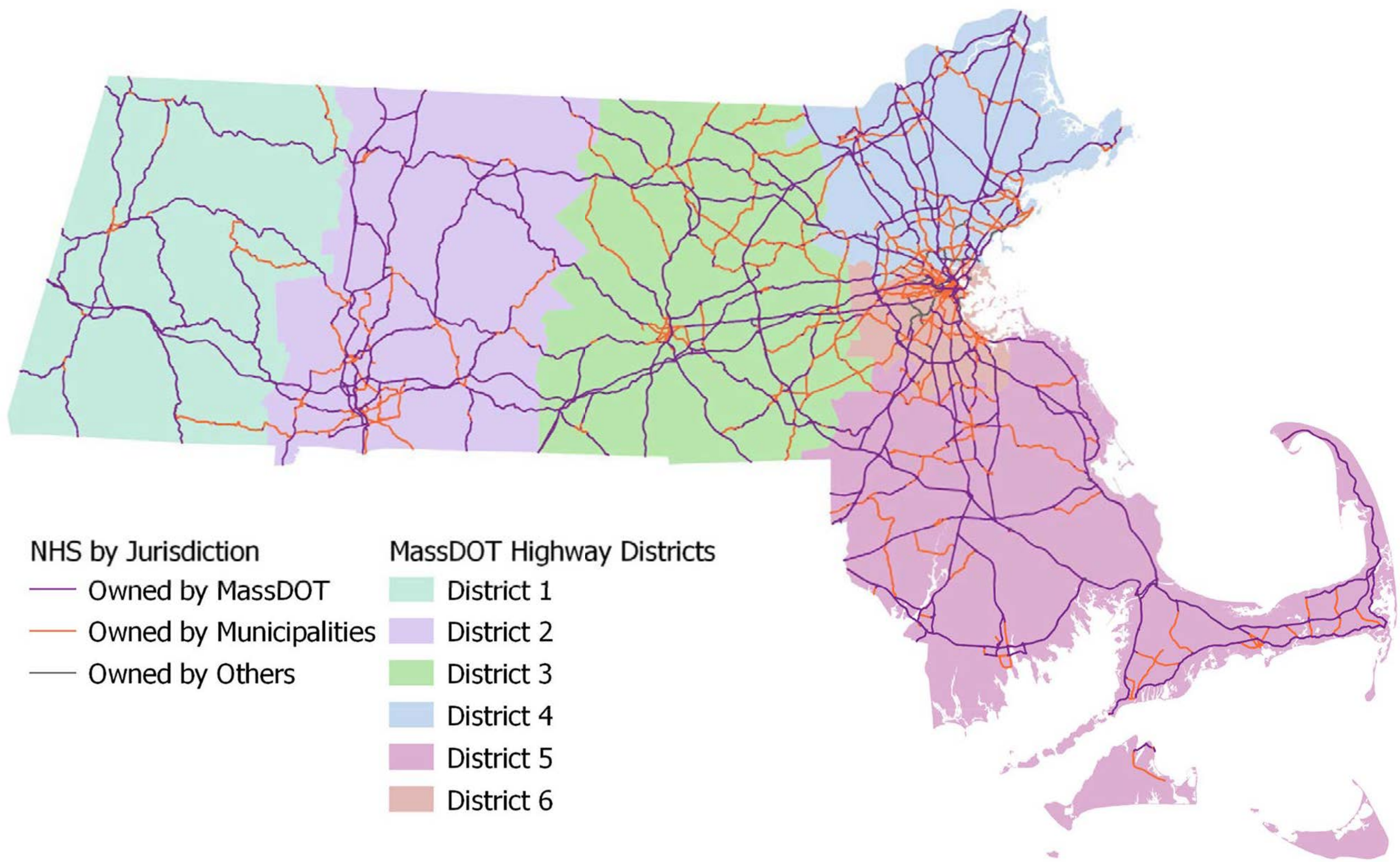
3 https://www.mass.gov/service-details/congestion-in-the-commonwealth-2019.

Exhibit 1.2 Map of the NHS in Massachusetts, *By Roadway System*



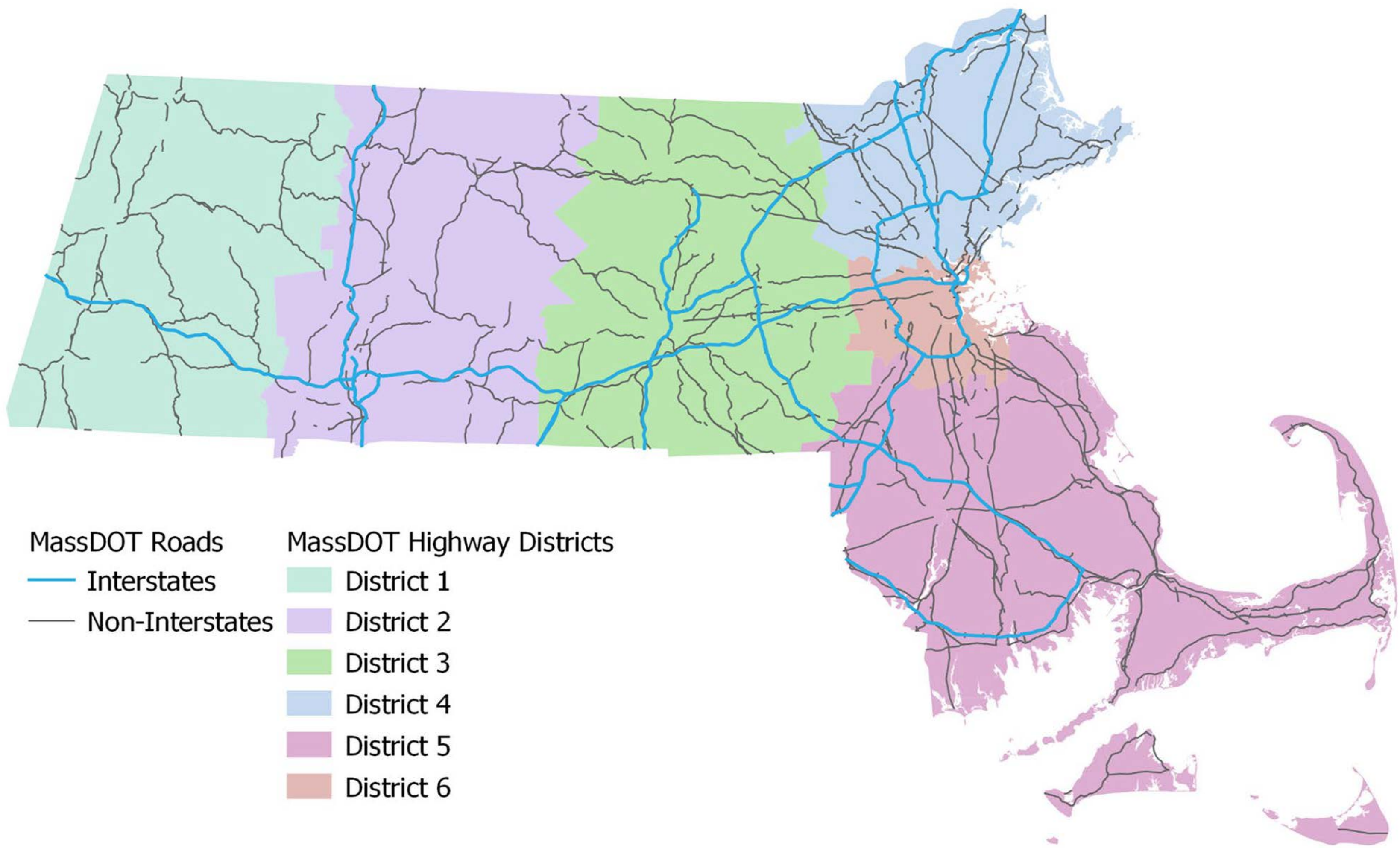
Source: 2018 Road Inventory File.

Exhibit 1.3 Map of the NHS in Massachusetts, *By Jurisdiction*



Source: 2018 Road Inventory File.

Exhibit 1.4 Map of MassDOT-Owned Roadways, *By Roadway System*

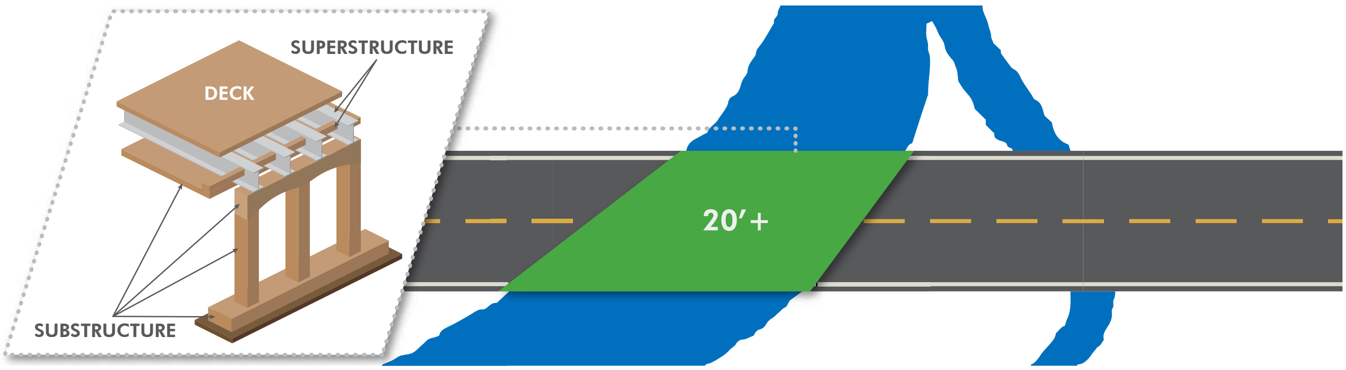


Source: 2018 Road Inventory File.
Note: Excludes some ramps and access roads for visual clarity.

2. BRIDGES

The National Bridge Inspection Standards (NBIS) define a bridge as a structure with a span length of over 20 feet. For the purposes of inventory and condition, bridges are typically comprised of three components. These components are deck, superstructure, and substructure, as shown in Exhibit 2.1.

Exhibit 2.1 Definition of a Bridge



MassDOT is responsible for the inspection, prioritization, and funding of capital projects on all state and municipally-owned bridges. Municipal owners are responsible for operation and maintenance of bridges within their jurisdiction. A table with count and area of bridges by owner is provided in Exhibit 2.2.

Exhibit 2.2 Count and Square Footage of Bridges by Owner

JURISDICTION	TOTAL – COUNT	TOTAL – FT^2	NHS – COUNT	NHS – FT^2
Total	**5,250**	**44,854,831**	**2,263**	**29,659,839**
MassDOT	3,497	37,702,444	2,183	28,687,830
Municipalities	1,633	4,350,268	73	897,067
MBTA	74	1,998,342	3	33,158
Massport	34	784,835	2	39,527
DCR	4	3,409	2	2,257
Other State Agency	8	11,641	0	0

Source: MassDOT Bridge Inspection Management System, May 2019.

As noted, approximately 44 percent (2,263 bridges) of the Massachusetts National Bridge Inventory (NBI) are on the NHS; however, due to the geometric requirements of the higher speed and multilane facilities typified by the NHS, over 70 percent of the bridge area is located on the NHS.

Within MassDOT, bridges are managed jointly by headquarters and regional District offices. Generally, the District offices manage the operation and maintenance of bridges, and headquarters focuses on planning, designing, and delivering projects to construction, at which point the district offices manage actual construction. Inspections are jointly managed between the Boston-based State Bridge Inspection Engineer and the District Bridge Section.

A summary of Bridge Section program governance is provided in Exhibit 2.3.

Exhibit 2.3 Division of Responsibility for Bridges within MassDOT

FUNCTION	HEADQUARTERS FUNCTION	DISTRICT FUNCTION
Inspect Bridges	» Oversee inspectors (double appointment). » Manage inspection contracts, dispatch some contractors. » Call for emergency inspections. » Set standards for inspection frequency. » Perform quality assurance/quality control (QA/QC) on inspection reports.	» Assign monthly list of structures to inspectors. » Request contracted inspections when needed. » Perform QA/QC on inspection reports.
Maintain Bridges	» Manage FHWA preservation funds. » Develop standards for preservation of bridges.	» Evaluate inspection reports and identify deficiencies. » Prioritize deficiencies for treatment and select treatment. » Manage maintenance contracts and administrate work.
Design Capital Projects for Bridges	» Prioritize structures for capital investment. » Allocate funding for capital investment. » Provide and procure design services for capital projects. (Shared)	» Provide feedback to headquarters on prioritization.
Manage Bridge Data	» Administrate, procure, and develop data systems (Bridge Management System and Pontis).	» Manage hard copy work orders, work logs, and informal spreadsheet tools.
Rate Bridges for Maximum Load	» Evaluate and recommend load ratings. (Primary)	» Evaluate and recommend load ratings. (Based on inspection)
Provide Geotechnical and Hydraulics Support to Projects	» Perform geotechnical and hydraulic evaluations for capital projects.	» None.
Evaluate Metals for Use on Bridges	» Perform materials testing on metals for bridge use, evaluate suitability.	» None.

2.1 Tracking Bridge Condition

2.1.1 Bridge Condition Measures

MassDOT defines bridge condition using the 9-point NBIS scale shown in Exhibit 2.4, where higher values indicate better condition. "Good" condition begins at a rating of 7, and "Poor" is defined as "structurally deficient" (SD), a rating of 4 or lower. In between the ratings of "Good" and "Poor," MassDOT assigns two condition states: "Satisfactory" and "Fair," whereas the NBIS considers this range to be "Fair." The "Satisfactory" rating is useful for accounting for improvements that do not bring a "Fair" structure to "Good," but has a positive affect on the structure. A marginal improvement is a common outcome from maintenance and preservation actions.

The condition rating of a bridge is determined by the lowest scoring component (deck, superstructure, substructure, or culvert).

Exhibit 2.4 NBI Condition Rating Scale for Bridge Elements

SCORE	MASSDOT NAME	DESCRIPTION	
		Structure	Culvert
9	Good	Pristine condition.	No deficiencies.
8		No problems noted.	Insignificant scraping.
7		Insubstantial flaws.	Superficial deterioration.
6	Satisfactory (NBIS Fair)	Minor deterioration.	Light deterioration.
5	Fair (NBIS Fair)	Elements sound, some defects.	Moderate deterioration.
4	Poor	Advanced defects.	Major disintegration or distortion.
3		Local failures, cracking begins.	Excessive disintegration or distortion.
2		Support failure, closure possible.	Damage to roadway above.
1		Elements moving, bridge closed.	Closed, repair could enable light use.
0		Out of service, beyond repair.	Closed and replacement necessary.

Source: Adapted/shortened from Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges, FHWA PD 96-001, 1995.

2.1.2 Collecting Bridge Condition Data

At minimum, all NBI bridges are inspected every two years. Bridges in poor condition are inspected annually or biannually based on the degree of deterioration.

MassDOT also has an inventory of smaller-span structures with 10- to 20-foot spans which are referred to as "Massachusetts Bridges" or "BRI Structures," and 4- to 10-foot structures that are classified as culverts. NBI structures are the priority for MassDOT's inspection program, but MassDOT also completed a full inventory and condition assessment for BRI structures in 2018. MassDOT performs culvert inspections in advance of pavement resurfacing projects and has also developed a strategy using geomorphology to identify and prioritize existing culverts that are vulnerable to storm damage. Identifying these less resilient structures provides opportunities for project bundling. Identifying these less resilient structures provides opportunities for project bundling with other corridor projects

District inspection teams and contractors carry out inspections in full accordance with NBIS requirements. Inspection reports include pictures, drawings, and other visual aids. District offices generally use in-house teams for the majority of inspections and assign "complex" structures to contractors. To inspect the underwater portions of bridges, MassDOT maintains an Underwater Operations Team (UOT).

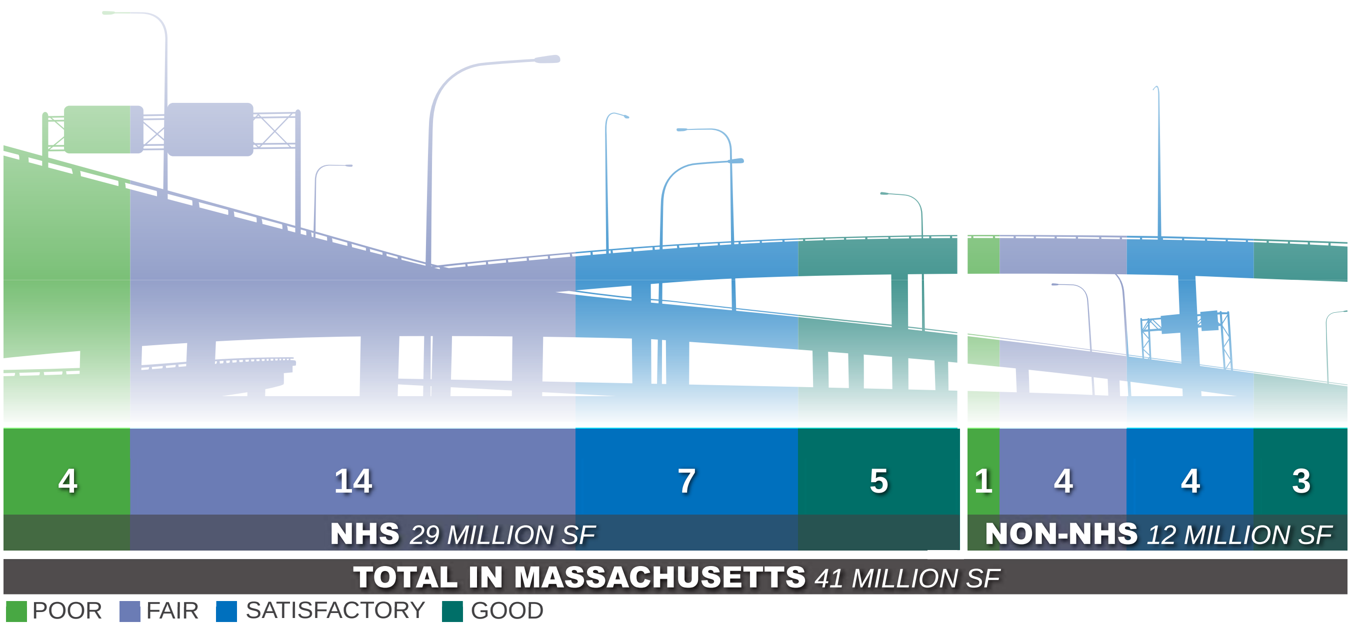
Bridge inspection data is stored electronically in the MassDOT *Bridge Inspection Management System (BMS)*. Reports are directly entered by inspectors, and the system allows for report review and approval by supervisory staff.

BMS is integrated with ProjectInfo, MassDOT's system for project development. The integration allows structures to be assigned to projects, which creates a work history of site-specific activities on bridges. In 2017, MassDOT established an additional link between BMS and its contract management system, allowing resident engineers to attribute individual pay items to specific bridges. This new functionality captures work history for various location repair contracts, and enables bridge work history record keeping.

2.1.3 The Inventory and Condition of Bridges Today

A breakdown of NHS and non-NHS Massachusetts NBI deck area by condition state is shown in Exhibit 2.5.

Exhibit 2.5 NBI Condition by Area



Inventory and Condition of NHS Bridges

A breakdown of NHS bridge condition is provided in Exhibits 2.6, 2.7, 2.8, and 2.9 by highway maintenance District, bridge material, and era of construction.

Exhibit 2.6 Summary Listing of NHS Bridges (Million Square Feet), *By Owner and Condition*

CONDITION	TOTAL	MASSDOT	MUNICIPALITIES
Total	**29.66**	**28.69**	**0.90**
Good	**4.99**	4.78	0.17
Satisfactory	**7.43**	7.18	0.23
Fair	**13.53**	13.17	0.34
Poor	**3.72**	3.56	0.16

Source: MassDOT Bridge Inspection Management System, May 2019.

Exhibit 2.7 shows the distribution of deck area by condition across the Commonwealth.

Exhibit 2.7 Summary Listing of NHS Bridges (Million Square Feet), *By District and Condition*

CONDITION	TOTAL	DISTRICT 1	DISTRICT 2	DISTRICT 3	DISTRICT 4	DISTRICT 5	DISTRICT 6
Total	**29.66**	**0.83**	**5.22**	**4.37**	**5.96**	**3.73**	**9.55**
Good	**4.99**	0.16	0.60	0.73	1.07	0.77	1.65
Satisfactory	**7.43**	0.18	0.79	1.35	1.32	0.92	2.86
Fair	**13.53**	0.45	3.51	1.92	2.60	1.64	3.40
Poor	**3.72**	0.04	0.33	0.36	0.96	0.40	1.63

Source: MassDOT Bridge Inspection Management System, May 2019.

Exhibit 2.8 shows that the majority of MassDOT's NHS bridge area is located on steel structures.

Exhibit 2.8 Summary Listing of NHS Bridges (Million Square Feet), *By Material and Condition*

CONDITION	TOTAL	STEEL	CONCRETE	OTHER
Total	**29.66**	**22.68**	**5.43**	**1.55**
Good	**4.99**	2.95	1.37	0.67
Satisfactory	**7.43**	5.00	2.17	0.26
Fair	**13.53**	11.37	1.55	0.6
Poor	**3.72**	3.36	0.35	0.01

Source: MassDOT Bridge Inspection Management System, May 2019.

Exhibit 2.9 depicts bridge condition by era of construction. The majority (19.2 of 29.6 million square feet) of MassDOT's NHS deck area is on bridges built between 1940 and 1980, roughly the construction era of the Interstate Highway System. The subsequent 40 years of bridge construction is responsible for just one quarter of the total area across the current system. While MassDOT and its predecessor agencies performed maintenance and preservation on Interstate-era bridges, the structures are now between 40 and 80 years old.

Exhibit 2.9 Summary Listing of NHS Bridges (Million Square Feet), *By Year Constructed and Condition*

CONDITION	TOTAL	BEFORE 1920	1920–1940	1940–1960	1960–1980	1980–2000	AFTER 2000
Total	**29.66**	**1.40**	**1.59**	**8.18**	**10.99**	**2.89**	**4.61**
Good	**4.99**	0.10	0.08	0.61	0.35	0.82	3.03
Satisfactory	**7.43**	0.60	0.31	1.82	2.34	1.03	1.33
Fair	**13.53**	0.50	0.82	4.42	6.50	1.03	0.25
Poor	**3.72**	0.19	0.38	1.34	1.80	0.01	0.00

Source: MassDOT Bridge Inspection Management System, May 2019.

Inventory and Condition of Statewide NBI Bridges

Exhibit 2.10 provides a breakdown of overall NBI bridge condition by District and number of bridges.

Exhibit 2.10 Statewide NBI Bridges (By Count), *By District and Condition*

CONDITION	TOTAL	DISTRICT 1	DISTRICT 2	DISTRICT 3	DISTRICT 4	DISTRICT 5	DISTRICT 6
Total	**5,130**	**710**	**840**	**1,171**	**848**	**876**	**685**
Good	**1,325**	262	175	287	162	272	167
Satisfactory	**1,603**	224	275	381	229	271	223
Fair	**1,741**	166	302	415	350	280	228
Poor	**461**	58	88	88	107	53	67

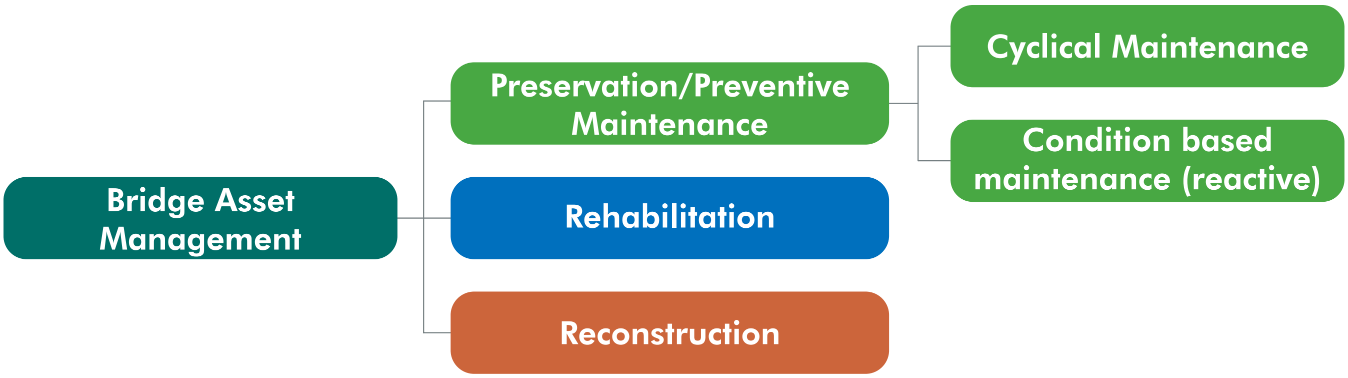
Source: MassDOT Bridge Inspection Management System, May 2019, DOT and Municipally owned bridges only.

2.2 Planning the Bridge Life Cycle

Life-cycle management is the process through which an owner manages useful life of an asset. An example approach to life-cycle management is "worst-first," where investment is solely focused on inventory at its end of life. For a bridge network owner, a "worst-first" approach commits the majority of funds to rehabilitation and replacement of the bridges in the poorest condition.

An alternative approach is to work toward an optimum mix of maintenance, preservation, rehabilitation, and reconstruction. This strategy is not only likely to result in lower overall costs but in a more reliable system as well. MassDOT applies a balanced life-cycle approach to maximize the effectiveness of its bridge program, at the policy level through the FHWA-approved MassDOT Bridge Maintenance Policy, and at the investments level through project selection within the CIP. This structure of investments is depicted in Exhibit 2.11.

Exhibit 2.11 Organization of MassDOT Bridge Life-Cycle Management



2.2.1 Preservation and Preventive Maintenance

MassDOT's bridge preservation and preventive maintenance activities can be classified as either cyclical or condition-based. Cyclical maintenance activities are intended to prevent deterioration. A prime example is bridge washing, which removes deicing chemicals and other deleterious materials from a structure, materials which left in place could cause corrosion or other degradation. In contrast, condition-based activities are reactive and driven primarily by inspection findings. This work can range from minor deficiencies and superficial repairs to more significant action to address advanced deterioration on poor structures.

A summary of cyclical and condition-based maintenance activities with approximate unit costs is provided in Exhibit 2.12.

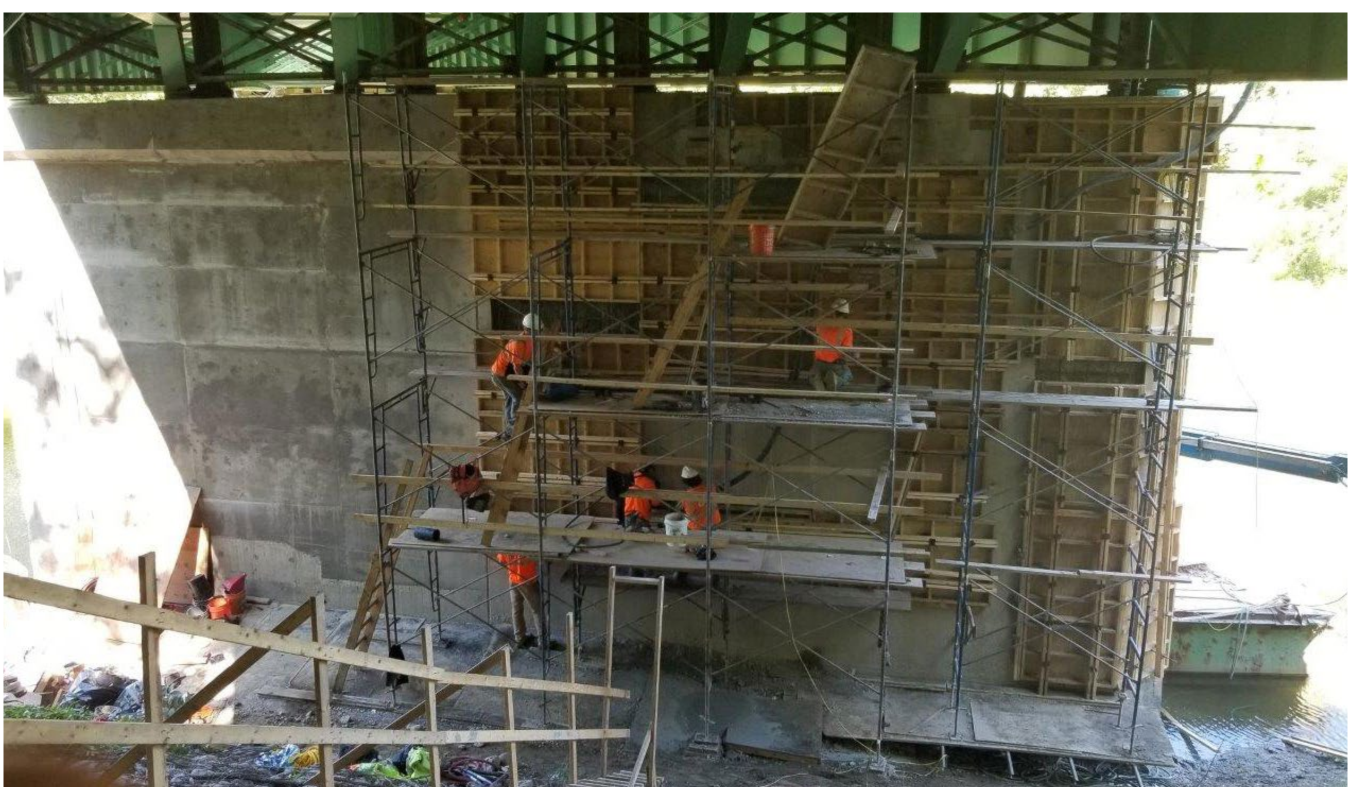


Exhibit 2.12 Cyclical and Condition-Based Bridge Maintenance Activities

	ACTIVITY	CYCLE	UNIT COST ($/FT²)
Cyclical Maintenance	Bridge washing	3 years	$0.67
	Cleaning drainage systems	3 years	$0.70
	Coating concrete surfaces	10 years	$2.85
	Deck sealing, healing, and cracks injections	8–12 years	$3.04
	Reactive deck and joint repairs	As needed	$0.74
	Lubricate bearings	5 years	$0.54
	Seal joint—pourable	5–7 years	$0.64
	Seal joint—neoprene (strip or compressions)	12–15 years	$1.66
Condition-Based Maintenance	Clean and paint (full removal)		$137.40
	Clean and paint (overcoat or zone painting)		$26.70
	Hot Mix Asphalt (HMA) wearing surface		$23.20
	Concrete overlay		$123.30
	P/S or reinforced concrete beam repairs		$19.40
	Reconstruct joints		$63.50
	Replace or repair bearings		$13.80
	Structural steel repairs		$19.50
	Substructure repairs		$20.80
	Scour protection, remediation, or repair		$85.50

Preservation and preventative maintenance activities are primarily managed by the highway District offices through projects within one of the following categories:

Non-Federal-Aid (NFA) Maintenance

These projects are funded from a statewide maintenance budget (currently $100 million per year) which is available to each District in proportion to the share its state-owned lane mileage. Within this budget, each District advances a portfolio of on-call maintenance projects to support scheduled and reactive maintenance needs. Typically, each District holds contracts for pavement, bridges and structures; traffic safety equipment (e.g., signals); facilities (e.g., maintenance buildings); and other roadway appurtenances (e.g., guardrail, drainage, and sidewalks), with bridges and structures accounting for approximately 45 percent of overall spending.

Typical bridge maintenance projects include substructure repair, structural repair, deck repair, joint repair, painting, and cleaning. The work performed under these contracts is primarily condition based and are used to address deficiencies identified through inspections. Where possible, District offices try to perform routine cyclical maintenance. These activities must be prioritized with other competing needs to address advanced deterioration on structures.

Federal Aid—Preservation

Of MassDOT's total Annual Federal aid appropriation, ten million dollars is dedicated to bridge preservation. Each District is eligible for one third of the budget on alternating years. These projects can include cleaning and painting, corridor structure maintenance, and deck replacement on smaller structures.

Federal Aid—Interstate and Non-Interstate Resurfacing

The Highway Division typically includes bridge maintenance activities in resurfacing projects. The bundling of work activities is done to limit repeat traffic disruptions, generate efficiencies from traffic control and contractor mobilization, and maintain a consistent condition level along the NHS. Typically, bridge work-related resurfacing projects are limited to deck repairs, resurfacing, and joint maintenance/replacement.

The benefit of this practice is the consistent replacement of bridge-wearing surface and joints, which are critical to protect structural elements from moisture and deicing chemicals. However, recent resurfacing on Interstate-era NHS structures has resulted in significant cost overruns and project delays, due to advanced deterioration of concrete bridge decks.

2.2.2 Rehabilitation and Reconstruction

MassDOT's State-level bridge prioritization process identifies both MassDOT-owned and municipally owned bridges as candidates for rehabilitation and reconstruction. Each structure is assigned a score from 0 to 100 based on four criteria:

» **Condition Loss (CL):** The percentage difference between a perfect condition rating (9) and the overall rating for the bridge (the average of the component ratings).

» **Change in Health Index (ΔHI):** MassDOT uses the American Association of State Highway and Transportation Officials (AASHTO) Bridge Management software tool to project the health index (HI) of individual bridges to a 15-year, no action scenario. ΔHI conceptually represents the remaining percentage of dollar value in an element for an overall structure. The assumptions MassDOT uses in this forecast are specific to the agency. MassDOT currently is considering whether it needs to update these assumptions and whether more up-to-date software packages should be considered as replacements for the current system.

» **Scour Critical Factor (SCF):** ΔHI is scaled up by a factor corresponding to its scour critical class. The value varies from 5 percent (1.05) for "Category D" and up to 20 percent (1.20) for "Category A."

» **Highway Evaluation Factor (HEF):** An average of five-point scores assigned for Average Daily Traffic (ADT), detour length, functional classification, load carrying restrictions, and deck geometry deficiency, expressed as a percentage of the maximum value (5).

The final rank factor is assessed on a 100-point scale, using the formula:

$$[\text{Rank Score}] = 0.3CL + 0.4(SCF \times \Delta HI) + 0.3HEF$$

Bridges are prioritized for investment based on the rank score, condition ratings, and remediation costs. The list of projects is forwarded to the Districts, which provide feedback on local priorities and also identify structures which require more maintenance resources. As reported in the NBI Bridge Data Site,[4] the current Massachusetts bridge replacement (reconstruction) cost is $420 per square foot, with rehabilitation cost estimated to be $285 per square foot. Reconstruction costs are updated annually to incorporate recent project bid results. These values are in-turn used to estimate the future cost of bridge rehabilitation and replacement.

2.3 Outcomes of Bridge Investment

To evaluate bridge performance, the Highway Division makes use of three measures—two measures for NHS Bridges and one measure for overall statewide bridge performance. In combination, these measures provide a comprehensive picture of statewide bridge performance and the effect of all bridge investments.

Performance Measures for NHS Bridges

For bridges on the NHS, FHWA's final rule has defined two condition measures for bridges: **the percentage of NHS deck area on bridges in good condition,** and **the percentage of NHS deck area on bridges in poor condition**. These measures compute NHS bridge condition in proportion to bridge size, specifically the area of the bridge. For example, a bridge twice the size of an adjacent structure will have double the impact to overall condition.

These Federal bridge measures clarify the cost implications associated with larger structures, which can remain obscured when the focus is solely on the number of bridges in a given condition state. Specifically, these measures highlight the significance of larger structures for MassDOT Capital Planning purposes. The repair (or deterioration) of large structures can have a dramatic impact on performance within this measure. The Accelerated Bridge Program (ABP), a $3 billion initiative to address the overall condition of Massachusetts bridges, funded 290 site-specific bridges and maintenance on hundreds of other structures. However, over half of all construction spending was related to 5 mega projects associated with large NHS structures.

Performance Measures for Statewide NBI Bridges

In parallel with the NHS area measures, MassDOT tracks the overall **number of poor bridges across the Commonwealth**, which includes bridges on and off the NHS. All bridges have local or regional importance and this measure views bridge condition from a statewide perspective.

Targets for Bridge Condition

In collaboration with the MassDOT Office of Performance Management and Innovation (OPMI) and in compliance with Federal regulation, the Highway Division has established short- and long-term targets for bridge condition.

MassDOT has collaboratively set the following targets for bridge condition:

4 https://www.fhwa.dot.gov/bridge/nbi/sd2018.cfm.

Exhibit 2.13 MassDOT Targets for Bridge Performance

MEASURE	DESIRED TREND	SHORT TERM CURRENT (AS OF 7/1/19)	SHORT TERM 2020	SHORT TERM 2022	LONG TERM[1]
Percent of NHS Bridges by Deck Area in Good Condition	Up	16.10%	15%	16%	>18
Percent of NHS Bridges by Deck Area in Poor Condition	Down	12.56%	13%	12%	<10
Percent of Statewide NBI Bridges Poor (by Count)	Down	9.06%			<10%

[1] This can be viewed as a state-of-good-repair target.

2.3.1 Bridge Performance Scenarios

The short-term NHS performance measure targets shown in Exhibit 2.13 were identified from a performance model that incorporates the effects of specific bridge projects, the effects of maintenance, and estimates of future deterioration. This model, which forecasts future condition, is based on the Highway Division Capital Investment Plan (CIP) and bridge inspection data.

This model has also been used to estimate longer-term performance (>5 years) in order to evaluate the performance of investment scenarios to achieve state-of-good-repair objectives. Exhibits 2.14, 2.15, and 2.16 demonstrate current and increased investment scenarios within the context of long-term/sustainable growth rate targets. These exhibits include projections based on the 2020 to 2024 CIP investment (base) and an alternative investment scenario, which is defined in Section 2.3.4.

Exhibit 2.14 NHS Bridges by Deck Area in Good Condition, *2014 to 2029*

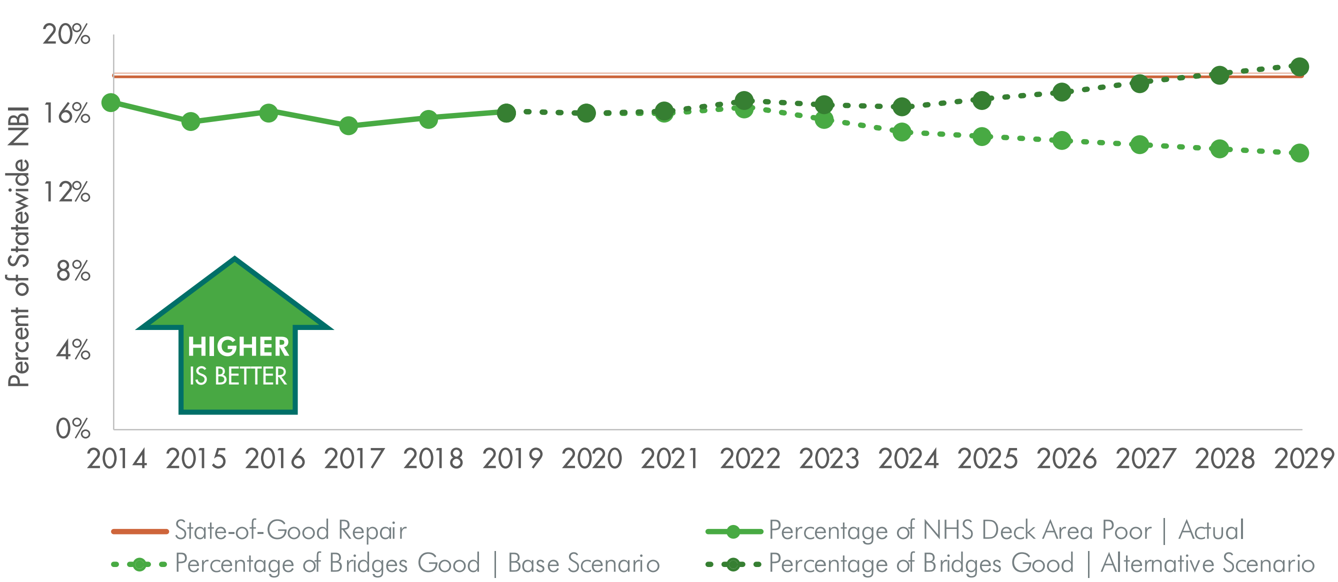


Exhibit 2.15 NHS Bridges by Deck Area in Poor Condition, *2014 to 2029*

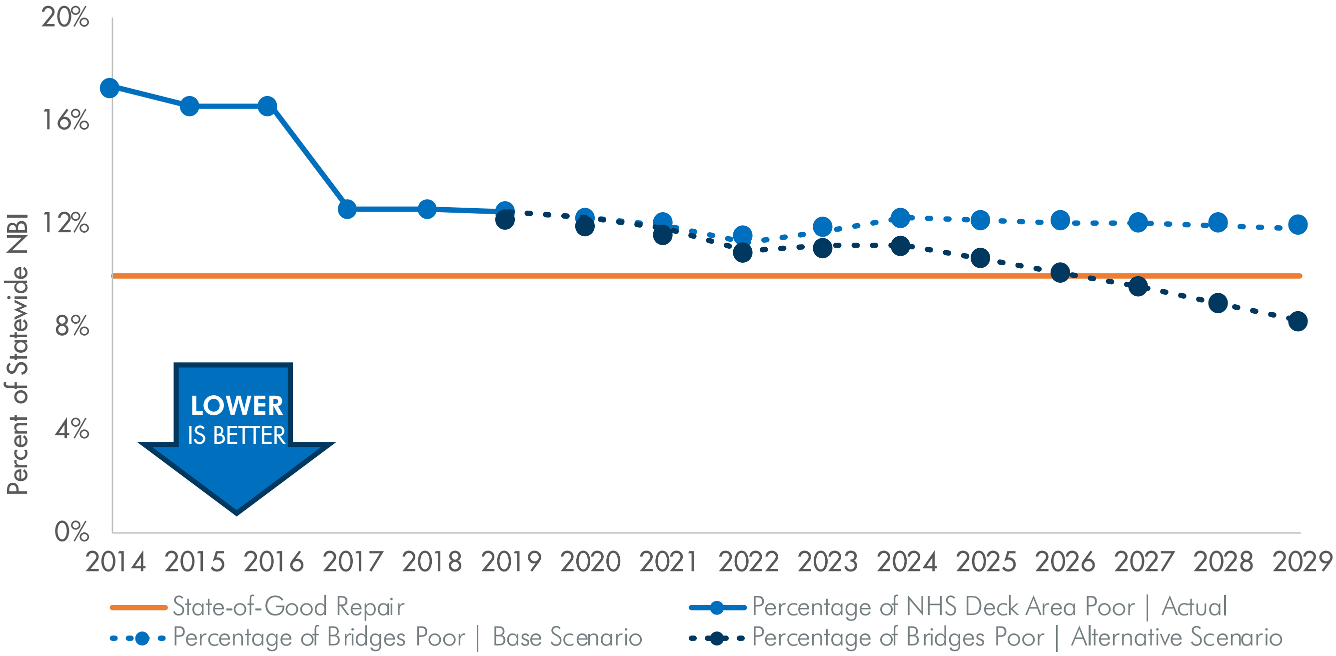
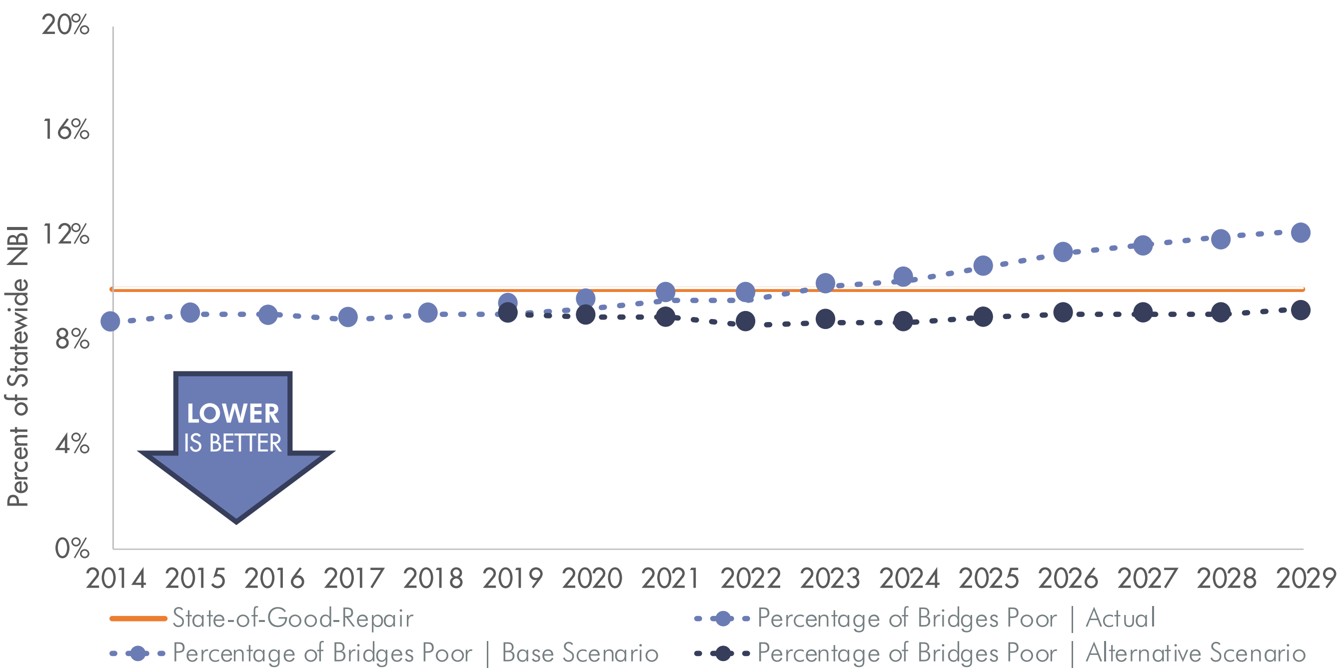


Exhibit 2.16 shows the growth trend in statewide NBI bridges in poor condition for the years 2014 to 2029 under both current (base) and alternative scenarios.

Exhibit 2.16 Number of Statewide NBI Bridges in "Poor" Condition, *2014 to 2029*



2.3.2 Performance Gap Assessment

Exhibit 2.17 NHS Bridges Gap Analysis

	MEASURE	TARGET	10 YEAR FORECAST	GAP
Federal Measures	Percent of NHS Bridges by Deck Area in Good Condition	>18	14	-4
	Percent of NHS Bridges by Deck Area in Poor Condition	<10	11.9	-1.9
State Measure	Percentage of Statewide NBI Bridges Poor (by Count)	<10	12.2	-2.2

Note: Negative values indicate gap to target

Performance Gap for NHS Bridges

Results of the model predict that NHS state-of-good-repair targets will not be achieved at the current investment, but also demonstrate marked improvement as a result of the ABP. To make meaningful progress toward state-of-good-repair and maintain the gains already achieved, an increased bridge investment with consideration for larger structures and NHS bridge preservation, is necessary.

Performance Gap for Statewide Bridges

In contrast to the NHS measure, statewide bridge condition currently is in a state-of-good-repair (<10 percent poor) by MassDOT targets, but is predicted to deteriorate beyond this threshold within the next 5 years. Similar to improvements within the NHS condition measure, the ABP had a positive effect on the count of poor bridges. Between the years 2008 and 2016, the program was the primary driver behind a 20 percent reduction in the number of poor bridges. These gains are not sustainable at the current investment level, and pre-ABP condition is expected to be reached by 2025.

2.3.3 Alternative Investment Strategy

The alternative scenario assumes an incremental increase of bridge program size, beginning in state fiscal year (FY) 2021, and culminating in 2025 where the program is approximately $200 million larger than the 2020 to 2024 average annual investment. The model assumes the bridge program will sustain the elevated investment level through 2029. The gradual increase will allow highway project delivery teams to reach a pace commensurate with the increased spending targets.

Additional funds would be used to fully fund a complete life-cycle approach to bridge management including:

» Doubling of bridge maintenance budget with annual targets for cyclical maintenance activities

» Creation/formalization of an NHS large structure and corridor bridge-deck replacement program.

» Additional funds provided for non-NHS on-system bridges.

2.4 Bridge Process Improvements

2.4.1 Bridge Management Process Improvements

MassDOT has begun the process of determining long-term BMS needs. General functional requirements include inventory, condition modeling, work management, and reporting. The next-generation BMS will support life-cycle planning for bridges by evaluating the costs and benefits for alternative treatments and sets of investments within fiscal constraint.

The review will determine whether current component technologies should be retained or replaced; evaluate the suitability of other systems in use at MassDOT; and explore external vendor solutions. Work to-date under this effort includes a survey of other departments of transportation to determine the current state of practice. A work plan for this effort will be completed by the end of calendar year 2020.

The Highway Division has launched an enterprise work and asset management system for District-level work order tracking. This system will complement existing ones and track maintenance and preservation at specific bridge locations. Bridge work orders are expected to be implemented by January 1, 2020.

2.4.2 Municipally Owned Bridges

MassDOT provides technical support and will explore avenues to share best practices for bridge preservation among all bridge owners in the Commonwealth. MassDOT will develop a work plan to support this effort within Calendar year 2020.

2.5 Valuation of Bridge Assets

The value of a bridge is most directly related to how much it would cost to replace. . Current replacement costs are maintained by MassDOT and are based on FHWA guidance, and excludes specific project cost elements including the demolition of existing structures; maintenance of traffic, right of way, utility relocation; and contingencies.[5] Replacement costs are separately calculated for bridges on and off the FHWA's Federal-aid highway system, which roughly aligns with the NHS. In 2018, MassDOT estimated a value of $472 per square feet for NHS bridges.[6]

Based on this factor, MassDOT owned bridges (37 Million square feet) are worth $18 billion overall. The NHS in Massachusetts comprises 29.66 million square feet, and its value is $14 billion across all owners.

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5 https://www.fhwa.dot.gov/bridge/nbi/uc_criteria.cfm.

6 This value correlates to Item 94 on the National Bridge Inventory (https://www.fhwa.dot.gov/bridge/mtguide.pdf page 64) and includes only cost of physical construction of a bridge in a single phase. Additional costs for demolition, traffic management, staged construction, and ancillary highway work are added at a project level.

3. PAVEMENT

Ownership of non-interstate NHS is shared between MassDOT and other public agencies, This plan seeks to align pavements on and off of the NHS around similar goals and objectives regardless of owner and to define an investment strategy for NHS and MassDOT-owned pavement to support MassDOT Capital Planning.

Approximately three-quarters of NHS mileage is within MassDOT jurisdiction, including the entirety of the interstate system. The remainder is shared between five entities: municipalities (i.e., cities and towns), the Department of Conservation and Recreation (DCR), the Massachusetts Port Authority (Massport), state institutions (e.g., colleges and universities), and the Federal Government.

A breakdown of the lane mileage owned by these entities is shown in Exhibit 3.1.

Exhibit 3.1 NHS Lane Mileage by Jurisdiction

JURISDICTION	NHS	TOTAL
Total	**10,492**	**72,216**
MassDOT	7,682	9,551
Municipalities	2,575	56,455
DCR	216	541
Massport	12	18
State Park	0	387
State Institutional	2	148
County Institutional	0	7
Federal	5	209
Unaccepted	0	4,899

Source: MassDOT Road Inventory Year-End Report 2018.

Responsibility for managing MassDOT-owned pavement is shared between the Highway Division Pavement Management Section, the Highway Division District offices, and the Office of Transportation Planning (OTP). Exhibit 3.2 describes how this responsibility is distributed.

Exhibit 3.2 Division of Responsibility for MassDOT-Owned Pavements

FUNCTION	HIGHWAY PAVEMENT MANAGEMENT FUNCTION	HIGHWAY DISTRICT FUNCTION	OFFICE OF TRANSPORTATION PLANNING
Inspect Pavement	» Routine condition data collection for all numbered highways and numbered routes on the NHS (Interstates annually, non-Interstates biannually). » Maintain database of detailed roughness, rutting, cracking, and raveling.	» Observe condition of pavements within jurisdiction. » Respond to feedback on pavement condition from municipalities, stakeholders, and the public.	
Maintain Pavement	» Prioritize road segments and select treatments to maximize incremental benefit/cost ratio. » Initiate projects and coordinate with District office for the Interstate and non-Interstate resurfacing programs. » Review pavement designs for all MassDOT managed Projects. » Provide condition data and technical support to District offices and municipalities	» Respond to emergency repairs (e.g., pothole fills), as notified. » Design responsibility/ review of Interstate and non-Interstate projects. » Manage District maintenance, preservation, and resurfacing contracts.	» Manage State Transportation Improvement Program and MassDOT CIP.
Manage Pavement Data	» Administer dTIMS Pavement Management System	» Maintain records of District Contract work locations.	» Maintain Pavement Condition data within the Road Inventory File, manage annual HPMS submission.

3.1 Tracking Pavement Condition

Pavement condition data is collected on one- and two-year cycles using MassDOT's automated Highway Inventory Collection and Management System (HICAMS). HICAMS measures pavement roughness and detects indicators for pavement distress, including cracking, rutting, and raveling. MassDOT uses a proprietary software—the Deighton Total Infrastructure Management System (dTIMS)—to combine these measures into an overall condition rating.

Once the annual data collection cycle has been completed, the information is analyzed, and quality assurance measures are performed, the Pavement Management Section shares the data with the OTP where it is published in the State Road Inventory File and prepared for submission to FHWA.

In addition to annual and biennial condition data collection, District maintenance staff monitor roadway conditions as part of their normal duties and respond to feedback from members of the public and other stakeholders. Areas of deterioration are typically stored in spreadsheets and generally represent a more up-to-the-minute condition report than the formal inspection. District maintenance staff also use mobile devices to record the location of localized pavement repairs in real time, with the data available in a public-facing dashboard.

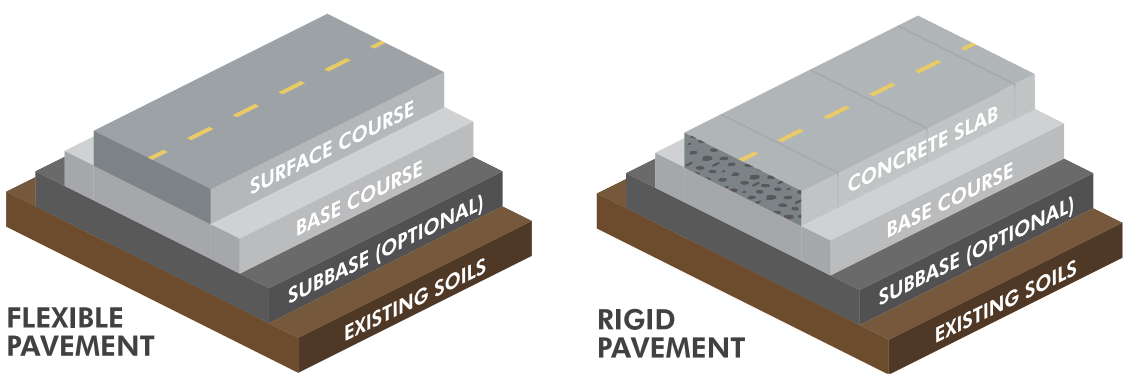
The location of site-specific pavement projects is recorded in ProjectInfo. For maintenance work, the District offices have begun to map the location of completed work through a web interface which registers the location to the State linear referencing system. Over the coming two to three years, this record keeping will be moved over to the MassDOT Enterprise Asset Management System (VUEworks).

Both condition and project data are available online through MassDOT's web-based Geographic Information System known as "GeoDOT," which is administered by OTP. Using the system, internal staff can overlay condition layers with project information to assist in maintenance and preservation decisions. Portions of the GeoDOT site are also open to the public.

3.1.1 Condition of Pavement Today

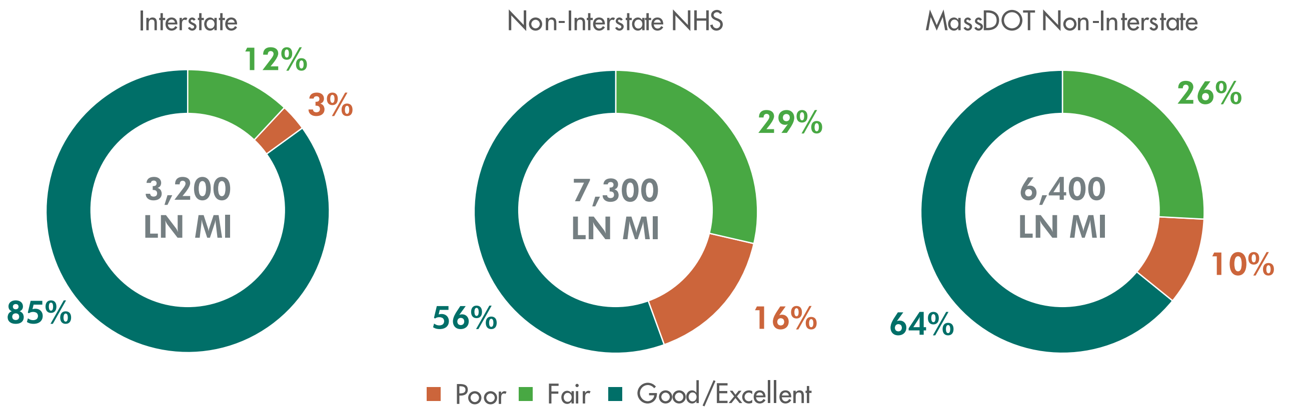
Massachusetts roadways overwhelmingly consist of flexible pavements which are typically constructed of hot mix asphalt (HMA). The use of rigid pavements, which are constructed of Portland cement concrete (PCC) is rare in Massachusetts. The major structural components of flexible and rigid pavement systems are shown in Exhibit 3.3.

Exhibit 3.3 Structural Components of Pavement



A breakdown of lane mileage on the NHS by condition (pavement serviceability index) by highway system is shown in Exhibit 3.4.

Exhibit 3.4 MassDOT & NHS Pavement Condition



Source: MassDOT Pavement Management System, 2018.

3.2 Planning the Pavement Life Cycle

The following section describes the approach to pavement life-cycle management in use by MassDOT for all state-owned roadways. For portions of the NHS outside of MassDOT jurisdiction, individual municipalities perform life-cycle planning and maintenance.

MassDOT invests in pavement in four major ways:

» **Maintenance:** Treatments include crack sealing, localized repairs, and pavement inlays.

» **Preservation:** Treatments include fog seals, chip, seals, microsurfacing, ultra-thin bonded overlays, high-performance thin overlays, and other thin (<2 inches) single lift overlay.

» **Rehabilitation:** Treatments include single and multi-lift overlay and reclamation.

» **Reconstruction:** Treatments include the removal and replacement of the entire roadway cross section.

Typical treatment costs are shown in Exhibit 3.5 and are based on MassDOT projects. The MassDOT pavement management system has not been configured for rigid pavement due to the very small portion (<0.4 percent) of concrete roadways within the State-owned system.

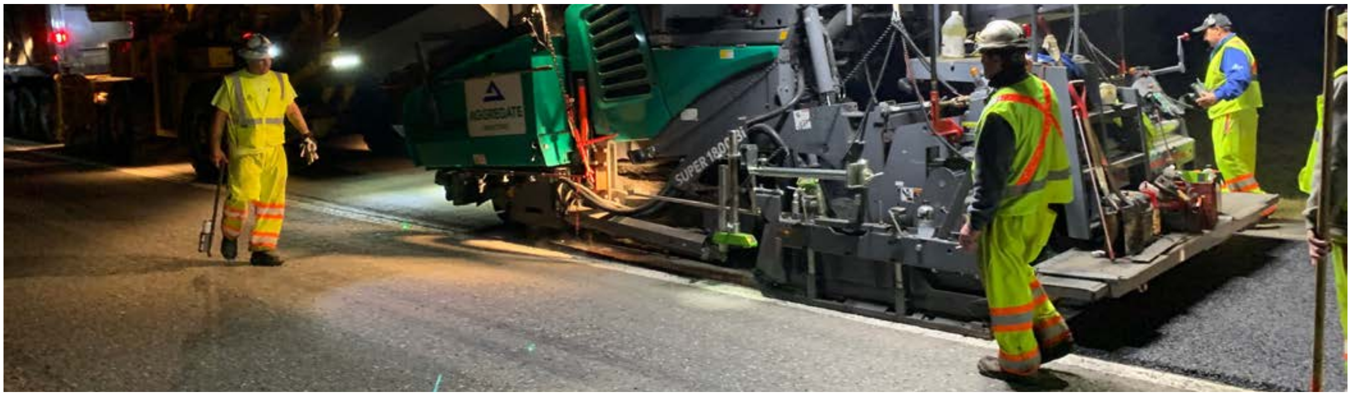


Exhibit 3.5 Pavement Treatment Costs

TYPE OF INVESTMENT	TREATMENT	PRICE PER LANE MILE
Maintenance	Asphalt crack sealing	$12,000
	Asphalt routing and sealing	$11,500
Preservation	Microsurfacing	$55,000
	Open-graded friction course (OGFC) with leveling	$220,000
	Ultrathin Bonded overlay	$110,000
	Rubber chip sealing	$63,325
	Rubber-gap-graded overlay	$180,000
	HMA overlay	$137,000
Rehabilitation	Full-depth reclamation	$400,000
	Functional overlay	$278,000
	Functional overlay | saw and seal	$300,000
	OGFC with dense binder	$280,000
	Structural overlay	$413,000
	Thick overlay | saw and seal	$450,000
	Rubber gap grading with functional overlay	$330,000
	OGFC with structural overlay	$395,000
Reconstruction	Reconstruction	$680,625

Costs reflective of 2017 analysis.

Headquarters Treatment Selection for Pavements

The Pavement Section determines treatment options for deteriorated pavement segments by comparing current condition to a treatment selection matrix while considering the type of pavement distress and roadway classification. The long-term impact of investment on condition is modeled in dTIMS, considering both immediate cost and deferred maintenance. The projection models are used to identify projects and investment levels for the MassDOT CIP.

MassDOT's Pavement Management Section uses an Incremental Benefit/Cost (IBC) Ratio to determine the "ideal timing" and "ideal treatment" for each road segment in the inventory, reflective of funding constraints. This allows MassDOT to identify:

» Segments that have an impact on safety (highest priority).

» Segments having the greatest value per dollar spent.

» Segments that are ideal candidates for immediate preservation or rehabilitation.

» Segments where rehabilitation can be deferred with less financial impact.

The IBC quantifies the improved pavement condition for the duration of pavement service life, considering traffic volume, using the equation:

$$IBC = AADT^k\ (PSI_{treatment} - PSI_0\ )\ /\ Cost_{treatment}$$

PSI_0 and $PSI_{treatment}$ are the serviceability index before and after treatment and k is the "traffic factor."

Using this assessment, investments are advanced or deferred, and a draft list of prioritized investments is vetted through MassDOT's six highway Districts. Duplicate projects are struck from the prioritization list, while unfunded projects are retained for future consideration. Districts are also consulted on the draft candidate list for input on local issues which are not captured in the overall ranking.

District-Level Treatment Selection for Pavements

Pavement maintenance at the District level is entirely state funded (NFA) through an annual budget assigned to each District. The Districts allocate the budget to contracts for pavement, structures, traffic safety equipment (e.g., signals), facilities (e.g., maintenance buildings), and other roadway appurtenances (e.g., guardrail, drainage, and sidewalks) based on needs and to ensure that there are resources in place to manage the breadth of infrastructure within their jurisdiction.

Districts identify segments for maintenance work based on several factors, including:

» Pavement Serviceability Index (PSI) rating and the project list provided by the Pavement Management Section.

» Number and severity of complaints about a segment.

» Coordination with utilities.

» Availability of maintenance resources.

The process of creating and rank-ordering projects is continuous, collaborative, and incorporates engineering judgment. Pavement maintenance in the Districts is mostly performed by contractors under MassDOT direction, but in-house crews also perform seasonal pothole repairs.

3.3 Outcomes of Pavement Investment

State Performance Measures

The Highway Division tracks performance of Interstate and non-Interstate pavements through separate measures, with a higher threshold applied to Interstates due to the higher speed and greater traffic volume found on these facilities. Pavement condition is measured through an internally developed indices, PSI. PSI is based on a five-point scale by which a segment is determined to be either excellent, good, fair, or poor. The number is a composite value derived from seven different pavement distress types.

Exhibit 3.6 Pavement Serviceability Index – Condition State Ranges

CONDITION STATE	PSI RANGE INTERSTATE	PSI RANGE NON-INTERSTATE
Excellent	3.5-5.0	3.5-5.0
Good	3.0-3.5	2.8-3.5
Fair	2.5-3.0	2.3-2.8
Poor	0.0-2.5	0.0-2.3

Pavement condition and PSI are a central component of MassDOT capital planning and performance management processes. Since the adoption of a performance-based capital plan, the size of MassDOT pavement program investments are considered from the standpoint of forecasted condition outcomes.

Federal Performance Measures

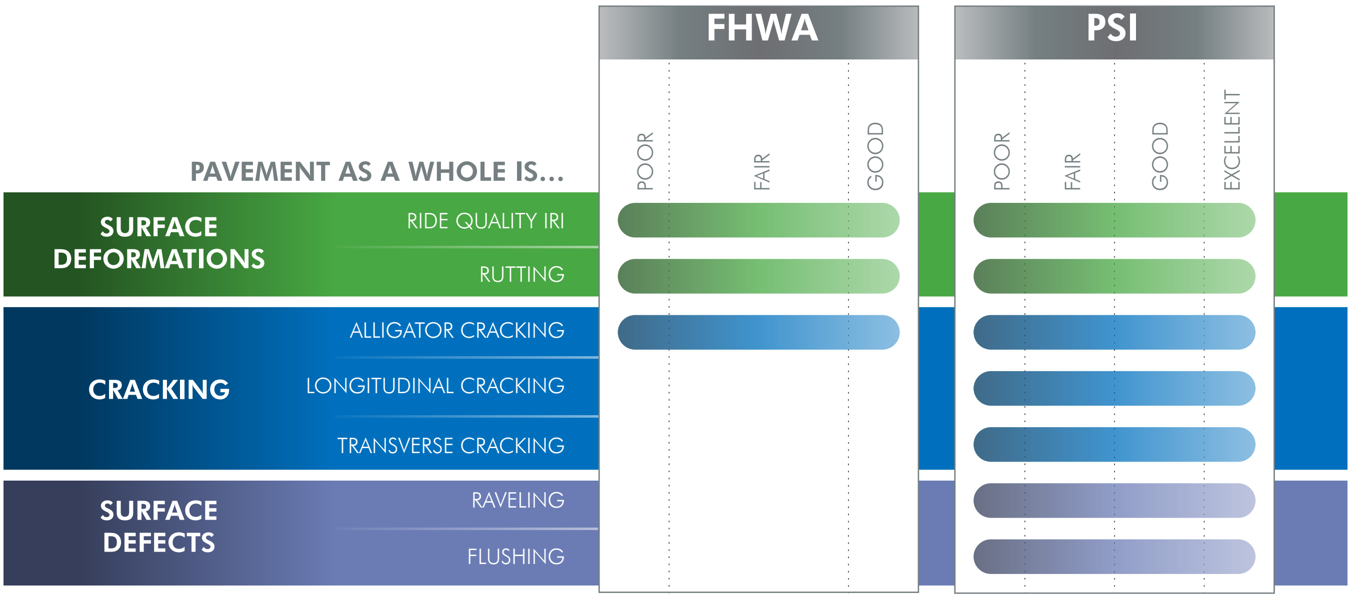
Federal regulation has introduced a national performance measure for pavement condition on the NHS (referred to here as the "FHWA Measure"), which incorporates three component measures of PSI: International Roughness Index (IRI), rutting, and fatigue/alligator cracking percentage. Each measure is graded as "Good," "Fair," or "Poor" on a scale defined within the regulations. If all three measures are rated "Good," the pavement is rated "Good." If two or more measures are rated "Poor," the pavement is rated "Poor." All other pavements are rated "Fair."

» In addition to the three components which form the FHWA Measure, PSI includes four additional component measures: two types of cracking and two types of surface defects.

» While all three components must be good for the FHWA Measure to grade the pavement as good, PSI is an index measure that computes an overall score on a 0 to 5 scale from the component measures. Generally speaking, a portion of good and poor pavements in PSI are rated fair in the Federal measure.

A visual comparison of the two performance measures is provided in Exhibit 3.7.

Exhibit 3.7 Comparison of FHWA Pavement Measure and PSI



MassDOT will continue to comply with all aspects of the Federal performance measure. However, MassDOT will continue to use PSI to determine trends, treatments, project selection, and spending levels. Since the three most heavily weighted parameters in PSI coincide with the FHWA criteria, MassDOT believes the relationship between PSI and FHWA measures will be linear for most pavements. Put another way, a decline or improvement in one measure will have a similar and proportional affect in the other. MassDOT will consider a full adoption of the Federal Measure in future years.

Targets for Pavement Condition

Based on the framework established by the MassDOT Office of Performance Management and Innovation (OPMI), both state and Federal target setting for pavements are on a similar two- and four-year schedule. The initial round of Federal target setting for the NHS was conducted in accordance with the schedule identified by Federal regulation and was done in conjunction with and adoption by the Commonwealth MPOs. Both state and Federal targets for pavement condition are provided in Exhibit 3.8.

Exhibit 3.8 Federal and MassDOT Targets for Pavement Performance in Lane Miles

	MEASURE	DESIRED TREND	CURRENT (AS OF 1/1/19)	SHORT TERM 2020	SHORT TERM 2022	LONG TERM[2]
Federal Measures	Percent of Interstate in Good Condition	Up	70.1	NA	70	NA
	Percent of Interstate in Poor Condition	Down	0.3	NA	4	NA
	Percent of non-Interstate NHS in Good Condition	Up	32.9[1]	30	30	NA
	Percent of non-Interstate NHS in Poor Condition	Down	31.4[1]	30	30	NA
State Measures (PSI)	Percent of Interstate in Good/Excellent Condition	Up	85.1	88	88	90
	Percent of Interstate in Poor Condition	Down	3.2	<4	<4	<4
	Percent of DOT-owned non-Interstate in Good/Excellent Condition	Up	63.8	60	62	>70
	Percent of non-Interstate in Poor Condition	Down	10.2	<20	<20	<15

[1] International Roughness Index (IRI) only, full implementation of measure in 2020 per regulation
[2] Can be viewed as a state-of-good-repair target

3.3.1 Pavement Performance Scenarios

Exhibits 3.9 and 3.10 provide trends of NHS pavement condition by Interstate and non-Interstate NHS systems, respectively. Recent historical performance is reported, and a 10-year forecast is provided for the 2020 to 2024 CIP and post CIP years 2025 to 2029. Alternative investment scenarios are discussed in more detail within section 3.3.3.

Exhibit 3.9 Condition (PSI) of Interstate Pavement, *2013 to 2029*

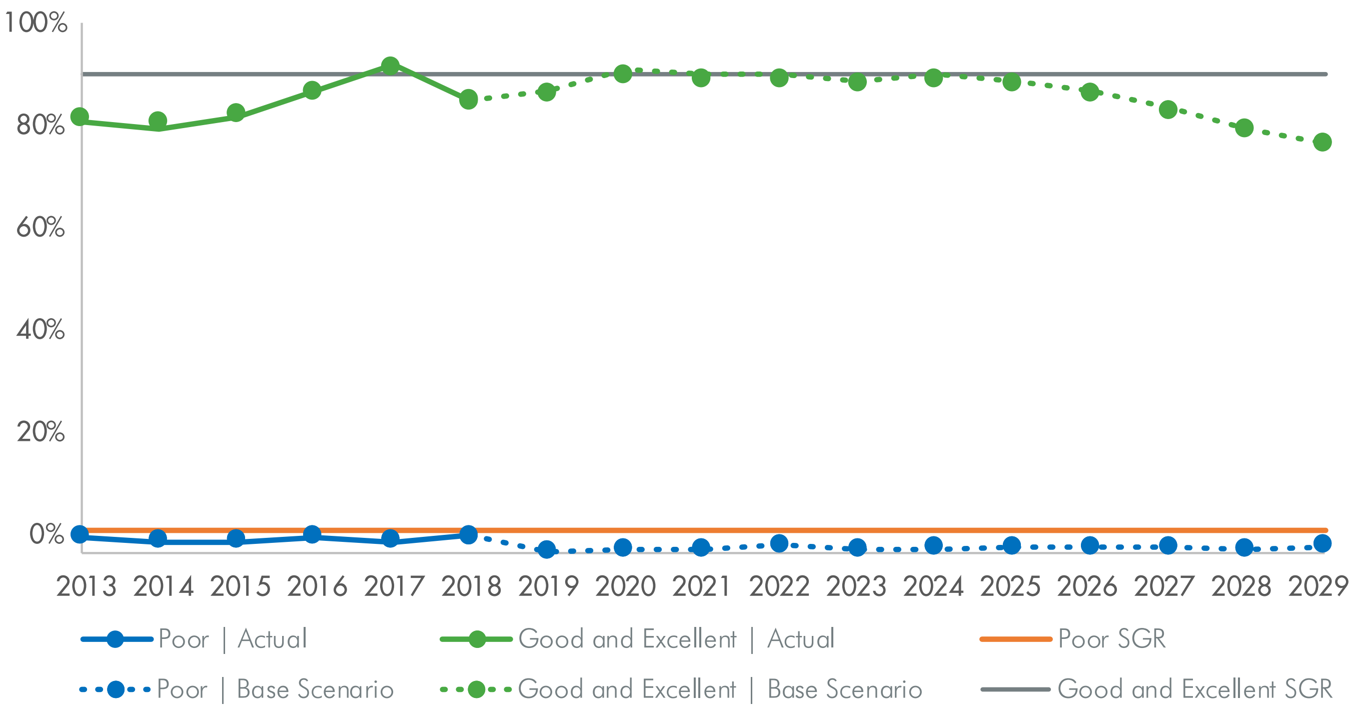
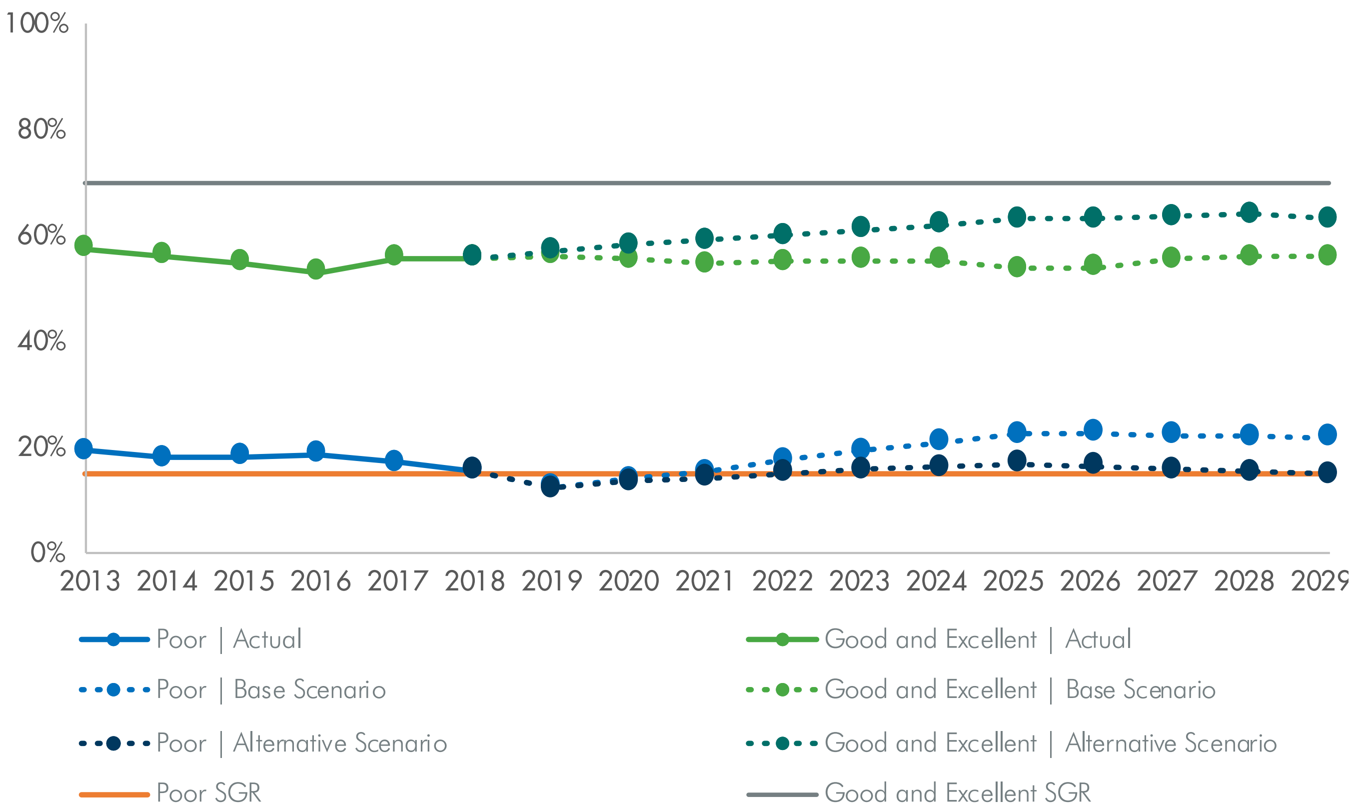


Exhibit 3.10 Condition (PSI) of Non-Interstate NHS Pavement – All Owners, *2013 to 2029*



3.3.2 Pavement Performance Gap Assessment

Interstate Pavement

Exhibit 3.11 NHS Pavement Gap Analysis

MEASURE		TARGET	10 YEAR FORECAST	GAP
State Measures (PSI)	Percent of Interstate in Good/Excellent Condition	90	77	-13
	Percent of Interstate in Poor Condition	<4	1.2	2.8
	Percent of NHS non-Interstate in Good/Excellent Condition	>70	63	-7
	Percent of NHS non-Interstate in Poor Condition	<15	15	-1

Note: Negative values indicate gap to target.

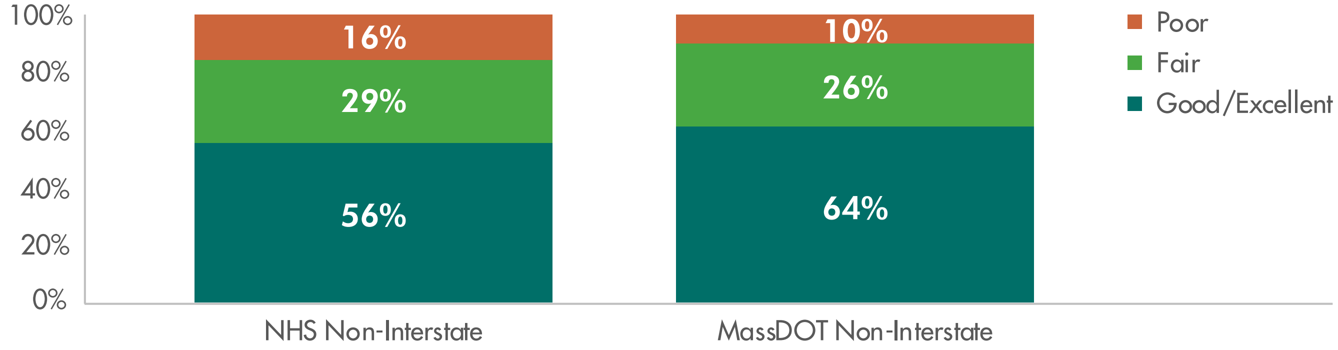
Interstate scenarios indicate that the current investment will lead to attainment of a state-of-good-repair in the near term. The current model suggests that condition may decline in the out years. Targets and investment levels will be reevaluated in subsequent planning cycles.

An impediment to performance is the use of Interstate program funds for non-pavement work within the scope of an Interstate project. The cyclical nature of corridor pavement projects provides the opportunity to repair or upgrade other highway features during the course of the project, including safety systems (e.g., guardrail or other barrier systems), drainage repairs and/or storm water improvements, and bridge repair. While this work is necessary and has clear safety and reliability benefits, these activities can increase individual project costs and reduce the overall number of projects the Highway Division can program on an annual basis.

Non-Interstate Pavement

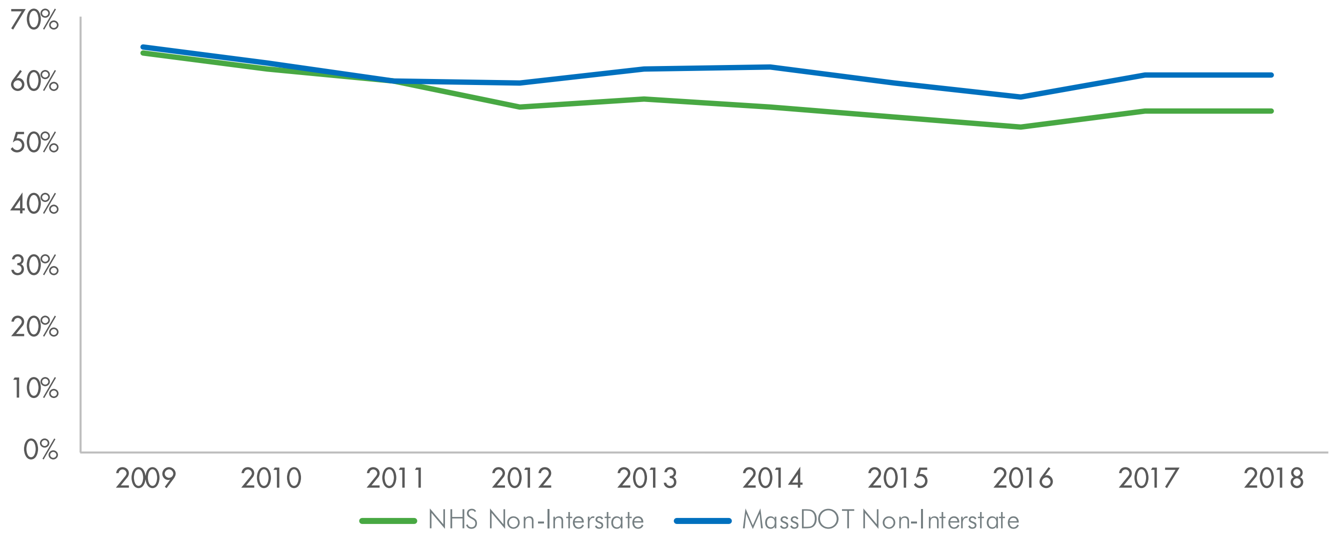
The NHS non-Interstate and MassDOT-owned non-Interstate systems are similar sized (7,293 versus 6,352 lane miles respectively) and in similar condition, with the MassDOT-owned comparatively better, as demonstrated in Exhibit 3.12:

Exhibit 3.12 Comparison of NHS Non-Interstate versus MassDOT Non-Interstate Pavement Condition (PSI), 2018 Condition Data



From a trend perspective, the condition of both systems has declined over the last decade, as detailed in Exhibit 3.12, with municipal condition driving the deterioration on the NHS system. Conversely, the improvements seen in 2017 were due to a reallocation of MassDOT investment from the Interstate to the non-Interstate programs, and because the additional spending was focused on DOT-owned NHS, both systems realized the benefits.

Exhibit 3.13 Comparison of NHS Non-Interstate versus MassDOT Non-Interstate Pavement Condition, Trend of Good/Excellent Condition (PSI)



What is consistent across both systems is the need for alternative strategies to support the achievement of state-of-good-repair.

3.3.3 Alternative Investment Strategy

Non-Interstate Pavement

MassDOT Non-Interstate Roadways

The needs within the Highway Division non-Interstate system have been well documented in previous state-level asset management reports, and as a result, incremental increases to the budget have been realized. Through an increase proposed in the 2020-2024 CIP, the non-Interstate program will receive an additional $155 million over the next five years, with the additional funds focused on MassDOT-owned roadways located on the NHS.

This funding increase is not predicted to achieve long-term targets, but the additional funds are expected to support progress toward state-of-good-repair targets on both MassDOT roads and the NHS as a whole.

Municipally-owned Non-Interstate NHS Roadways

An increase to MassDOT spending will have a positive effect on the state-owned NHS, but the investment level on the municipal side (40 percent of NHS non-Interstate lane mileage) also has a substantial effect on NHS condition. MassDOT is considering delivery mechanisms for a municipal pavement grant program, which would incentivize work on the NHS. Based on lane mileage, to match the increase on MassDOT-owned roads, would require a five-year grant program amounting to $100 million.

3.4 Pavement Process Improvements

3.4.1 Pavement Preservation Policy

A team of FHWA, MassDOT, Municipal, consultant, and contractor engineers participated in a Pavement Preservation Task Force with the goal of furthering preservation activities on all roads of the Commonwealth. The major outcome from this effort is a MassDOT pavement preservation policy directive.

The policy provides guidance to ensure that MassDOT's pavement investments are made through a program of long-term network-level preservation strategies. Similarly, the policy will provide local Government and public works officials with guidance for their own decision-making. In general, the policy will promote more efficient investment in the NHS and on all roads in Massachusetts.

The policy's objective is to institutionalize pavement preservation. It provides funding guidance, treatment selection matrices and strategies to economically maintain pavements at their highest feasible level of service. Concurrent with this effort, MassDOT is systematically rolling out updated specifications for the preservation treatments referenced in the policy. These treatments are intended for use across the Commonwealth's NHS, DOT, and municipal roadways.

The Preservation Policy Directive is being harmonized with the Healthy Transportation Policy. The goal is to provide a balance between the preservation approach of utilizing thin cost-effective pavement treatments to "keep good roads in good condition" and allowing roadway conditions to decline to a service level where an increased scope of work is cost effective. By systematically identifying preservation projects early in the planning process, the DOT is able to target them with cost-effective treatments, while allowing the design efforts to commence on the projects requiring substantial bicycle and pedestrian improvements.

Implementation of the policy's objectives has commenced prior to its formal adoption at both the statewide and District levels. Preservation projects have been advertised at unprecedented levels, targeting multilane NHS and Interstate highways. More than 4 million square yards (580 lane miles) of preservation treatments are scheduled for advertising or placement during the next 12 months. Also, Districts are embracing preservation activities by incorporating preservation treatments into various location maintenance contracts and dedicating funds to expand the use of crack sealing across the Commonwealth.

3.4.2 Municipally Owned Pavement

MassDOT administers an annual legislative authorization of state aid to the 351 cities and towns of Massachusetts through the Chapter 90 Program, which supports the maintenance, repair, improvement, and construction of municipally owned roads and bridges and other transportation assets. The annual Legislative authorization is formulaically apportioned to the municipalities based on roadway mileage, population, and employment.

Municipalities apply for reimbursement on a project-by-project basis, and eligible work activities are reimbursable on any town-accepted roadways, including those on the NHS. Under current program accounting, it is not feasible to accurately report what portion of annual Chapter 90 investment is dedicated to NHS facilities; however, analysis for an enhanced intake process is underway. If implemented as expected, the enhanced process will enrich the quality of data on location and work activity. The updates are expected to be implemented within calendar year 2020.

3.5 Value of Pavement

Replacement costs per mile of road are dependent on geographic location (i.e., urban/rural), type of construction, number of lanes, lane width, and number of bridges. The FHWA Elemental Capital Improvement Costs were used to estimate pavement replacement cost. The values for "Pavement Reconstruction" were selected and a factor has been applied to account for shoulders and breakdown lanes. All values have been inflated for early 2018 using the consumer price index.[7]

Exhibit 3.14 shows the unit costs for MassDOT pavement. Interstate pavement is valued as "Interstate," while non-Interstate pavement is valued as "Arterial."

Exhibit 3.14 Per-Mile Unit Replacement Cost for Pavement, *2018 Dollars*

	INTERSTATE	ARTERIAL	COLLECTOR	LOCAL
Unit Cost—Rural	$1.29 million	$1.00 million	$0.92 million	$0.92 million
Unit Cost—Urban	$3.68 million	$2.65 million	$1.83 million	$1.35 million

Source: Performance and Asset Management Advisory Council, 2015.

Using these assumptions, **NHS pavement in Massachusetts is valued at approximately $20 billion**.

7 Inflation Calculator, Bureau of Labor Statistics: https://www.bls.gov/data/inflation_calculator.htm.

4. FINANCIAL PLAN

The MassDOT Capital Investment Plan (CIP) is the authoritative document on investments to the NHS and MassDOT owned infrastructure. Structured as a rolling five-year plan, MassDOT and MBTA staff collaborate with various transportation stakeholders on an annual basis to add a year to the plan, and update investments from the previous planning cycle.

As noted, MassDOT capital planning is guided by three fundamental priorities: reliability, modernization, and expansion. Each category includes programs with specific projects aligned to that priority. The CIP seeks to align these programmatic investments with specific outcomes; for reliability programs, these outcomes are commonly tied to targets for asset condition or performance. The TAMP is intended to guide the selection of investment levels and strategies established for the MassDOT CIP.[8]

Investment in NHS pavements by municipalities and other owners is not well documented at this time; a work plan has been established to improve reporting of this information through a web portal. Once implemented, future updates to this plan will include a more comprehensive overview of state and municipal NHS Investment.

4.1 Sources for Capital Investment

4.1.1 Federal Sources

The Federal portion of the MassDOT CIP is developed through the State Transportation Improvement Program (STIP). The STIP is compiled annually by MassDOT OTP in coordination with the Highway Division, the MassDOT Rail and Transit Division, Metropolitan Planning Organizations (MPOs), regional transit authorities (RTAs) and MassDOT's Federal-aid Programming and Reimbursement Office (FAPRO). Updated every year, and prepared in conjunction with the annual CIP process, the STIP identifies how annual Federal aid will be obligated for transportation uses within the Commonwealth over the subsequent five Federal fiscal years.

The Highway Division receives reimbursement from FHWA through several programs, including:[9]

» **The National Highway Performance Program (NHPP):** The NHPP provides support for the condition and performance of the NHS, for the construction of new facilities on the NHS, and 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.

» **The Surface Transportation Block Grant Program (STBG):** The FAST Act converts the long-standing Surface Transportation Program into the Surface Transportation Block Grant Program. The STBG program promotes flexibility in state and local transportation decisions and provides flexible funding to best address state and local transportation needs.

8 https://www.mass.gov/service-details/capital-investment-plan-cip.

9 Adapted from FHWA FAST Act fact sheets, available at: http://www.fhwa.dot.gov/fastact/factsheets/.

- **Congestion Mitigation/Air Quality (CMAQ):** The CMAQ program provides a flexible funding source to state and local governments for transportation projects and programs to help meet the requirements of the Clean Air Act.

- **The Highway Safety Improvement Program (HSIP):** HSIP targets a significant reduction in traffic fatalities and serious injuries on all public roads, including non-state-owned public roads and roads

Approximately one third of the annual STIP budget is distributed between the MPOs based on a formula that considers road mileage and population; the formula is developed by the Massachusetts Association of Regional Planning Agencies (MARPA). The remainder is budgeted for statewide investments identified by MassDOT, including the Bridge Program and the Pavement Program, and for enterprise activities, including bridge inspection and pavement management.

The STIP identifies the obligation of Federal funds by Federal fiscal year, in contrast to the MassDOT CIP which provides spending on a state fiscal year basis. The STIP obligation amounts are calculated as the Federal participating value of projects which are advertised for bidding in each year. For large budget projects the total amount can be applied over multiple years, through a programming tool known as advanced construction.

During development of the five-year STIP, MassDOT can also forecast the actual spending of obligated Federal projects. Federal financing of STIP projects is done through the reimbursement of eligible expenditures, which are typically at a rate of 80% Federal - 20% state. The table below forecasts the amount of expenditures eligible for Federal reimbursement (i.e. the 80%). Because these amounts are constrained by annual obligation limits, they therefore represent the total amount of Federal sources available for investment in the CIP. These expenditures are inflated by 4% annually, to the middle year of construction for each project.

Total Federal revenue in 2020-2029 is shown in Exhibit 4.1.

Exhibit 4.1 Federal Revenue Sources, *2020 to 2029 ($ millions)*

	2020	2021	2022	2023	2024	2025-2029	2020-2029
Total Federal	$624	$706	$696	$702	$677	$3,400	$6,805

4.1.2 State Sources

The two primary state sources for Highway Infrastructure capital investment are revenues derived from the issuance of bonds and user fees collected on tolled facilities.

The Commonwealth of Massachusetts provides capital funding to MassDOT from two types of bonds:[10]

- **General Obligation (GO):** MassDOT receives approximately $815 million annually in General Obligation (GO) bonds, of which approximately $650 million (includes $200 million per year for Chapter 90 program) is targeted for the Highway Division. GO bonds are used to match Federal Aid as well as

[10] Adapted from the language in the *Commonwealth of Massachusetts FY2018-2022 Five-Year Capital Investment Plan.*

support state-funded projects and local transportation grant programs. These bonds are backed by the full faith and credit of the Commonwealth.

- **Special Obligation Bonds (SOB):** SOBs are bonds that are backed by dedicated transportation revenues—the gas excise tax and Registry fees—and fund the ABP and the Rail Enhancement Program (REP). MassDOT currently is completing the final projects to be funded by the ABP, accounting for the decline in SOB funding for Highway over the CIP period.

MassDOT collects tolls on two facilities:

- **The Western Turnpike (WT)** I-90 from the New York Border to I-95 in Weston, connecting Boston with Worcester and Springfield.
- **The Metropolitan Highway System (MHS)** includes the eastern end of I-90 from just west of I-95 in Weston to MA-1A in Boston. It also includes the Tobin Bridge, the Zakim Bunker Hill Bridge, the Tip O'Neill Tunnel (I-93 in Downtown Boston), the Ted Williams Tunnel, the South Bay Interchange (I-90 and I-93), and the Sumner and Callahan Tunnels (MA-1A) in Boston. Each of these facilities except those on I-93 are tolled.

Tolls from each facility are collected in separate revenue streams. MassDOT is required to spend toll revenue solely on the facility on which it was collected.

Capital sources from toll revenue are determined by first ensuring that operating expenses are fully funded, and for the case of the MHS, the annual debt service is paid. The remaining amount is available for capital investment and is summarized in Exhibits 4.2 and 4.3.

Exhibit 4.2 State Capital Revenue Sources, *2020 to 2029 ($ millions)*

	2020	2021	2022	2023	2024	2025-2029	2020-2029
Total	**$652**	**$765**	**$740**	**$728**	**$765**	**$3,562**	**$7,213**
Bond	$473	$464	$460	$436	$497	$2,300	$4,631
Tolls (Net)	$156	$241	$210	$246	$231	$1,100	$2,182
Other	$24	$60	$70	$46	$38	$162	$400

Exhibit 4.3 Total Revenue Sources, *2020 to 2029 ($ millions)*

	2020	2021	2022	2023	2024	2025-2029	2020-2029
Total	**$1,277**	**$1,471**	**$1,436**	**$1,430**	**$1,442**	**$6,962**	**$14,018**
State	$652	$765	$740	$728	$765	$3,562	$7,213
Federal	$624	$706	$696	$702	$677	$3,400	$6,805

The CIP uses these sources to fund the delivery of projects from preliminary design to completion. Project delivery costs include project planning and design, environmental permitting & mitigation, right of way acquisition, utility relocation, construction contract costs and construction engineering. All of these project costs are funded through the CIP. The CIP also provides for statewide operation equipment and materials, and the municipal small bridge and complete street grant programs.

As described, the CIP is guided by the priorities of reliability, modernization and expansion. For the Highway Division, reliability investments form the majority of CIP investment and support the bridge and pavement programs.

4.2 MassDOT Pavement & Bridge Planned Investments

The following information is based on the MassDOT 2020 to 2024 CIP and summarizes planned construction expenditures across all funding sources. The CIP executes MassDOT's asset management investment strategy, a strategy which is directly informed by the life cycle management systems and processes outline in the previous chapters. In general, MassDOT's investment strategy is focused on preserving existing infrastructure, which is illustrated by the absence of spending on initial construction within the CIP.

Spending forecasts do not include project management, design, or other associated costs, which are included within the actual CIP program sizes. Actual spending from state fiscal year 2019 is included for reference.

4.2.1 Bridge Program Planned Investment

Exhibit 4.4 Planned MassDOT Investment in Bridges (NHS & Non-NHS), *2019 to 2029 ($ millions)*

	2019	2020	2021	2022	2023	2024	2025-2029	2020-2029
Total	**$386**	**$382**	**$433**	**$414**	**$311**	**$281**	**$1,821**	**$3,642**
Maintenance	$70	$62	$80	$68	$21	$31	$263	$525
Preservation	$11	$21	$34	$28	$31	$33	$146	$293
Rehabilitation	$148	$168	$123	$90	$73	$82	$537	$1,074
Reconstruction	$157	$130	$195	$228	$186	$135	$875	$1,750

Approximately 60 percent of site-specific bridge spending is forecasted on the NHS, and additional NHS investment is expected within task order maintenance and preservation projects. Estimated spending on NHS bridges is summarized in Exhibit 4.5.

Exhibit 4.5 Planned MassDOT Investment in Bridges (NHS), *2020 to 2029 ($ millions)*

	2019	2020	2021	2022	2023	2024	2025-2029	2020-2029
Total	**$327**	**$247**	**$285**	**$270**	**$202**	**$186**	**$1,190**	**$2,381**
Maintenance	$53	$47	$60	$51	$16	$23	$197	$394
Preservation	$8	$21	$34	$28	$31	$33	$146	$293
Rehabilitation	$140	$101	$74	$54	$44	$49	$322	$644
Reconstruction	$127	$78	$117	$137	$112	$81	$525	$1,050

4.2.2 Pavement Program Planned Investments

Exhibit 4.6 Planned MassDOT Investment in NHS Pavement, *2020 to 2029 ($ millions)*

	2019	2020	2021	2022	2023	2024	2025-2029	2020-2029
Interstate	**$86**	**$120**	**$72**	**$47**	**$56**	**$79**	**$373**	**$746**
Maintenance	$0	$1	$4	$7	$5	$5	$22	$45
Preservation	$1	$11	$9	$2	$0	$7	29	$58
Rehabilitation	$85	$108	$58	$38	$51	$66	$322	$644
Reconstruction	$0	$0	$0	$0	$0	$0	$0	$0
Non-Interstate (MassDOT Only)	**$102**	**$93**	**$140**	**$124**	**$104**	**$148**	**$609**	**$1,218**
Maintenance	$14	$5	$5	$0	$0	$0	$10	$20
Preservation	$2	$6	$37	$35	$5	$9	$93	$185
Rehabilitation	$86	$82	$99	$89	$99	$139	$506	$1,013
Reconstruction	$0	$0	$0	$0	$0	$0	$0	$0

Exhibit 4.7 Planned MassDOT Investment in MassDOT Non-Interstate Pavement, *2020 to 2029 (millions)*

	2019	2020	2021	2022	2023	2024	2025-2029	2020-2029
MassDOT Non-Interstate	**$106**	**$128**	**$154**	**$136**	**$104**	**$152**	**$674**	**$1,347**
Maintenance	$18	$35	$15	$12	$0	$0	$62	$123
Preservation	$2	$10	$37	$35	$5	$9	$97	$193
Rehabilitation	$86	$83	$103	$89	$99	$143	$516	$1,031
Reconstruction	$0	$0	$0	$0	$0	$0	$0	$0

Note: Includes spending on MassDOT owned non-Interstate NHS

4.2.3 Summary of Bridge and Pavement Planned Investments

Exhibit 4.8 MassDOT Statewide Pavement & Bridge Planned Investment, *2020 to 2029 ($ millions)*

	2019	2020	2021	2022	2023	2024	2025-2029	2020-2029
Total	**$579**	**$629**	**$658**	**$597**	**$472**	**$512**	**$2,868**	**$5,736**
Bridge	$386	$386	$433	$414	$311	$281	$1,821	$3,642
Pavement	$193	$248	$226	$183	$160	$231	$1,047	$2,094

4.3 Bridge and Pavement Investment Needs Gap Analysis

As identified within previous chapters, planned investments in bridge and non-Interstate pavement are not expected to achieve long term state-of-good-repair targets.

Based on this plan's recommendations, the 2020-2024 CIP includes an additional $155 million above the previous CIP for investment in MassDOT-owned non-Interstate NHS pavements to improve performance compared to performance targets. However, a proportional increase is also needed on non-DOT owned NHS roads. Exhibit 4.9 identifies the gap for non-DOT NHS pavements in years 2020-2024, and is combined with the gap to sustain elevated investment on the DOT roads in years 2025-2029.

For bridges, meeting long-term condition targets requires an increase of spending to $200 million above current levels. Investment needs to achieve state-of-good-repair is summarized below

Exhibit 4.9 MassDOT Statewide Pavement & Bridge Investment Needs, *2020 to 2029 ($ millions)*

	2020	2021	2022	2023	2024	2025-2029	2020-2029
Total	**$20**	**$45**	**$70**	**$95**	**$120**	**$1,250**	**$1,600**
Bridge	$0	$25	$50	$75	$100	$1,000	$1,250
Pavement	$20	$20	$20	$20	$20	$250	$350

5. RISK MANAGEMENT

In prior chapters, this TAMP has identified objectives and strategies for the preservation of the NHS and state-owned infrastructure in Massachusetts. These strategies are founded upon best practices and best available data, though as is common with any plan, outcomes are subject to the effects of external forces. A risk management program serves to identify, address, and monitor risks so that the impact of outside forces can be minimized. This section of the plan outlines how MassDOT is currently addressing risk within the organization and how it plans to do so in the future.

5.1 Identifying Risk

MassDOT has a long history of identifying, avoiding, and/or mitigating of risk. Many current and former departmental initiatives are borne from a recognition of specific process vulnerabilities. For the development of this plan, MassDOT reviewed its internal processes with the purpose of formalizing risk management activities, and also looked externally for best practices in use at peer DOTs and in other industries.

An outcome of this review is the recognition that the final phase of risk management, the monitoring of risk, is best supported through **performance management**, and that in general, risk and performance management can be seen as interwoven processes. For example, in addition to measures for asset condition discussed within this document, the Highway Division maintains a series of performance measures, which serve as markers for specific risks to agency goals. These measures are noted where relevant throughout this section.

MassDOT risk management can be viewed within a three-tier hierarchy of **Enterprise**, **Program**, and **Project** Risks.

5.2 Enterprise Risks

Enterprise risks affect the mission, vision, and overall results of MassDOT's asset management efforts. The section summarizes the following high-priority enterprise risks actively being addressed by the department. In many cases, these risks are pursued at the direction of MassDOT leadership with the support of the Transportation Board.

5.2.1 Communication and Transparency

Likelihood and Consequence

*MassDOT identifies excellent customer service as central to its stated mission.
The loss of credibility with stakeholders and the public will undermine this objective,
and without a clear strategy for public engagement, there is a high likelihood this could occur. Should this occur, Agency decision-making ability could be undermined.*

Examples of measures underway to mitigate (this) enterprise risk include:

- Improved tracking of external maintenance service requests by the Highway Division;
- Livestreaming of MassDOT's board meetings on the Internet;
- Commitment to a strong social media presence, both for the agency and for individual administrators and managers, that provides reminders of public meetings and collaboration opportunities; notifications about coming operational impacts; and progress reports and photographs on major projects, smaller local projects, and routine preventive maintenance;
- Increased use of comprehensive project-focused communication plans to raise awareness and solicit stakeholder collaboration. Examples include the Commonwealth Avenue Bridge, the Allston Interchange, the Longfellow Bridge, the North Washington Street Bridge (all in Boston), the I-91 Viaduct in Springfield, and the Kelley Square redesign in Worcester, among many other successful and ongoing efforts;
- Ongoing commitment to increased awareness and engagement in the MassDOT Capital Planning Process;
- External access to current asset condition data; and
- Participation in the Every Day Counts 5 Committee on Virtual Public Involvement.

5.2.2 Coastal Vulnerability

Likelihood and Consequence

The effects of extreme weather and climate change are not projected to have a high likelihood in the short term, but long-term impacts are projected to have a dramatic effect on coastal infrastructure.

MassDOT has undertaken several recent studies of coastal vulnerability to weather and climate change-induced flooding. These include:

- The ongoing **Coastal Transportation Vulnerability Assessment** is refining the state-of-the-art Boston Harbor Flood Risk Model (BH-FRM) and extending it to the entire Massachusetts coastline to identify transportation assets vulnerable to sea level rise and storm surge. This project will evaluate impacts associated with the current year, 2030, 2050, and 2070/2100 climate scenarios and recommend conceptual-level adaptation strategies, considering both natural and built protection measures.
- The **Coastal Flood Exceedance Probability Maps** show the likelihood that a location within the BH-FRM domain will be flooded by 2 or more inches of water encroaching on the land surface at a particular location in any given year. Exceedance probabilities range from 0.1 percent (probability associated with the 1000-year water surface elevation) to 100 percent (probability associated with the highest annual tide).

» The **Central Artery/Tunnel (CA/T) Vulnerability and Adaptation Assessment**, completed in June 2015, created the hydrodynamic BH-FRM to identify risk and depth of water resulting from storm surge-induced coastal flooding in Boston under current and future sea levels. Based on the CA/T system's high sensitivity to flooding and little redundancy built into it, the CA/T study recommended conceptual-level adaptation strategies for current and future time horizons—flood entry points for the 2030 scenario were then taken up by the City of Boston for adaptation. The CA/T Vulnerability and Adaptation Assessment team also developed Coastal Flood Exceedance Probability Maps and Estimated Flood Depth Maps for the 2013, 2030, and 2070/2100 climate scenarios for four other locations: Allston, Morrissey Boulevard, Prudential Tunnel (I-90), and Muddy River.

5.2.3 Stream and River Crossing Vulnerability

Likelihood and Consequence

Culverts on many high-volume corridors date back to original construction. The age of the infrastructure, along with increased duration and intensity of storm events, increase the likelihood of a culvert failure which has the potential of limiting mobility on high-priority corridors.

In the aftermath of significant damage to roads and bridges in the Deerfield River watershed from Tropical Storm Irene, MassDOT partnered with the University of Massachusetts Amherst to both identify culverts in the watershed and rate the danger to those culverts and to bridges from river flooding (culverts that are overwhelmed by flooding can undermine and damage the highways above). The study was completed in 2016.

After the completion of the Deerfield River pilot, MassDOT received funding from FHWA to expand its approach in the **Statewide Vulnerability Assessment**. Specifically, both studies sought to:

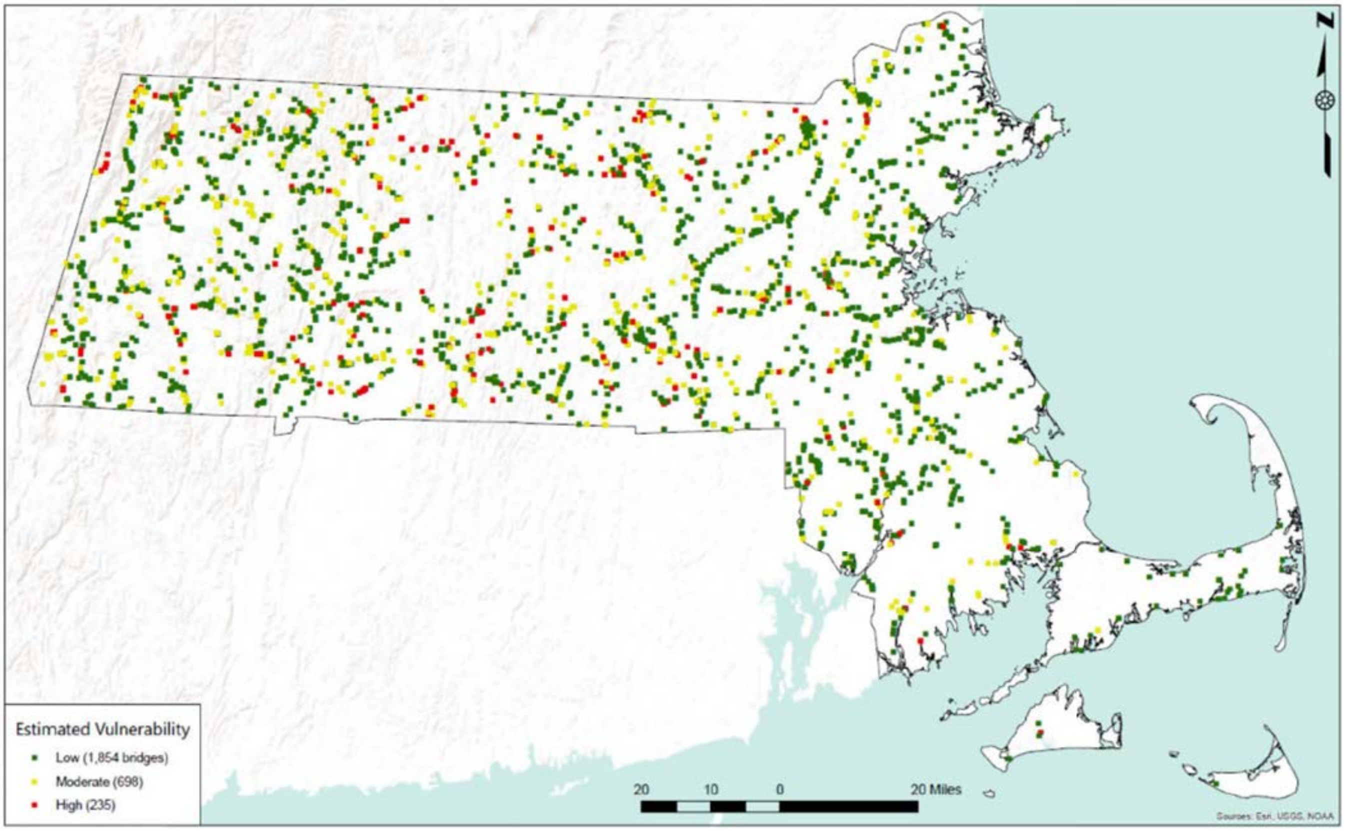
» Identify culverts and small bridges that cross streams and rivers. **MassDOT studied 1,100 department-owned culverts and 2,700 bridges**.

» Identify structures with poor "geomorphic" design, i.e., a design where the distance between the sides of a cylindrical (pipe) culvert or the walls of a box culvert is narrower than the maximum width the stream can attain during a typical flood (the "bank-full width"). If this is the case, the structure itself can cause the stream to speed up in a "firehose," causing damage to the structure.

» Identify locations on streams and rivers where "stream power" (measured in Watts and related to flow rate) is high and "bed resistance" (related to the smoothness and composition of the riverbed) is low. Structures should not cross at these high-risk locations. **MassDOT found that 906 of approximately 16,000 miles of rivers and streams feature these conditions.**

Taken together, MassDOT found that a large percentage of its culverts are vulnerable while a smaller, but still significant percentage of its bridges are vulnerable. A map of these locations is provided in Exhibit 5.1. When climate change-enhanced future rainfall rates are considered, 90 culverts are considered vulnerable.

Exhibit 5.1 Vulnerable Bridges over Massachusetts Rivers and Streams, *Physical Design and Flow Characteristics*



This information will be used to drive inspection and replacement efforts going forward.

5.2.4 Construction Coordination and Management Planning

Likelihood and Consequence

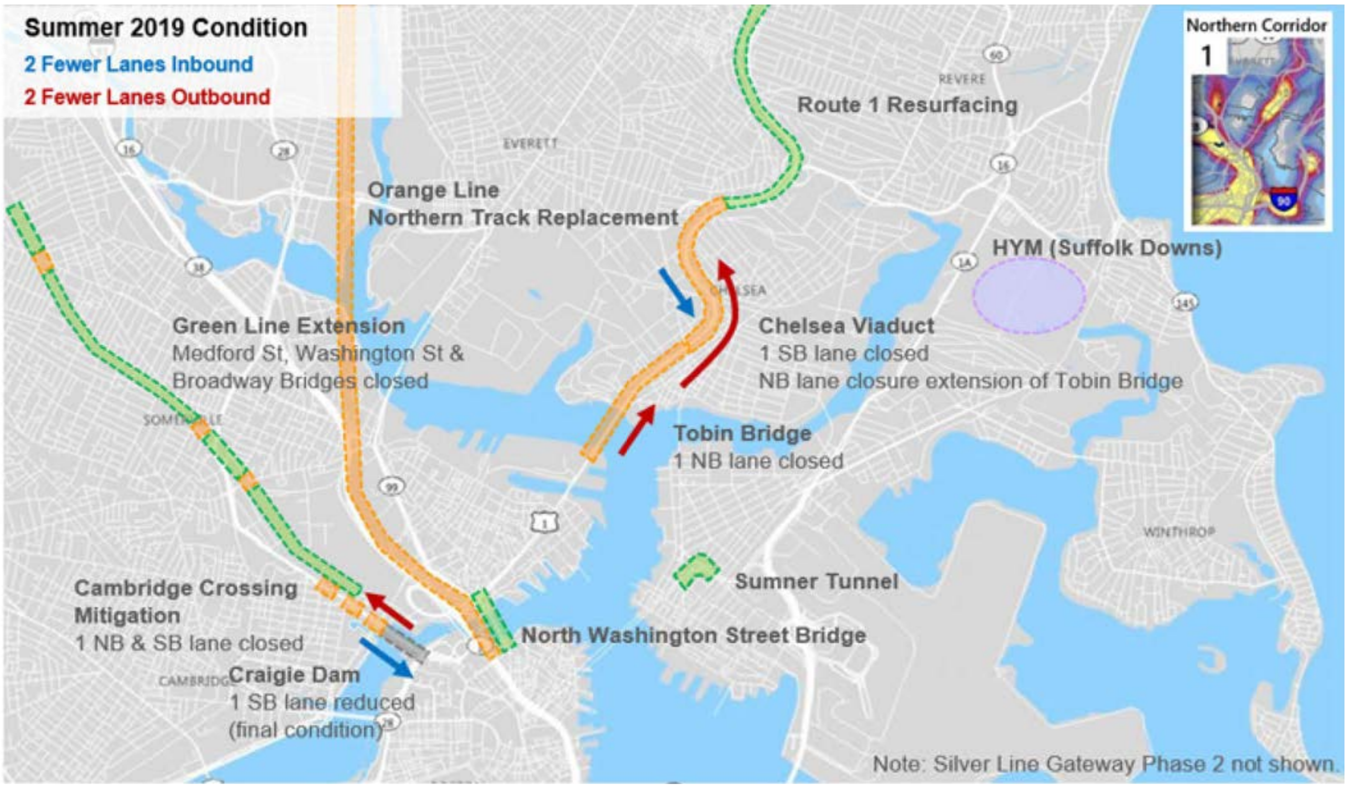
The repair or replacement of infrastructure on highly traveled corridors or regions poses a challenge to the flow of cars, pedestrians, bicycles, and transit vehicles. MassDOT and the MBTA together expect to invest billions of dollars in the coming decade to improve state of good repair, and if these efforts are not coordinated, mobility will be severely impacted.

MassDOT and the MBTA have recognized the need for a coordinated approach to capital planning, including:

- Project identification, sequencing, and coordination;
- Development of mitigation, diversion, and mobility options; and
- Strategizing for customer/stakeholder outreach and communication.

The Highway Division and the MBTA implemented construction coordination and management planning during the fall 2017, winter 2018, and winter 2019 project development and construction periods. These efforts began by focusing on the North Shore, including crossings of the Malden River, Mystic River, Charles River, and Inner Harbor to approach Boston. The team identified 17 critical projects with weekday peak-period capacity impacts, then harmonized their construction schedules and created a unified mapping tool to plan lane closures and other constraints, as shown in Exhibit 5.3.

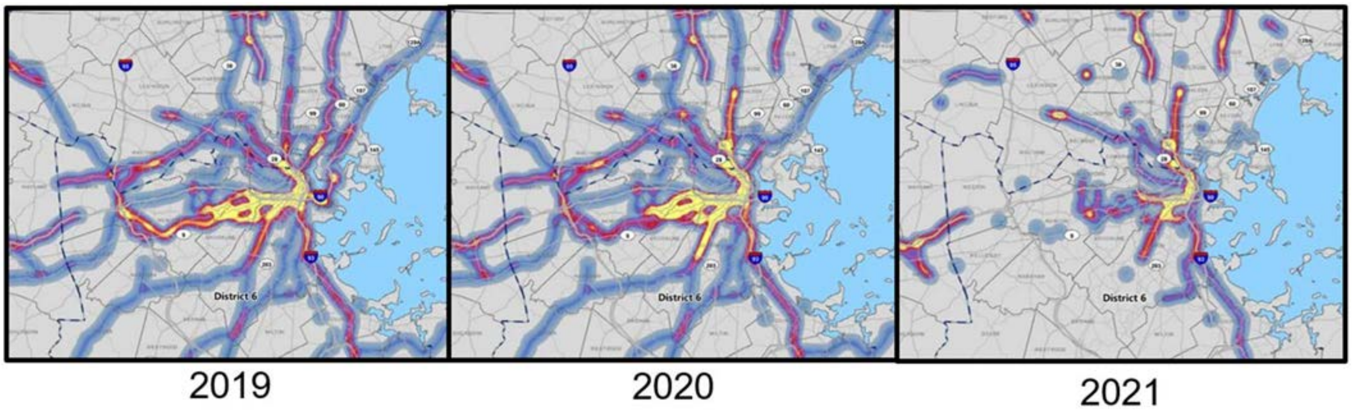
Exhibit 5.2 Capacity Constraints for Critical Projects, *Summer 2019*



At the direction of the Governor of Massachusetts, the two agencies expanded this effort to all of Greater Boston (within I-95 and Route 128) over winter 2018 using an internal coordination team with buy-in across MassDOT and the MBTA, as well as the Central Transportation Planning Staff of the Boston MPO. This team coordinated not only Highway Division and MBTA projects, but also work conducted by DCR, Massport, municipalities, the Massachusetts Water Resources Authority (MWRA), utility companies, and private real estate developers, using a single submission form and unified project database and mapping system.

The winter 2018 effort produced not only a geospatial dataset of work, but also an interactive map tool for use in public meetings. The tool displays not only the impacts of the project under discussion, but also those nearby, regardless of owner. In addition, the dataset was used to produce a "heat map" of the Boston Area, identifying "hot spots" of operational impacts. This heat map is shown in Exhibit 5.4 over the 2019 to 2021 construction seasons and represents 1,118 projects.

Exhibit 5.3 Heat Map of Capacity Impacts from All Agencies, *2019 to 2021*



Beginning in winter 2019 and moving forward, MassDOT will use these tools to make more informed construction sequencing decisions that will reduce congestion and economic loss while ensuring that MassDOT can address some of its most risky highway assets (along with equivalent assets for the MBTA and others).

In the coming years, MassDOT's ambition is to expand the database, mapping tools, and business practice improvements to the whole of the Commonwealth.

5.2.5 Information Technology—Disaster Recovery Plan

Likelihood and Consequence

While the likelihood of a general emergency, security breach, or disaster that will compromise MassDOT's IT Environment is low, the consequence of a significant outage would affect MassDOT's ability to deliver its core functions.

MassDOT has initiated a process (led by MassDOT IT) to develop an agency-wide disaster recovery protocol. The result will be a living document which identifies key departmental functions and the IT resources necessary for those functions to operate under normal circumstances. The plan will consider the following:

- **Core Business Processes:** Top four to six activities that each department is tasked with performing for constituents or for MassDOT as a whole which each department must complete to be considered "operational."
- **Recovery Time Objectives (RTOs):** The maximum amount of time a core business process can be unavailable to a department before the business impact is unacceptable.
- **Software Applications, Vital Records, and Dependencies:** The identification and detailing of technology applications, vital records, and organizational dependencies (both internal and external) are necessary to complete each business process.
- **Enterprise Impact Parameters:** The set of categories used to understand the impact of a disruption of a business process across MassDOT.

5.3 Program Risks

Program risks affect MassDOT's ability to successfully deliver the capital program and meet performance targets.

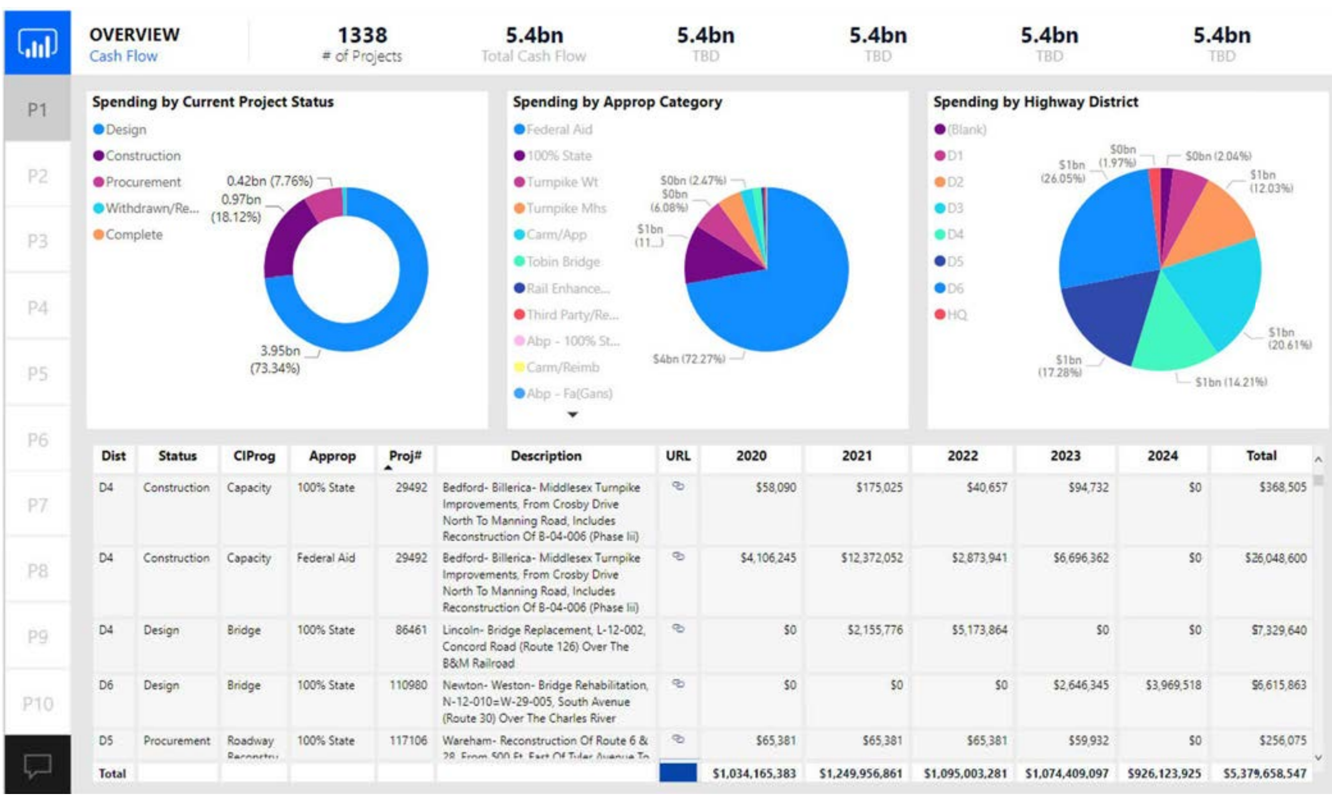
5.3.1 Highway Capital Delivery

Likelihood and Consequence

Increased capital budgets can only be realized if there is a capacity to deliver it in the form of projects. Staff turnover, increased process, and loss of efficiency are forces at work in every organization. These influences have a high likelihood of inhibiting MassDOT from realizing increased investment.

The ability to deliver a capital project from preliminary design to actual construction requires capable people, robust but agile processes, and properly configured technology. Each of these Capital Delivery components must be attended to in order for investments to be realized. The Highway Division is looking at inputs to each major component through work force planning (see below), process re-engineering and increased and improved access to data.

Exhibit 5.4 Excerpt from the Highway Division Project Delivery Dashboard



Dist	Status	CIProg	Approp	Proj#	Description	URL	2020	2021	2022	2023	2024	Total
D4	Construction	Capacity	100% State	29492	Bedford- Billerica- Middlesex Turnpike Improvements, From Crosby Drive North To Manning Road, Includes Reconstruction Of B-04-006 (Phase Iii)		$58,090	$175,025	$40,657	$94,732	$0	$368,505
D4	Construction	Capacity	Federal Aid	29492	Bedford- Billerica- Middlesex Turnpike Improvements, From Crosby Drive North To Manning Road, Includes Reconstruction Of B-04-006 (Phase Iii)		$4,106,245	$12,372,052	$2,873,941	$6,696,362	$0	$26,048,600
D4	Design	Bridge	100% State	86461	Lincoln- Bridge Replacement, L-12-002, Concord Road (Route 126) Over The B&M Railroad		$0	$2,155,776	$5,173,864	$0	$0	$7,329,640
D6	Design	Bridge	100% State	110980	Newton- Weston- Bridge Rehabilitation, N-12-010=W-29-005, South Avenue (Route 30) Over The Charles River		$0	$0	$0	$2,646,345	$3,969,518	$6,615,863
D5	Procurement	Roadway Reconstru...	100% State	117106	Wareham- Reconstruction Of Route 6 & 28, From 500 Ft. East Of Tyler Avenue To...		$65,381	$65,381	$65,381	$59,932	$0	$256,075
Total							$1,034,165,383	$1,249,956,861	$1,095,003,281	$1,074,409,097	$926,123,925	$5,379,658,547

5.3.2 Large Assets and Megaprojects

Likelihood and Consequence

The deterioration of large legacy NHS structures is an eventuality, and advanced planning is necessary to lay the groundwork for replacement and avoid lengthy delays in delivery of replacement projects.

As described in the Bridge chapter, MassDOT recognizes the influence that an asset's size has on its condition.

Along with outsized costs, replacing larger structures also poses complex planning challenges, as these facilities may need to be reconfigured for the next generation of transportation infrastructure. An extended planning process can delay resolution of these structures and impact MassDOT's ability to improve bridge condition. The Highway Division is forming a team within its project delivery section to manage these projects.

5.3.3 Contractor Capacity

Likelihood and Consequence

MassDOT is successful through partnerships with its customers, transportation stakeholders, the Con sulting community and ultimately the construction industry. Contractor capacity can directly affect the cost, pace, and quality of construction. A thriving private construction market, labor shortages, and increased complexity has a high likelihood of limiting MassDOT's capital program.

MassDOT mitigates this risk through close coordination with the construction industries of Massachusetts.

5.3.4 Workforce Planning

Likelihood and Consequence

MassDOT faces a number of workforce-related challenges, including an increasing volume of retirements and a thriving and dynamic private sector competing for increasingly specialized skill sets. This is an ongoing challenge that will affect all areas of the agency if not addressed.

MassDOT human resources is meeting this challenge head-on through a multifaceted approach of **recruitment, retention, employee development, knowledge transfer, and succession planning**.

5.4 Project Risks

Project risks directly affect project outcomes, and therefore, have a direct bearing on asset condition.

5.4.1 Project Prioritization

Likelihood and Consequence

The project selection process inherently involves the management of risk. When programming reliability projects, multiple factors are weighed to arrive at the project that is likely to provide the most benefit. A successful project selection will result in the most utility to the user and the most efficient use of available funding. Both the pavement and bridge sections employ a project selection process, which recognizes and attempts to mitigate risk.

» **Bridge prioritization** uses a scoring system that incorporates an individual structure's risk from scour, weight limits, and geometry, as well as the consequence of disruption of the structure as expressed through traffic volume and detour length.

» **Pavement prioritization** assesses the vulnerability of segments to risk in two ways—safety and value per dollar. The second of these measures is used to identify not only segments where significant performance gains can be attained most cost effectively, but also segments where deferring maintenance results in the least risk to operations and to the department in general.

5.4.2 Project Management and Project Controls

Likelihood and Consequence

The one constant in construction is uncertainty. Complexity, tight design schedules, and latent condi tions can all affect the ability to deliver projects on-time and on-budget. However, MassDOT's ability to deliver on the performance and customer service improvements in its annual CIP depends upon the on-time and budget delivery of projects. To this end, the Highway Division employs a series of project management and project control measures meant to support project outcomes.

» **Project Scoping:** Projects tend to be more successful if a scope is clearly defined early in the process. Additional needs within project limits and/or latent complexity can increase costs and delay design. The Highway Division has established procedures to ensure there is early multidisciplinary coordination in advance of the first formal design submittal. These meetings are attended by local proponents, District staff, bridge and highway designers, utility engineers, and design consultant staff.

- » **Accurate Cost Estimating:** Large cost increases not only reduce MassDOT's ability to fund the full work program but can also delay a project while new funding is identified—in extreme examples, increases can render a project infeasible. Accurate estimating provides planners with reliability within the capital plan and encourages confidence in the project. Based on project type and complexity, preliminary estimates include a design contingency to account for uncertainty. As design progresses, the contingency is reduced ,and the project becomes more reliant upon unit costs. For current unit prices, MassDOT maintains a database of all bids which is available to both internal and external staff.
- » **Project Classification:** To guide the level of review resources a risk assessment is performed early in preliminary design.
- » **Reporting:** The Highway Division has established performance measures for project delivery that it reports on an annual basis: percentage of projects completed on time, percentage of projects completed under budget, and percentage of planned advertised projects that were successfully advertised. These three measures can be impacted by a wide range of risks, including cost variability, and contractor availability.

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The Federal Rule requires that MassDOT conduct a statewide evaluation to determine if there are reasonable alternatives to roads, highways, and bridges that have required repair and reconstruction activities on two or more occasions due to emergency events.

As required by the Final Rule, MassDOT conducted a study of assets damaged in declared emergencies between January 1, 1997 and December 31, 2018. This study has determined that one asset – **a sidewalk on MA-18 at the Matfield River crossing on the border of East Bridgewater and South Bridgewater** – required repair or reconstruction activities on more than one occasion due to emergency events during that time period. As described below, MassDOT has addressed the root cause of this failure.

6.1 Emergency Declarations in Massachusetts

Massachusetts was subject to approximately 30 (depending on how duplicates and multipart emergencies are counted) declarations of emergency during the study period. These were mainly in response to storms and their attendant flooding, with a small number of human-caused events (the Worcester warehouse fire in 1999, the MWRA water main break in 2010, the Marathon Bombing in 2013, and the Merrimack Valley Gas Explosion in 2018). Massachusetts has had not declared emergencies due to wildfires, seismic activity, or any other natural disaster beyond severe weather.

Of these events, only five produced damage to MassDOT assets according to department records:

» Flooding as a result of a series of rainstorms (May 2006);

» Flooding as a result of a series of rainstorms (March 2010);

» A tornado and other severe weather in Springfield and the surrounding region (June 2011);

» Tropical Storm Irene (September 2011); and

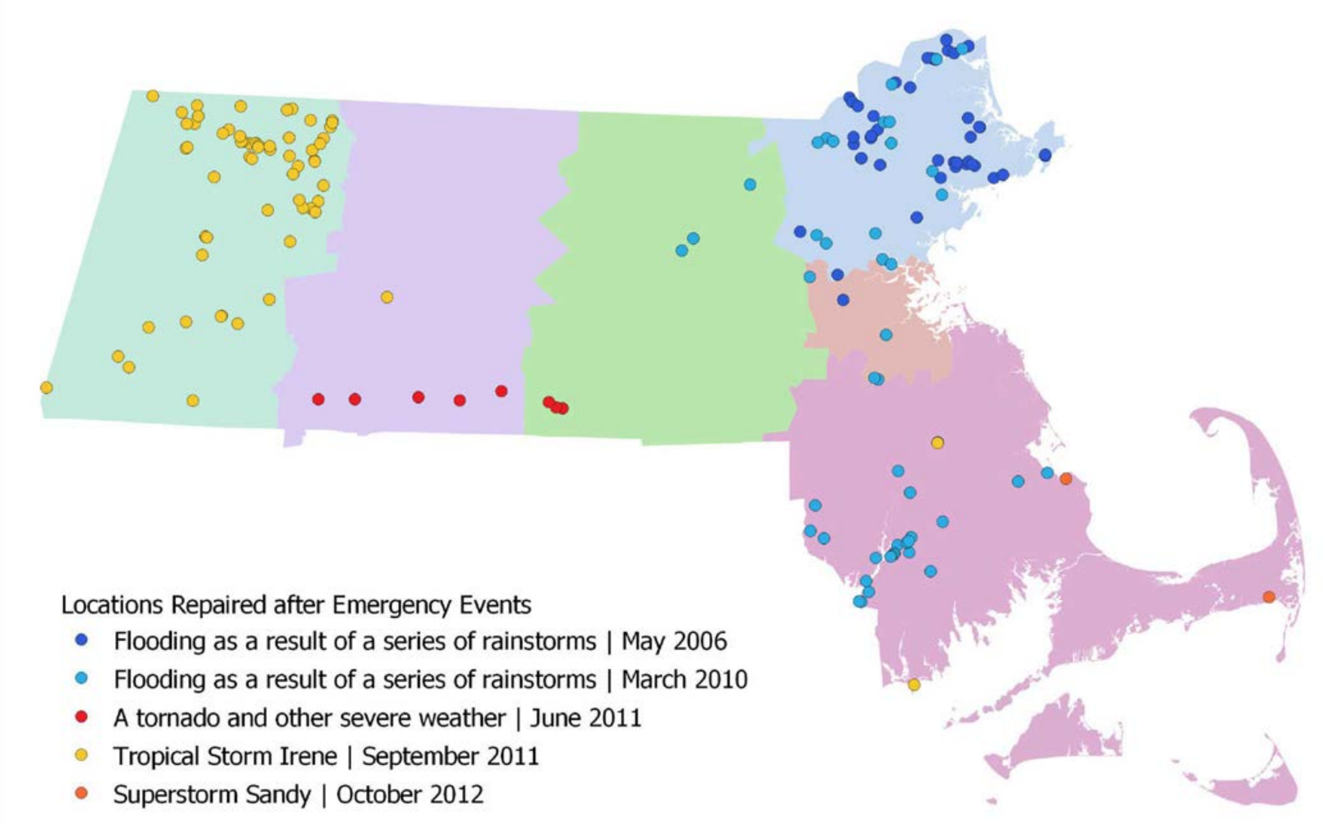
» Superstorm Sandy (October 2012).

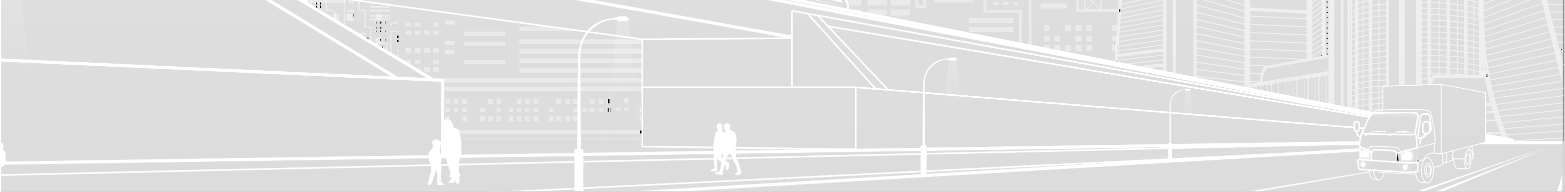
6.2 List of Assets Damaged in Emergency Events

MassDOT's Highway Districts provided records of all requests for state or Federal disaster reimbursement on highway bridges and pavement. These requests concerned 161 locations spread across the Commonwealth, as shown in Exhibit 6.1.

MA-18 at the Matfield River was cited twice for disaster reimbursement, for the March 2010 flooding event and for Tropical Storm Irene. MassDOT has since improved the location, reconstructing the roadway and building drainage best management practices. No other location received disaster reimbursement on multiple occasions during the study period.

Exhibit 6.1 Locations where Assets were Damaged by Emergency Events, *1997 to 2018*





APPENDIX A. DEFINITIONS AND TERMINOLOGY

The Final Rule defined the following terms:

- **Asset Class:** A group of assets with the same characteristics and function (e.g., bridges, culverts, tunnels, guardrail).
- **Benefits Cost:** The lifetime cost of the benefits provided by an asset. In effect, the "life-cycle cost" with an eye toward benefit/cost analysis.
- **Asset Subgroup:** A specialized group of assets within an Asset Class with the same characteristics and function (e.g., concrete pavement or asphalt pavement).
- **Critical Infrastructure:** Facilities having the incapacity or failure of which would have a debilitating impact on national or regional economic security, national or regional energy security, national or regional public health or safety, or any combination of those matters.
- **Financial Plan:** A long-term plan spanning over 10 years or longer, presenting a state DOT's estimates of projected available financial resources and predicted expenditures in major asset categories that can be used to achieve state DOT targets for asset condition during the plan period, and highlighting how resources are expected to be allocated based on asset strategies, needs, shortfalls, and agency policies.
- **Life-Cycle Planning:** Management of the operation and maintenance of assets to minimize their cost relative to benefits over the entire useful life.
- **Minimum Practicable Cost:** The lowest feasible cost to achieve the objective. Thus, the lowest cost action may not be a feasible action if it does not help states to achieve their objectives.
- **Work Type:** The Final Rule requires that all work be summarized into five categories: initial construction, maintenance, preservation, rehabilitation, and reconstruction.

In addition to these terms, Exhibit A.1 lists common abbreviations and other terminology both from FHWA and specific to MassDOT.

Exhibit A.1 Definitions of Common Terminology

AASHTO	**The American Association of State Highway and Transportation Officials**
BMS	**Bridge Inspection Management System:** The system through which MassDOT bridge inspectors submit their inspection reports and which MassDOT uses as its system of record for bridge inventory and condition.
BrM	**AASHTOWare Bridge Management:** A software package developed by AASHTO to serve as a bridge inventory and management system for all states. MassDOT is in the process of implementing it for modeling the future condition of bridges.
CFR	**Code of Federal Regulations:** A codification of the general and permanent rules published in the Federal Register by the Executive departments and agencies of the Federal Government, based on an interpretation of the U.S. Code.
CIP	**Capital Investment Plan:** MassDOT's department-wide annual capital plan. Includes projects identified in the State Transportation Improvement Program, as well as projects for rail, transit, and air modes; for the registry of motor vehicles; and for enterprise functions.
CL	**Condition Loss:** The percentage difference between the average of the three 9-point bridge component scores—deck, superstructure, and substructure—and the maximum score of 9 points.
dTIMS	**Deighton Total Infrastructure Management System**
FAPRO	**MassDOT Federal-Aid Programming and Reimbursement Office**
FAST Act	**Fixing America's Surface Transportation Act**
FHWA	**Federal Highway Administration**
HEF	**Highway Evaluation Factor:** For bridges; the average of five-point scores for Average annual Daily Traffic (AADT), detour length, functional classification, structural evaluation, and deck quality.
HI	**Health Index:** A 0 to 100 score computed by a bride management system that reflects the remaining utility of a bridge based on the condition of its elements, as reflected in inspection results, where a score of 100 is indicative of a bridge with full useful life.
HPMS	**Highway Performance Monitoring System:** An FHWA-maintained, national-level highway information system that includes state DOT-submitted data on the extent, condition, performance, use, and operating characteristics of the Nation's highways.
IBC	**Incremental Benefit/Cost Ratio:** A 0 to 100 value.
IRI	**International Roughness Index:** A statistic used to estimate the amount of roughness in an MPO measured longitudinal profile of roadway pavement.
MAP-21	**Moving Ahead for Progress in the 21st Century:** Signed into law by President Obama on July 6, 2012. MAP-21 Section 1310 codifies in 23 U.S.C. §168 an additional authority for the use of planning products in the environmental review process required under the National Environmental Policy Act. The text of 23 U.S.C. §168 is attached to this overview.
MPO	**Metropolitan Planning Organization**
MARPA	**Massachusetts Association of Regional Planning Agencies:** This group develops the formula used to distribute Federal-aid funds among MPOs during the development of TIPs and the STIP.

NBI	**National Bridge Inventory:** 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.
NHPP	**National Highway Performance Program:** Provides support for the condition and performance of the NHS, for the construction of new facilities on the NHS, and to ensure 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.
NHS	**National Highway System:** A network of roadways important to the Nation's economy, defense, and mobility.
NPMM	**National Performance Management Measures:** MAP-21 requires the Secretary, in consultation with states, MPOs, and other stakeholders, to establish performance measures in the following areas: Pavement condition on the Interstate System and on remainder of the NHS, Performance of the Interstate System and the remainder of the NHS, Bridge condition on the NHS, Fatalities, and serious injuries—both number and rate per vehicle mile traveled—on all public roads, traffic congestion, on-road mobile source emissions; and freight movement on the Interstate system.
NPRM	**Notice of Proposed Rulemaking:** A public notice published in the Federal Register indicating a Federal agency's intent to revise the Code of Federal Regulations (CFR) according to the agency's interpretation of Federal law. Publication of an NPRM, usually prompted by the passage of a Federal law like MAP-21, provides interested parties with the opportunity to comment on the proposed revisions to the CFR.
PFP	**Planning for Performance:** An Excel-based scenario planning tool used by MassDOT during the development of program investment levels for the CIP.
PSAC	**Project Selection Advisory Council:** Scores proposed projects supporting MassDOT's goals of modernization and expansion during the CIP process.
PSI	**Pavement Serviceability Index:** MassDOT's day-to-day condition measure for pavement, incorporating roughness, raveling, and three types of cracking.
RF	**Ranking Factor:** MassDOT's prioritization score for bridges, incorporating condition loss, highway effectiveness factor, scour criticality factor, and projected health index.
SCF	**Scour Criticality Factor:** A multiplier applied to the bridge ranking factor to represent the danger posed by scour.
STIP	**State Transportation Improvement Program:** An annual document that combines the products of 13 TIPs into a statewide fiscally constrained list of Federally aided projects.
TIP	(Regional) **Transportation Improvement Program**
UOT	**Underwater Operations Team:** Conducts underwater inspections of all state, city, and town bridges where required, on a year-round basis. It also assists in repairing bridge substructure elements and installing scour countermeasures.
USC	**United States Code:** A consolidation and codification by subject matter of the general and permanent laws of the United States.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