TRANSPORTATION ASSET MANAGEMENT PLAN

massDOT
Massachusetts Department of Transportation

UPDATED FALL 2023

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STOP

EXHIBITS

1 INTRODUCTION

1.1 Goals and Objectives of the TAMP

The Massachusetts Department of Transportation (MassDOT) has developed this 2023 update to its Transportation Asset Management Plan (TAMP) to document its progress toward a long-term state-of-good repair (SOGR) in its pavement and bridge assets. This TAMP complies with 23 CFR 515.7, which calls for state departments of transportation (DOTs) to develop and implement a 10-year risk-based asset management plan for pavement and bridge assets on the National Highway System (NHS). For these assets, the TAMP must discuss inventory and condition; objectives and measures; a gap assessment against those measures; life cycle planning practices; investment strategies; risk management practices; and financial projections (cost of future work and available funding) to a 10-year horizon. MassDOT has chosen to include in the TAMP all pavement and bridges on the NHS (regardless of owner) and all pavement and bridges owned by MassDOT (regardless of NHS status).

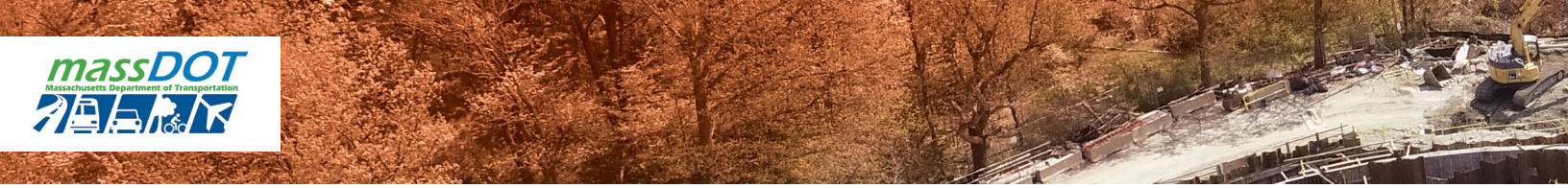
MassDOT's mission is to deliver excellent customer service to people traveling in the Commonwealth by providing transportation infrastructure which is safe, reliable, robust and resilient. We work to provide a transportation system which can strengthen the state's economy and improve the quality of life for all.

This TAMP advances MassDOT's mission through several objectives:

- Define Highway Division asset management practices.
- Summarize current and future asset condition with high-quality data.
- Analyze current and future performance through performance targets and goals.
- Identify planned investment strategies as well as other scenarios to illustrate gaps in funding (and other gaps) that prevent MassDOT from achieving SOGR within the 10-year timeframe.
- Document how MassDOT uses life cycle planning to achieve SOGR for individual assets at minimal cost.
- Discuss how MassDOT mitigates risks to performance and establish the Department's enterprise risk management approach and enterprise risk tolerance.

These objectives are the same ones that drove the first MassDOT TAMP in 2019. In building on that document, MassDOT has focused on three themes:

- **Capital Delivery |** Massachusetts received the sixth-largest state apportionment of Bridge Formula Program Funds through the Infrastructure, Investment, and Jobs Act of 2021 (IIJA). Combined with the Commonwealth's Next Generation Bridge Financing Program, MassDOT will be able to support over $3 billion in bridge investment over the coming ten years. Massachusetts is currently in low standing nationally with respect to bridge



condition (see Section 3.1), and this funding can make a substantial difference. Feeding the design pipeline and coordinating construction to realize the potential benefits will test all areas of the organization.

» **Workforce |** As legacy staff retire, MassDOT must both attract a new generation of public servants and also train, promote and retain future leaders within its ranks. During the COVID-19 Pandemic, MassDOT adopted new technologies, team strategies, and work schedules while continuing to fulfill core functions. Building on this success, the Department and its workforce must now adapt to increased levels of investment and new demands on the Commonwealth's infrastructure.

» **Operational Modernization |** Physical condition is not the only measure of effectiveness. MassDOT must continue to consider other infrastructure functions, including support of multimodal travel and resiliency to extreme weather and temperature – as it addresses a repair backlog and makes generational investments with hundred-year lifespans.

1.2 Implementation of the TAMP

Implementation of this TAMP can be observed in three focus areas: investment; asset conditions; and organizational structure/process improvement.

» **Investment |** The MassDOT Capital Investment Plan (CIP)[1] realizes the investment strategies discussed in the TAMP (see Section 4.1). The 2023-2027 CIP will serve as the baseline to measure actual expenditures through the consistency determination process conducted by the Federal Highway Administration (FHWA) Massachusetts Division Office. This process has proven invaluable as an opportunity for State and Federal agencies to coordinate and discuss TAMP implementation and infrastructure investment.

» **Asset Conditions |** The strategies in this TAMP are intended to have a measurable benefit for Massachusetts transportation infrastructure. These benefits should be observable in Federal performance management reporting[2] and through the MassDOT Tracker.[3]

» **Organizational Structure/Process Improvement |** The MassDOT Highway Division is administratively divided into engineering; construction; operations/maintenance; and traffic/safety. All of these focus areas intersect with asset management. To coordinate their efforts and provide day-to-day leadership, since 2019 MassDOT has established a dedicated asset management team to liaise with pavement and bridge engineers and to provide program, data, and project-focused support for initiatives across the Department. MassDOT has also established a Project Management Office (PMO) to manage risks to delivery of the CIP. The PMO's role and accomplishments are discussed Section 4.2.

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

2 https://www.fhwa.dot.gov/tpm/reporting/state/

3 https://www.mass.gov/lists/tracker-annual-performance-management-reports

2 PAVEMENT

2.1 Inventory and Condition for Pavement

2.1.1 Pavement Inventory and Data Collection

MassDOT owns approximately 75% of NHS lane-mileage in Massachusetts, including the entire Interstate System. The remainder of the NHS is shared among five types of entities: municipalities, the Department of Conservation and Recreation (DCR), the Massachusetts Port Authority (Massport), State institutions such as colleges and universities, and the Federal Government. Lane-mileage under the jurisdiction of these groups is shown in Exhibit 2.1. A table of NHS lane-mileage by municipality is provided in **Appendix B**.

Exhibit 2.1 **Pavement Lane-Mileage by Jurisdiction**

JURISDICTION	NHS	ALL PUBLIC ROADS
TOTAL	**10,713**	**76,829**
MASSDOT	7,639	9,526
MUNICIPALITIES	2,825	58,285
DCR	208	537
MASSPORT	17	35
STATE PARK	0	367
STATE INSTITUTIONAL	1	154
COUNTY INSTITUTIONAL	0	8
FEDERAL	3	169
OTHER (E.G., PRIVATE)	18	7,748

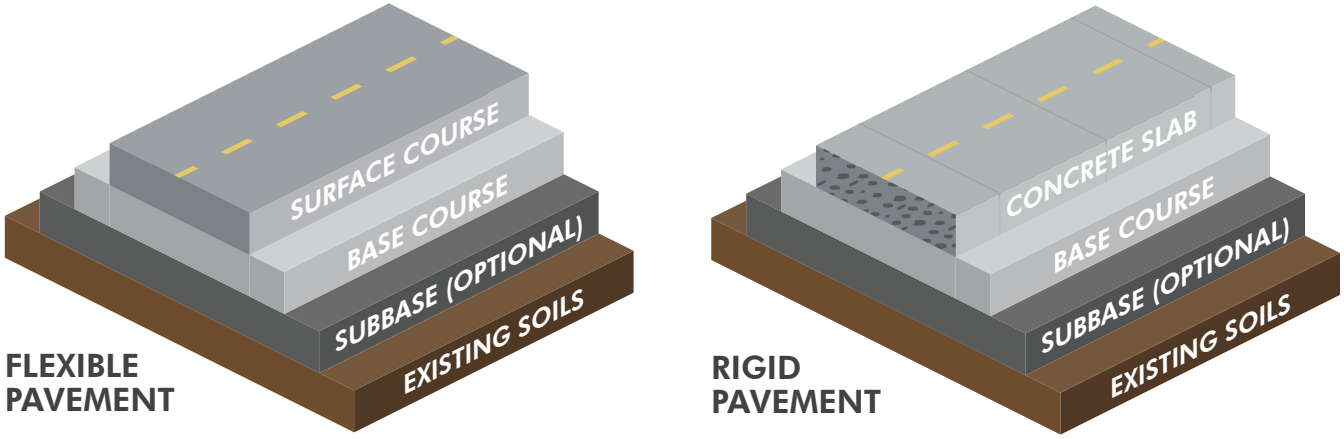
Source: 2021 Massachusetts Road Inventory File

Pavement condition data are collected annually for the Interstate System and biannually for all other State-owned roads (NHS and non-NHS) and for non-State-owned NHS roads. Collection is conducted 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 aggregates an overall condition rating from these component distresses using the Deighton Total Infrastructure Management System (dTIMS).

2.1.2 Current Pavement Condition

Exhibit 2.2 illustrates the differing structure of flexible (asphalt) and rigid (concrete) pavements. 96.4% of the Massachusetts highway network is made up of flexible pavements.

Exhibit 2.2 **Structural Components of Flexible and Rigid Pavement**



MassDOT follows the Federal rule[4] in reporting the condition of its pavements to the Highway Performance Monitoring System (HPMS) using an index of three distresses – international roughness index (IRI); rutting; and cracking – as described in Exhibit 2.3.

Exhibit 2.3 **Calculation of the FHWA Pavement Condition Measure**

Roughness | Measured by the "International Roughness Index" or IRI.

0 GOOD **95** FAIR **170** POOR

Cracking | Measured by percent of wheelpath area with fatigue cracks.

0 GOOD **5%** FAIR **20%** POOR

Rutting (FLEXIBLE) | Measured by average depth to the nearest 0.1"

0 GOOD **0.2"** FAIR **0.4"** POOR

Faulting (RIGID) | Measured by average height to the nearest 0.01"

0 GOOD **0.1"** FAIR **0.15"** POOR

If flexible, use 3 components – IRI, Cracking, Rutting.
If rigid, use 3 components – IRI, Cracking, Faulting.
If **all three distresses are good**, the segment overall is **good**.
If **two or three distresses are poor**, the segment overall is **poor**.
All other segments are **fair**.

[4] 23 CFR Part 490

Exhibit 2.4 summarizes the lane-mileage of Interstate, Non-Interstate NHS, and Non-NHS MassDOT-owned pavement in Massachusetts that is good, fair, and poor as of December 2021 (collected in 2020 and 2021).

Exhibit 2.4 NHS Pavement by System and Condition, 2021 (FHWA-Federal Measures*)

	TOTAL LANE MILES	GOOD		FAIR		POOR	
		LANE MILES	%	LANE MILES	%	LANE MILES	%
INTERSTATE	3,204	2,356	74%	847	26%	1	0%
NON-INTERSTATE NHS	7,319	2,336	32%	4,761	65%	222	3%

Exhibit 2.5 summarizes the condition of NHS pavement by jurisdiction.

Exhibit 2.5 Non-Interstate NHS Pavement by Jurisdiction and Condition, 2021 (FHWA-Federal Measures*)

	TOTAL LANE MILES	GOOD		FAIR		POOR	
		LANE MILES	%	LANE MILES	%	LANE MILES	%
MASSDOT NHS	4,528	1,966	43%	2,454	54%	108	3%
MUNICIPAL NHS	2,791	370	13%	2,307	83%	114	4%

**Note: The mileages and percentages were calculated using the same criteria used for FHWA-Federal reporting measures however there may be slight discrepancies when compared to the official published records.*

For all purposes other than Federal reporting MassDOT tracks pavement condition using the Pavement Serviceability Index (PSI), a composite value derived from seven component distresses: roughness; rutting; alligator cracking; longitudinal cracking; transverse cracking; raveling; and flushing. Unlike the Federal measure that bases its final rating on ranges and a decision tree, PSI is a computed index. The Interstate and non-Interstate ranges of PSI values assigned the rating of excellent, good, fair, and poor are provided in Exhibit 2.6.

Exhibit 2.6 Pavement Serviceability Index – Condition State Ranges

CONDITION STATE	PSI RANGE	
	INTERSTATE	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

A summary of NHS pavement condition by PSI in Massachusetts in 2021 is provided in Appendix A.

2.2 Investment Strategies and Target Setting for Pavement

MassDOT strives for performance-based capital planning to provide transparency on how and why transportation funds are invested. Each MassDOT Division works with OTP and the Office of Performance Management and Innovation (OPMI) to develop program-level measurements and targets which are then used to support funding levels in the CIP and measure their outcomes. This process also supports the Federal performance management format with both near and long-term targets.

FHWA performance measures for pavement are:

Percent of lane-miles in good condition for Interstate pavement.
Percent of lane-miles in poor condition for Interstate pavement.
Percent of lane-miles in good condition for non-Interstate NHS pavement.
Percent of lane-miles in poor condition for non-Interstate NHS pavement.

FHWA requires states to report performance targets for all measures over three horizons:

Two years (2024).
Four years (2026).
Long-term (taken to be ten years, or 2032). MassDOT calls this the state of-good-repair (SOGR).

MassDOT defines its state of-good-repair for pavement as:

95% of Interstate pavements in good condition | 1% in poor condition
75% of non-Interstate NHS pavements in good condition | 5% in poor condition
using MassDOT's PSI metric.

MassDOT sets pavement performance targets using PSI and translates them to the Federal metric. While some pavements rated good and poor by PSI are rated fair in the Federal metric, MassDOT has observed that a treatment that addresses the underlying cause of distress based on PSI will have a similar and proportional impact on the Federal metric.

Exhibit 2.7 provides performance targets in the Federal performance metric for NHS pavement.

Exhibit 2.7 **MassDOT Pavement Condition Targets for 2022-2026 (Federal Metric)**

	GOOD (DESIRED TREND UP)				POOR (DESIRED TREND DOWN)			
% OF LANE MILES	BASE	2 YEAR	4 YEAR	SOGR	BASE	2 YEAR	4 YEAR	SOGR
INTERSTATE	72%	70%	70%	75%	0%	2%	2%	0%
NON-INTERSTATE NHS	33.9%	30%	30%	40%	2.9%	5%	5%	5%

Exhibit 2.8 provides the performance targets in MassDOT's PSI metric.

Exhibit 2.8 **MassDOT Pavement Condition Targets for 2022-2026 (PSI)**

	GOOD (DESIRED TREND UP)				POOR (DESIRED TREND DOWN)			
% OF LANE MILES	BASE	2 YEAR	4 YEAR	SOGR	BASE	2 YEAR	4 YEAR	SOGR
INTERSTATE	91%	88%	88%	95%	1%	3%	3%	1%
MASSDOT NON-INTERSTATE	70%	70%	70%	75%	10%	10%	10%	5%

2.2.1 *Interstate Pavement Investment Scenarios*

MassDOT models alternative investment strategies for pavement in dTIMS. Alternatives modeling assumes that all projects already included in the State Transportation Improvement Program (STIP) or CIP are fully funded in the appropriate year or years before distributing the remaining funding. Intestate pavement performance has been modeled for three budget scenarios based on total Federal participating cost: a $25 million scenario; a $43 million scenario; and a $75 million scenario. These scenarios are not defined by the investment level in tolled Interstates, on which all three scenarios assume adequate funding. As noted in Exhibits 2.13 and 5.1, total anticipated investment in Interstate Pavement in 2023-2032 is $90 million per year on average.

Exhibit 2.9 illustrates the performance implications of the $25 million scenario, under which Federal funds have been shifted from Interstate to non-Interstate NHS and current performance levels are not maintained.

Exhibit 2.9 **Interstate Pavement Performance under the $25 Million Scenario**

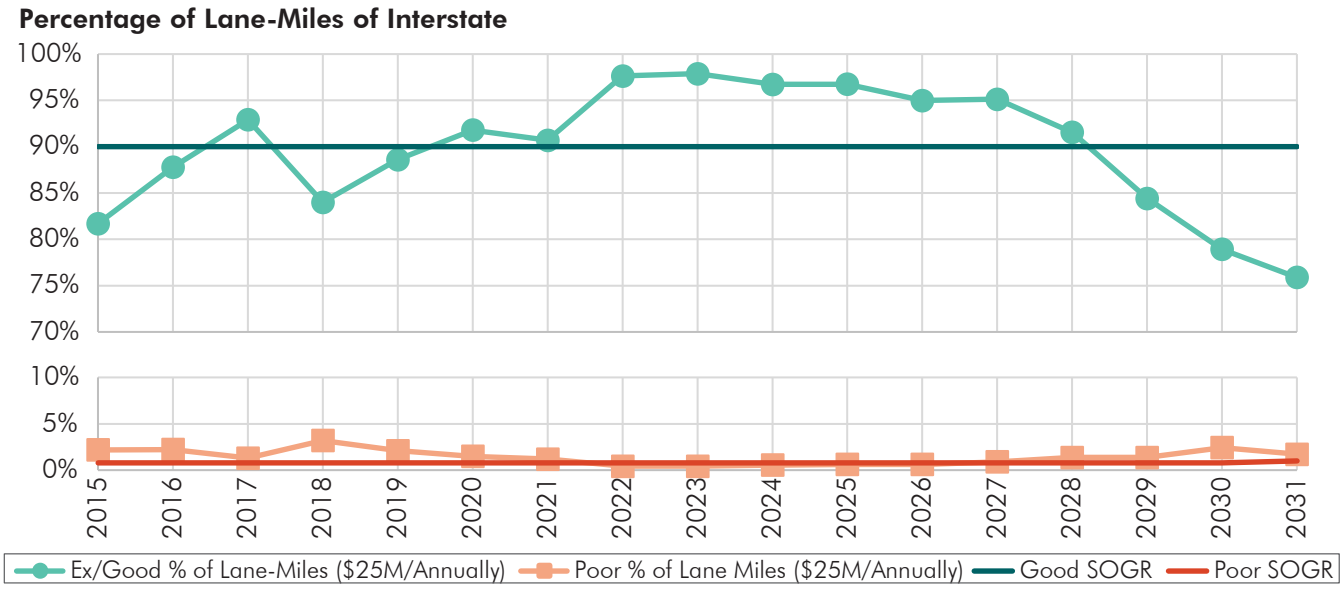


Exhibit 2.10 illustrates the performance implications of the $43 million scenario, in which current performance is sustained through 2031 without any significant performance gaps, and which correlates to Interstate Program spending targets in the 2023-2027 STIP/CIP.

Exhibit 2.10 **Interstate Pavement Performance under the $43 Million Scenario**

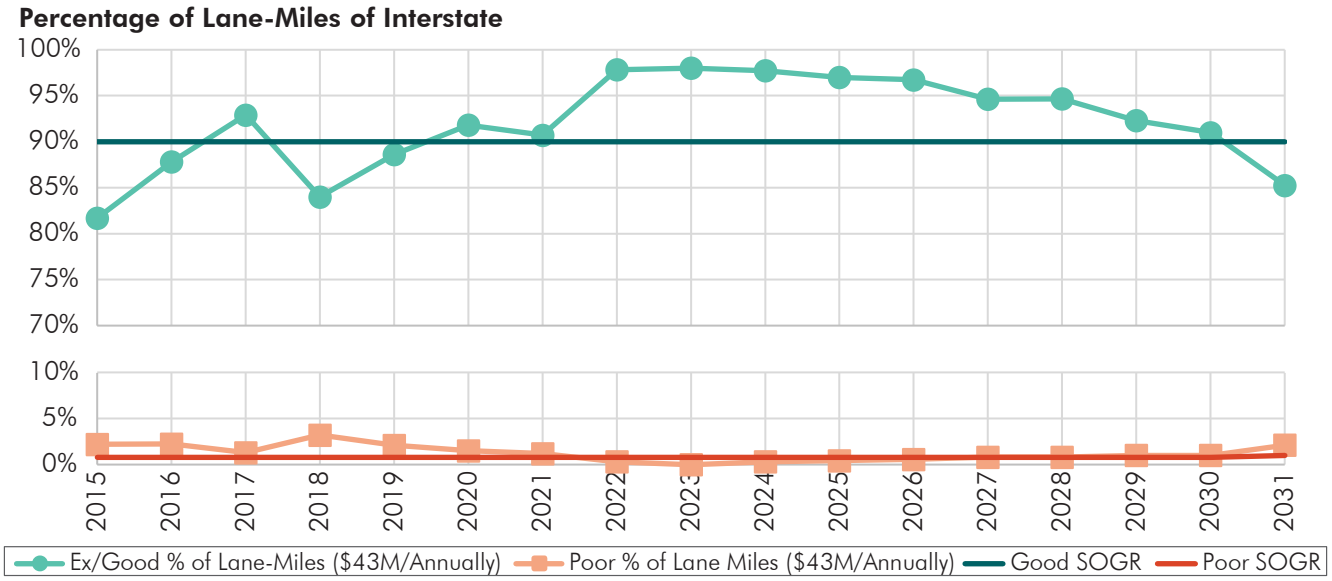
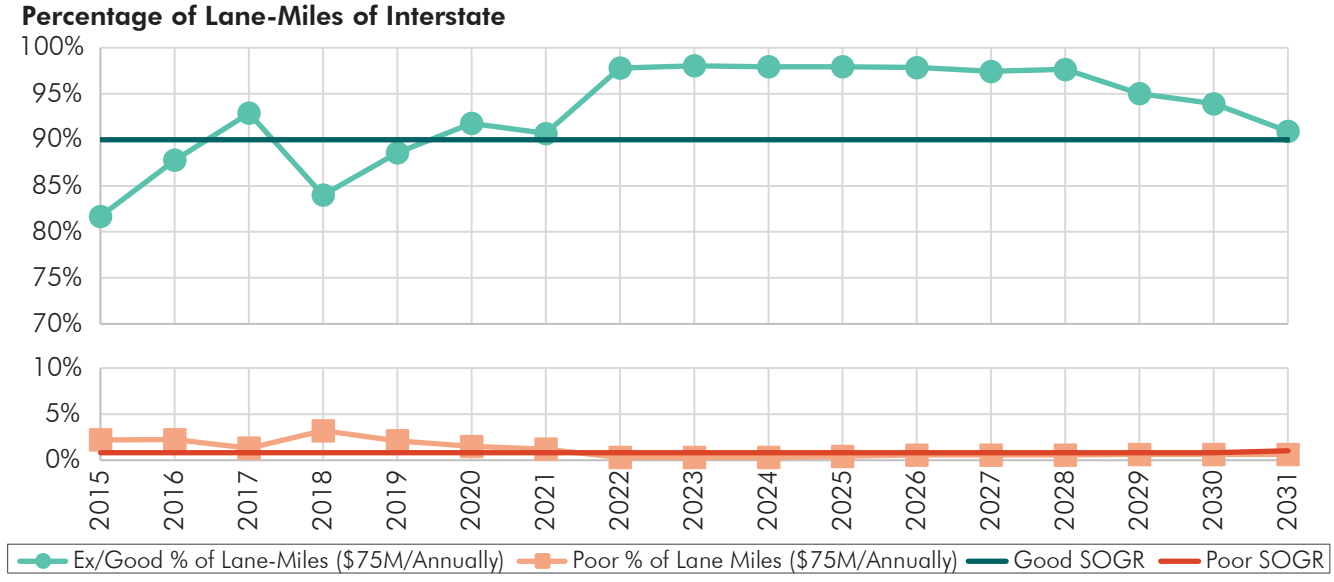


Exhibit 2.11 illustrates the performance implications of the $75 million scenario, which assumes that investment is directed away from non-Interstate NHS roadways to Interstate roadways. This scenario is not recommended at this time.

Exhibit 2.11 **Interstate Pavement Performance under the $75 Million Scenario**



2.2.2 Non-Interstate Pavement Investment Scenarios

MassDOT has seen significant improvement in non-Interstate pavement through a focused State and Federal investment beginning in the 2017-2021 CIP/STIP. Additional funding and promotion of preservation treatments has driven the near-term gains.

However, management of non-Interstate roadways requires a multi-faceted investment strategy to account for a network that ranges in character from limited access highways to downtown streets. Investments in non-lim-

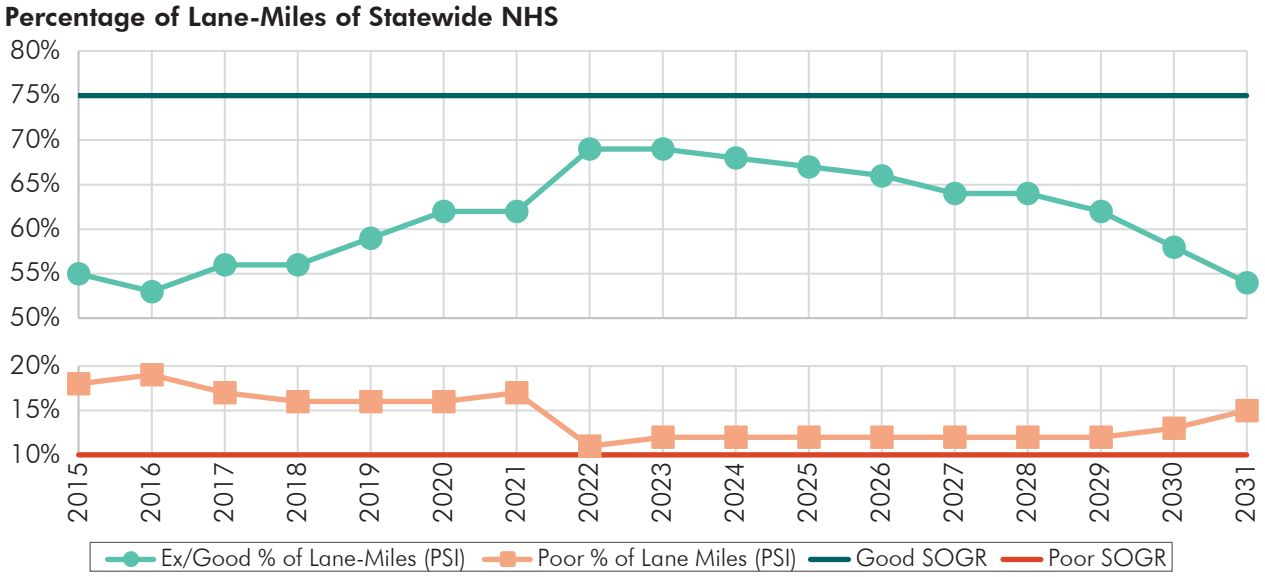
ited-access roads must often include safety and mobility improvements well beyond the purpose and need of typical SOGR-driven projects.

In order to rationalize these competing needs and build on its recent success in non-Interstate pavement performance, MassDOT will begin in 2024-2028 to prioritize roadway modernization (safety and mobility) on key corridors through the new Roadway Reconstruction Program and reorient the non-Interstate Pavement Program to focus on preservation and maintenance (e.g., resurfacing).

Considering the programmatic changes underway, this plan does not recommend alternative investment strategies for non-interstate pavement. In the near term, MassDOT will be prioritizing and scoping projects for each program, which will then support for more accurate forecasting of outcomes and gaps.

Exhibit 2.12 illustrates the performance implications of MassDOT's projected non-Interstate NHS pavement funding, including the new programs.

Exhibit 2.12 **Non-Interstate Pavement Performance under Projected Funding**



2.2.3 *Municipal Pavement Investment Strategy*

MassDOT actively funds municipal NHS pavement through two capital programs:

» **Chapter 90 |** MassDOT administers an annual legislative authorization of State Aid to the 351 cities and towns in the Commonwealth through the Chapter 90 Program,[5] which supports highway construction, preservation, and improvement projects; pedestrian and bicycle facilities; road-building machinery and equipment; and consulting services for transportation planning. Chapter 90 funds both pavement and bridge projects. The annual Legislative authorization is apportioned to 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. For state fiscal year (SFY) 2023, MassDOT has provided municipalities with a geospatial online intake system and improved guidance, including a planning toolkit and a quick-start guide.

[5] https://www.mass.gov/chapter-90-program

» **Municipal Pavement Program |** A Municipal Pavement Program[6] was created in SFY 2022 which funds pavement improvements on municipal roadways. Municipally-owned NHS roadways are estimated to be 50% of this program. Treatments under this program include preservation, rehabilitation, and reconstruction. Segments are selected/grouped by MassDOT each fiscal year based on local inventory and condition. Approximately 125 lane miles of roadways were identified in Districts 1, 2, and 3 for work in SFY 2022, while SFY 2023 will focus on Districts 4, 5, and 6. The Projects are being implemented through existing MassDOT pavement construction contracts. MassDOT has allocated $125 million to the program between SFY 2023 and SFY 2027.

2.3 Performance Gap Analysis for Pavement

Exhibits 2.9-2.11 demonstrate three funding scenarios and condition forecasts for Interstate pavement, and Exhibit 2.12 provides a single corresponding forecast for non-Interstate. Through the four-year horizon: non-Interstate pavements are not projected to reach SOGR, whereas in all funding scenarios Interstate pavement will achieve SOGR. Interstate conditions beyond the four-year horizon vary among scenarios.

As shown in Exhibit 2.13, MassDOT's Interstate pavement performance gap is estimated to be $25M annually. Additional funding for Interstate pavement will be sought in subsequent STIP/CIP cycles.

MassDOT's non-Interstate performance gap is influenced by safety and mobility needs. MassDOT is focused on balancing pavement investments through this lens and will develop funding scenarios in coming years to achieve both aims. Values are estimated to the year of expenditure. A breakdown of planned spending by work type is provided in Exhibit 5.1.

Exhibit 2.13 **MassDOT's Investment Needs on NHS Pavement, 2023-2032 (millions)**

	2023	2024	2025	2026	2027	2028	2029-2032	2023-2032
INTERSTATE PLANNED SPENDING	$45.06	$99.08	$108.82	$104.53	$66.05	$87.91	$388.24	$899.69
INTERSTATE SOGR SPENDING	$45.06	$99.08	$133.82	$129.53	$91.05	$112.91	$488.24	$1,149.69
INTERSTATE GAP	**$0.00**	**$0.00**	**$25.00**	**$25.00**	**$25.00**	**$25.00**	**$100.00**	**$250.00**
NON-INTERSTATE PLANNED SPENDING	$127.53	$101.41	$108.84	$134.79	$110.25	$97.76	$517.29	$1,197.87
NON-INTERSTATE SOGR SPENDING	$127.53	$101.41	$108.84	$134.79	$110.25	$97.76	$517.29	$1,197.87
NON INTERSTATE GAP	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
TOTAL PLANNED SPENDING	$172.59	$200.48	$217.66	$239.32	$176.30	$185.67	$905.53	$2,097.55
TOTAL SOGR SPENDING	$172.59	$200.48	$242.66	$264.32	$201.30	$210.67	$1,005.53	$2,347.55
TOTAL GAP	**$0.00**	**$0.00**	**$25.00**	**$25.00**	**$25.00**	**$25.00**	**$100.00**	**$250.00**

[6] https://www.mass.gov/municipal-pavement-program

2.4 Life Cycle Planning for Pavement

MassDOT's life cycle planning practice for pavement follows best practices for pavement asset management while actively identifying and managing internal and external risk factors, including vulnerability and resiliency. A general overview of MassDOT pavement roles and responsibilities is provided in Exhibit 2.14.

Exhibit 2.14 **Division of Responsibility for MassDOT-Owned Pavements**

FUNCTION	HIGHWAY PAVEMENT MANAGEMENT FUNCTION	HIGHWAY DISTRICT FUNCTION	OFFICE OF TRANSPORTATION PLANNING (OTP)
INSPECT PAVEMENT	• Regular data collection for condition on all numbered highways and routes on the NHS (Interstates annually, non-Interstates biannually). • Maintain a 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 and program projects in coordination 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.
MAINTAIN PAVEMENT DATA	• Administer dTIMS Pavement Management System, support annual HPMS data submission	• Maintain records of District Contract work locations.	• Maintain Pavement Condition data within the Road Inventory File, manage annual HPMS submission.

2.4.1 Life Cycle Planning for Pavement in the Pavement Management Section

MassDOT's Pavement Management Section uses an Incremental Benefit/Cost (IBC) ratio to optimize the selection of projects and treatments. This process considers the current and projected condition for individual pavement distress of each pavement segment over the duration of the analysis period. The most beneficial distress-specific pavement treatments are determined for each pavement segment for every year of the analysis period. The long-term impact of investment on every alternative is modeled in dTIMS, considering both intermediate cost and deferred maintenance. The projection models are used to identify projects and treatments and to assess the impacts of potential investment levels in the STIP and CIP.

MassDOT pavement treatments are categorized within four categories:

» **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, in-place recycling, and other thin (<2 inches) single lift overlays.

» **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 2.15. These are "typical" costs based on MassDOT projects and can vary significantly depending on many factors. dTIMS has not been configured for rigid pavement because it represents a very small share (<0.4%) of the State-owned system.

Exhibit 2.15 **Pavement Treatment Costs**

TYPE OF INVESTMENT	TREATMENT	PRICE PER LANE MILE
MAINTENANCE	Asphalt crack sealing	$5,000
	Asphalt routing and sealing	$10,500
PRESERVATION	Microsurfacing	$75,000
	Open-graded friction course (OGFC) with leveling	$300,000
	Ultrathin Bonded overlay	$180,000
	Rubber chip seal treatment	$75,000
	Asphalt Rubber Gap-Graded HMA overlay	$280,000
	Conventional HMA overlay	$165,000
REHABILITATION	Full-depth reclamation	$450,000
	Functional overlay	$265,000
	Functional overlay | saw and seal	$300,000
	OGFC with functional overlay	$350,000
	Structural overlay	$415,000
	Thick overlay | saw and seal	$455,000
	Asphalt Rubber Gap-Graded HMA with structural overlay	$450,000
	OGFC with structural overlay	$395,000
RECONSTRUCTION	Reconstruction	$1,400,000

Note: Costs are reflective of 2022 analysis.

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

$$IBC = \frac{AADT^{k} \left(PSI_{treatment} - PSI_{0} \right)}{Cost_{treatment}}$$

Where PSI_0 and $PSI_{treatment}$ are the serviceability index before (PSI_0) and after treatment ($PSI_{treatment}$) and k is the "traffic weighting factor" used to help prioritize roads that have larger traffic volumes that are in similar condition to those with smaller traffic volumes.

To compliment the projects selected through IBC, the pavement program is balanced between "worst first" projects which address factors beyond that of just the pavement condition alone. These projects generally incorporate more costly elements and bridge the gap between state of good repair and modernization. The result in a balanced approach to project selection that 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.
- Segments in poor condition.

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.

2.4.2 Life Cycle Planning for Pavement in the Highway Districts

Maintenance at the District level is entirely state funded (a.k.a., "Non-Federal Aid", or NFA) through an annual budget assigned to each District. The Districts allocate their NFA allotment 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 several factors, including:

- PSI rating and the project list provided by the Pavement Management Section.
- Number and severity of requests (e.g., from citizens and local officials) about a segment.
- Coordination with utilities.
- Increasing efforts to expand pavement preservation.

The prioritization process is a continuous and collaborative effort that incorporates engineering judgment. Pavement maintenance in the Districts is mostly performed by contractors under MassDOT direction, but in-house crews perform seasonal pothole repairs.

2.4.3 Life Cycle Planning for Pavement in Municipalities and Regions

When MassDOT collects and models condition data on municipally-owned NHS pavement in a manner identical to that applied to State-owned pavement, the Department stores those data alongside data on the State-owned system. Massachusetts' metropolitan planning organizations (MPOs) have delegated HPMS reporting on municipal NHS to MassDOT. In addition, many municipalities collect and maintain their own condition data within their own pavement management system (PMS).

To improve its understanding of municipal and regional pavement management and prompted by the 2019 TAMP, MassDOT began a Federally funded research project in 2020 to catalog the different PMS being used by municipalities, MPOs, and regional planning councils (RPCs) throughout Massachusetts. Findings from on-site interviews with municipalities included:

- Municipalities use their PMS for general guidance, to forecast deterioration, to assist in the development of a capital plans, to educate the public on what they're doing, and to prioritize and fix roads using a non-arbitrary method. Municipality PMS selection was based on user friendliness, open-source soft-

ware (i.e., reduced cost), compatibility with existing condition survey practices, capability to include other municipal asset work (utilities), and recommendations from other municipal users. PMS and datasets were managed both in-house and by outside consultants.

» Condition data was collected at varying collection cycles from annually to every five years. Data collection was completed both in-house and by consultants. Some municipalities reported data in capital plans, while others don't report it at all. Structural condition was not collected by any of the municipalities, however some collected field cores to determine pavement layer thicknesses. Little information was available/known on exactly how condition indices were calculated. These calculations were generally made by the PMS.

» Triggers for potential projects included: condition index, age, user complaints, budget analysis, experience, and engineering judgement. Costs were based on proposed work estimates and MassDOT weighted bid averages. Treatment selection and unit costs were typically handled within the utilized PMS. Some municipalities used this information combined with field observations to make treatment selection. The PMS usually indicated a generic category of service (reconstruction, rehabilitation, preventive maintenance, etc.), each with different treatment options.

Findings from on-site interviews with MPOs and RPCs included:

» MPOs are primarily concerned with condition of Federal aid eligible roads under their jurisdiction. All MPOs interviewed indicated that they would be willing to consider switching to a unified PMS software if MassDOT would be willing to pay for and support it. Many MPOs are currently looking at upgrading/changing their PMS software.

» MPOs primarily used their PMS to prioritize funding for Transportation Improvement Plan (TIP) projects or to assist in the development of long-range Regional Transportation Plans (RTPs). Data were generally used to make prioritization lists/recommendations to municipalities or to simply report condition. PMS selection was based on legacy (already in-use at agency prior to employment), part of a group-based purchase for multiple MPOs at the same time, initial setup and annual maintenance costs, and compatibility with existing GIS systems.

» Condition data was typically collected/reported on a three-year cycle. No MPOs collected any structural condition data. Data was often reported on a website or in a published report. Data was primarily managed internally by each individual MPO.

» Little information was available/known on exactly how condition indices were calculated. These calculations were left to the discretion of the PMS software supplier during initial setup. Methods used to predict deterioration were typically deterioration curves generated by the PMS.

» Triggers for treatment included condition index, road classification, maintenance/repair cost, or a combination of these factors. Treatment selection and unit costs were typically handled within the PMS. Most agencies could specify the available treatment options during the initial software setup. Unit costs could be default or input/updated by a specific agency.

MassDOT will use the findings of this research to identify opportunities to support municipalities in management of NHS and non-NHS pavements.

2.5 Risk Management for Pavement

The MassDOT pavement program is subject to both internal and external risks and uncertainties with potential to affect performance outcomes. This section describes risks identified as having a high impact and high likelihood. Chapter 5 holistically discusses enterprise risk management at MassDOT.

2.5.1 Extreme Weather and Resiliency Risks for Pavement

Pavements are susceptible to temperature extremes and fluctuations. Due to the distinct seasonality of New England, Massachusetts pavements are designed with an inherent degree of built-in resiliency to temperature changes. MassDOT strives to remain current on national mix design and material philosophy and has transitioned to polymer modification in all surfaces to provide additional high temperature stability. Balanced Mixture Design methods are being incorporated into all future Hot Mix Asphalt mixtures to better balance mixture cracking and moisture damage. In addition to improving resiliency through pavement design, resilient roads are those in good condition, and MassDOT will continue to emphasize routine preservation to ensure pavements are up to the challenge of extreme weather.

Outside of the pavement structure itself, extreme weather events can cause other systems to be overwhelmed or fail. Most of the NHS in Massachusetts was initially constructed more than 50 years ago, and drainage components are nearing the end of their life span. To ensure these systems continue to function as designed, MassDOT pavement projects include drainage cleaning and repairs in preservation projects, building resiliency with every mile of roadway paved.

Though not a direct measure of pavement condition, safety is the overarching goal of any roadway investment. MassDOT has utilized open-graded friction course (OGFC) on limited access roadways for many years to limit sheet flow of water, reduce tire spray and mitigate potential hydroplaning. OGFC does not extend lifecycle per se but provides an added level of safety in wet weather conditions. While OGFC mitigates risk associated with extreme weather conditions, it also results in higher maintenance costs due to its shorter service life. MassDOT's continued use of OGFC will necessitate finding a balance between potential crash rates and elevated pavement maintenance costs.

2.5.2 Pavement Program Risks

MassDOT has evaluated the pavement program and identified the following high probability and actionable risk factors.

- The first is **project scope control**, which has historically impacted the outcomes of the program by reducing the per lane mile pavement investment through work outside of the pavement. The two major influences are bridge repairs and expansion of bicycle/pedestrian infrastructure. MassDOT will seek to limit the effects of bridge work by separately funding these activities above a specific cost threshold. Expansion of bicycle and pedestrian infrastructure, where extensive, will be pursued through the Roadway Reconstruction Program. This strategy will help to ensure pavement life cycle investments are targeted toward efficient preservation activities intended to optimize long-term investments.
- **On-schedule project completion** is a MassDOT performance measure which along with predictable project completion also impacts pavement conditions. When forecasting network conditions, improvements are typically reflected one year after a project's advertising, which is a reasonable assumption for

limited scope and duration projects. In instances where expanded project scope delays completion of pavement improvements, or timing of contract notice to proceed is not aligned to the active construction season, condition outcomes are harder to forecast and will make achievement of targets difficult. MassDOT is committed to advertising resurfacing projects earlier in the fiscal year and developing construction sequencing that ensures pavement work is at the forefront of the schedule.

» **Pavement quality control and assurance** has a substantial impact on the effectiveness of pavement life cycle management. Mix designs and the application of preservation treatments have become more complex and workmanship remains a critical element to pavement long term reliability. Volume of work, staff capacity and loss of institutional knowledge put quality at risk. Continued partnering between MassDOT, pavement contractors and consultants is the best strategy to ensure life cycle management investments.

2.5.3 Demographic and Economic Factors

MassDOT may also face unexpected needs in pavement and bridge performance as a result of increased traffic and enhanced risk and consequence of severe weather and sea level rise. Increasing traffic or congestion will contribute to pavement deterioration from fatigue damage, which will be evident in increased wheelpath cracking – these impacts are more severe in warmer weather. MassDOT may need to either increase the durability of its materials or accept a shorter service life.

Changing demographics can also impact the volume and type of vehicles using a roadway. Some changes, such as the elimination of traffic lanes, increased use of public transit, and construction of bike facilities may increase the congestion levels and channel increased buses on roadways. This may require constructing facilities better suited to heavier stopping and turning movement, changes which can be incorporated into future design activities.

2.6 Valuation for Pavement

MassDOT computes the value of its pavement by multiplying lane mileage and per-lane-mile unit costs shown in Exhibit 2.16. It can be assumed that Interstate pavement is valued as "Interstate," while non-Interstate pavement is valued as "Arterial".

Exhibit 2.16 **Unit Costs used in Valuation of MassDOT NHS Pavement**

	INTERSTATE	ARTERIAL	COLLECTOR	LOCAL
UNIT COST—RURAL	$1.55 million	$1.20 million	$1.11 million	$1.11 million
UNIT COST—URBAN	$4.42 million	$3.18 million	$2.20 million	$1.62 million

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 2022 using the Consumer Price Index.[7]

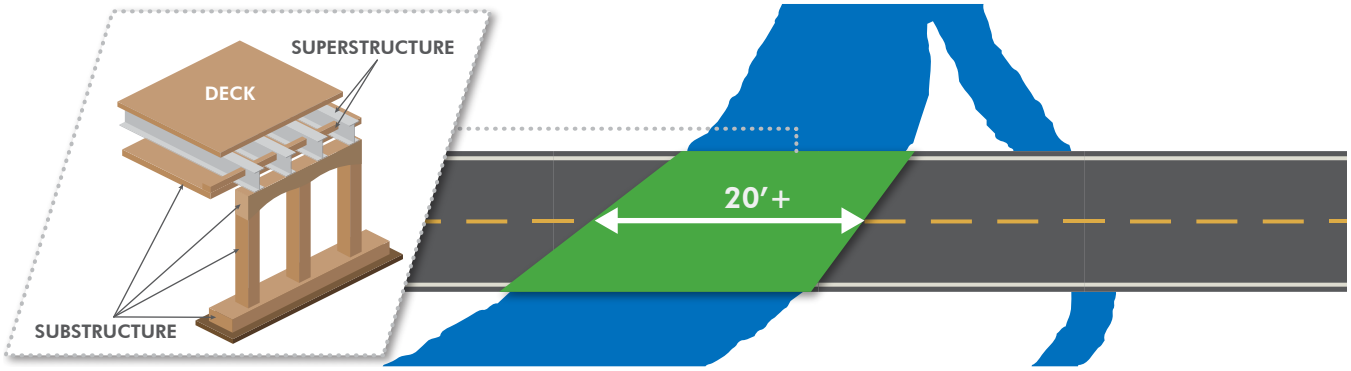
Based on this approach, NHS pavement in Massachusetts is valued at approximately $24 billion.

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

3 BRIDGES

The National Bridge Inspection Standards (NBIS)[8] 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: deck, superstructure, and substructure, as shown in Exhibit 3.1.

Exhibit 3.1 **Definition of a Bridge**



3.1 Inventory and Condition for Bridges

3.1.1 Bridge Inventory and Data Collection

MassDOT is responsible for managing all State-owned and municipal-owned bridges in the National Bridge Inventory (NBI).[9] Municipal owners are responsible for operation and maintenance of bridges within their jurisdiction. All other owners of NHS bridges in Massachusetts – the MBTA; Massport; the Federal Government; and other state agencies – are fully responsible for the life cycle management of their structures.

For example, the Army Corps of Engineers (USACE, part of the Federal Government) maintains and operates the Bourne Bridge (MA-28) and Sagamore Bridge (US-6) over the Cape Cod Canal. In 2020, MassDOT and USACE signed a memorandum of understanding that committed MassDOT to assume ownership of replacements for these structures upon their entry into service.[10]

Exhibit 3.2 summarizes the number and total deck area of bridges under each type of jurisdiction. A detailed table by owner is provided in **Appendix C**.

[8] https://www.fhwa.dot.gov/bridge/nbis2022.cfm

[9] https://www.fhwa.dot.gov/bridge/snbi.cfm

[10] https://www.mass.gov/news/memorandum-of-understanding-reached-between-massdot-and-the-us-army-corps-of-engineers-regarding-bourne-and-sagamore-bridges

Exhibit 3.2 **Count and Square Footage of Bridges by Jurisdiction**

JURISDICTION	TOTAL COUNT	TOTAL FT²	NHS COUNT	NHS FT²
TOTAL	**5,268**	**45,007,395**	**2,298**	**29,741,772**
MASSDOT	3,495	37,742,235	2,220	28,789,544
MUNICIPALITIES	1,654	4,395,273	72	884,321
MBTA	74	2,068,780	2	26,123
MASSPORT	33	782,165	2	39,527
FEDERAL	2	184,110	2	184,110
DCR	4	3,409	2	2,257
OTHER STATE AGENCY	8	15,534	0	0

Source: MassDOT Bridge Inspection Management System, May 2022.

MassDOT conducts an extensive, hands-on inspection of all NBI bridges in Massachusetts every two years. Inspections are performed more frequently on bridges that are in poor condition or that have a known problem. Inspections are conducted by both MassDOT personnel and by consultant teams – they may require special measures and equipment to access challenging locations. For instance, a specially-trained group of MassDOT divers perform underwater inspections of subsurface elements at water crossings, and the MassDOT Aeronautics Division has operationalized the use of drones for some tasks.

Bridge inspection reports are entered directly to the MassDOT Bridge Management System (BMS) where the findings are reviewed and approved by engineers in the District and at Headquarters. These standardized reports include pictures, diagrams, and, if necessary, recommendations for repair.

3.1.2 Current Bridge Condition

Inspectors assign a condition rating to "national bridge elements" (NBEs) on a four-point scale. NBEs include items such as beams, cables, piles, abutments, and columns, among others. These element-level ratings are then rolled up into inventory ratings for deck, superstructure, and substructure for bridges; or into a single rating for large culverts. These ratings use the nine-point scale of the National Bridge Inspection Standards (NBIS) shown in Exhibit 3.3.[11] The overall condition of the structure is said to be the lowest of the ratings it receives.

[11] https://www.fhwa.dot.gov/bridge/snbi/snbi_march_2022_publication.pdf

Exhibit 3.3 **NBI Component Condition Rating Scale**

SCORE	NAME	DESCRIPTION
9	Good	Isolated inherent defects.
8		Some inherent defects.
7		Some minor defects.
6	Fair	Widespread minor or isolated moderate defects.
5		Some moderate defects, strength and performance not affected.
4	Poor	Widespread defects, strength and performance affected.
3		Major defects, strength and performance seriously affected.
2		Structure compromised, requires action to keep open.
1		Bridge closed, may be possible to save with repair or rehab.
0		Bridge closed, replacement required.

Current performance of NHS bridges in Massachusetts by thousands of square feet of deck area (KSF) is provided in Exhibit 3.4.

Exhibit 3.4 NHS Deck Area by Jurisdiction and Federal Performance, 2022

	TOTAL KSF	GOOD		FAIR		POOR	
		KSF	%	KSF	%	KSF	%
TOTAL NHS	29,926	4,944	17%	21,381	71%	3,601	12%
MASSDOT NHS	28,790	4,797	17%	20,675	72%	3,318	11%
MUNICIPAL NHS	884	107	12%	611	69%	166	19%
OTHER NHS	252	40	16%	95	38%	117	46%

Source: MassDOT Bridge Inspection Management System, May 2022.

3.2 Investment Strategies and Target Setting for Bridges

MassDOT strives for performance-based capital planning to provide transparency on how and why transportation funds are invested. Each MassDOT Division works with OTP and OPMI to develop program-level measurements and targets which are then used to support funding levels in the CIP and measure their outcomes. This process also supports the Federal performance management format with both near and long-term targets.

FHWA performance measures for bridge are:

- Percentage of NHS bridges classified as in good condition.
- Percentage of NHS bridges classified as in poor condition.

FHWA requires states to report performance targets for all measures over three horizons:

- Two years (2024).
- Four years (2026).
- Long-term (taken to be ten years, or 2032). MassDOT calls this the state of-good-repair (SOGR).

MassDOT defines its state of-good-repair for pavement as 18% in good condition and 8% in poor condition.

Exhibit 3.5 provides performance targets for NHS bridges.

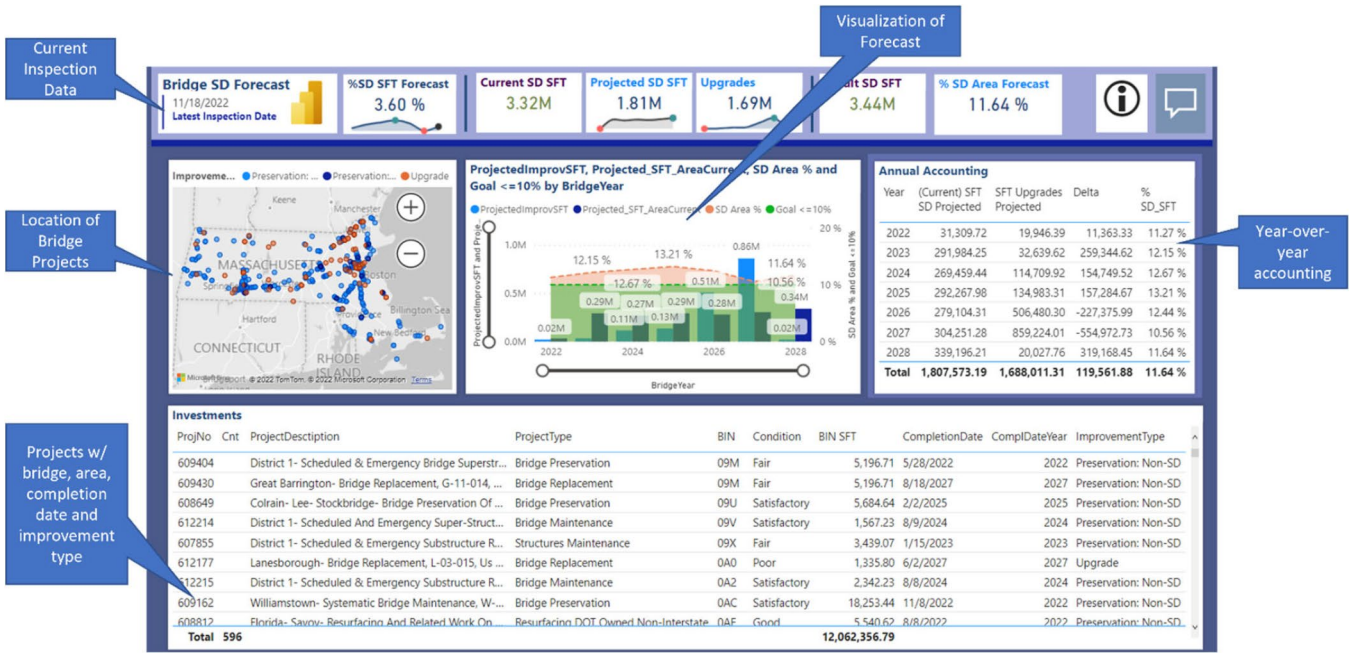
Exhibit 3.5 **Federal Bridge Condition Targets for 2022-2026**

	GOOD (DESIRED TREND UP)				POOR (DESIRED TREND DOWN)			
	BASE	2 YEAR	4 YEAR	SOGR	BASE	2 YEAR	4 YEAR	SOGR
NHS	16%	16%	16%	18%	12%	12%	12%	8%

3.2.1 *Bridge Condition Modeling*

To better visualize outcomes from the bridge program, MassDOT has enhanced its forecast model to include a direct integration with bridge and project management systems. With these connections, the forecast adjusts in real-time to bridge inspection data and changes to the CIP. The model is built in Microsoft PowerBI and provides an interactive user interface accessible to all MassDOT employees. Exhibit 3.6 provides a screenshot from the MassDOT Bridge Model.

Exhibit 3.6 **Screenshot from the MassDOT Bridge Model**



The model determines future conditions by projecting the net difference of future improvements and deterioration:

» **Deterioration** is estimated by determining the probability of condition decline for bridges within a particular condition state. The probabilities are calculated based on historical year-over-year changes, taken as a rolling five-year historical average.

To account for preservation, project history is used to establish "preservation windows" for individual bridges, which assumes the bridge will fall not into poor condition during this timeframe. Maintenance work yields a five-year window; preservation yields a 12-year window; and rehabilitation and replacements projects yield a 40-year window. When applying the probabilities to the inventory for future year condition, bridges with an active preservation window are excluded. Conversely, preserved bridges are excluded when calculating the decline probabilities themselves.

In this approach preservation is directly factored into bridge condition projections, creating a management framework to set preservation goals. For example, in any given year some number and area of bridges will fall out of preserved status as windows end. A baseline goal of the program could be to match (or better yet exceed) the rate of new preservation work with the rate of elapsing historical work.

» **Improvements** are derived from the Highway Division Cash Flow Reporting System, which is the basis for the CIP and is reflective of actual program investments. The system aggregates spending projections and completion dates for planned and active projects.

All bridge projects have bridge locations defined within the MassDOT project management system (ProjectInfo) and with this attribution the bridge model is able to forecast the completion of a specific bridge to the appropriate year.

To support state and Federal performance management, the bridge model forecasts performance by area and count, and can be filtered by NHS, MassDOT region and a variety of other attributes. It is important note that aggregated or estimated deterioration is only used to develop aggregated investments. Day-to-day operational decisions are made on the level of individual bridges.

3.2.2 Bridge Investment Scenarios

The 2021 Massachusetts Transportation Bond Bill authorized the Next Generation Bridge Program (NGB) and $1.25 billion of Grant Anticipation Notes in support of an expanded bridge program. The Bridge Formula Program (BFP) through IIJA provides a similar amount of new bridge funding to Massachusetts. The 2023-2027 CIP and STIP commit nearly all the NGB and IIJA funds allocated to the Commonwealth to address bridge performance.

The combined state and Federal funds are sorely needed. Massachusetts has the fourth-largest percent of its NHS deck area in poor condition and is 15th-worst in the nation for the number of poor bridges. Massachusetts is one of five states that exceeds the Federal minimum condition threshold. The historical performance of MassDOT's bridges is marked by year over year volatility due to large structures becoming poor or replaced and affecting performance in proportion to size. It's also evident that the Massachusetts Accelerated Bridge Program ($3 billion, major construction 2008-2018) was successful in controlling the backlog growth but sustained high levels of investment are needed to make meaningful, long-term progress.

Beginning with Federal fiscal year 2023, preservation funding has been quadrupled from previous levels ($40 million from $10 million annually), with an emphasis on building multiple locations for efficiency and on preventing NHS bridges in fair condition from deteriorating to poor condition. Bridge preservation funding will also be used on corridor resurfacing projects to gain economies of scale and limit repeated impacts to road users. The remaining balance of new bridge funding is dedicated to accelerating rehabilitation and replacements and is expected resolve conditions of over 100 poor structures. The plan includes high priority bridge locations in all areas of the Commonwealth including large NHS bridges, technically challenging movable structures, and local bridges with limited options for detour routes. MassDOT must also consider equity in and consider the negative impacts of major bridge infrastructure on the neighborhoods where it exists. Investment in bridge condition does not always benefit abutters, but often simply makes it easier for vehicles to pass through neighborhoods.

MassDOT has programmed 160 projects in the 2023-2027 CIP to improve conditions of more than 300 bridges. The plan is oriented around two basic goals: slow the rate of deterioration through preservation and reduce backlog through increased rate of capital rehabilitations and replacements. For rehabilitation and replacement candidate projects, the selection process is described in Section 3.4.2. For maintenance and preservation candidate projects, that ranking system is one component. MassDOT considers additional factors in maintenance and preservation prioritization that include: extent of deficiencies; geographic proximity (to allow bundling); and adjacency to upcoming work (both bridge-specific and open-ended).

Through focused internal process improvement, streamlining and an emphasis on building the workforce of the future, MassDOT is positioning itself to translate funding from the NGB and IIJA to improvements in Massachusetts bridge condition. As of mid-2023, most of these funds have been programmed, and design is underway for many new bridge projects made possible with these funds. Long term funding is needed to reach a sustainable state of good repair for Massachusetts bridges. MassDOT will continue to advocate for sustained investment for the Commonwealth's bridges through vehicles such as this TAMP.

Exhibits 3.7 and 3.8 illustrate illustrates two scenarios, both of which assume current NGB and IIJA funding through 2027:

- Reversion to pre-IIJA/NGB bridge funding ($400 million per year).
- Sustained investment ($750 million per year) expected to achieve state of good repair (figures in 2022 dollars).

Significant improvement begins in 2026 because of the anticipated benefit from IIJA funding and completion of improvements on the large Tobin Bridge and Allston Viaduct.

Exhibit 3.7 **Poor Bridge Condition on the NHS by Deck Area, 2017-2031**

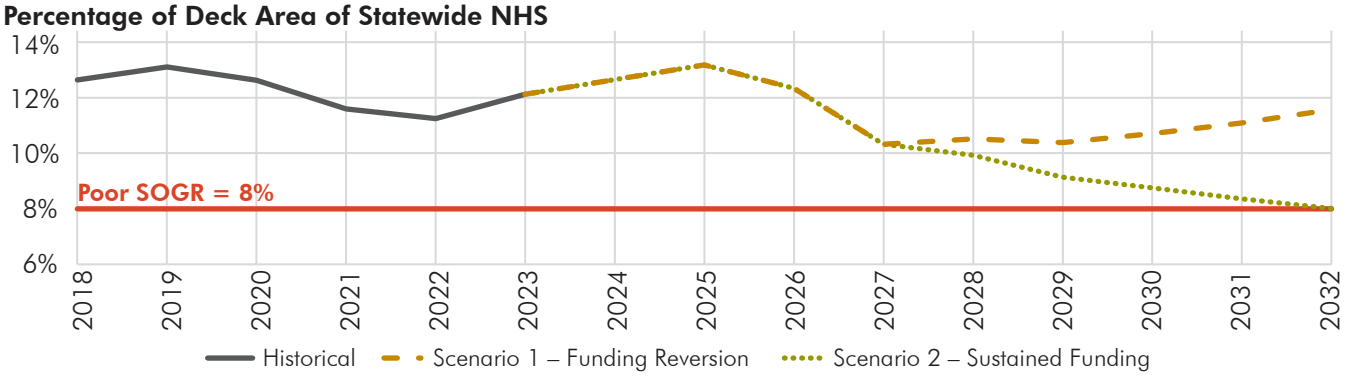
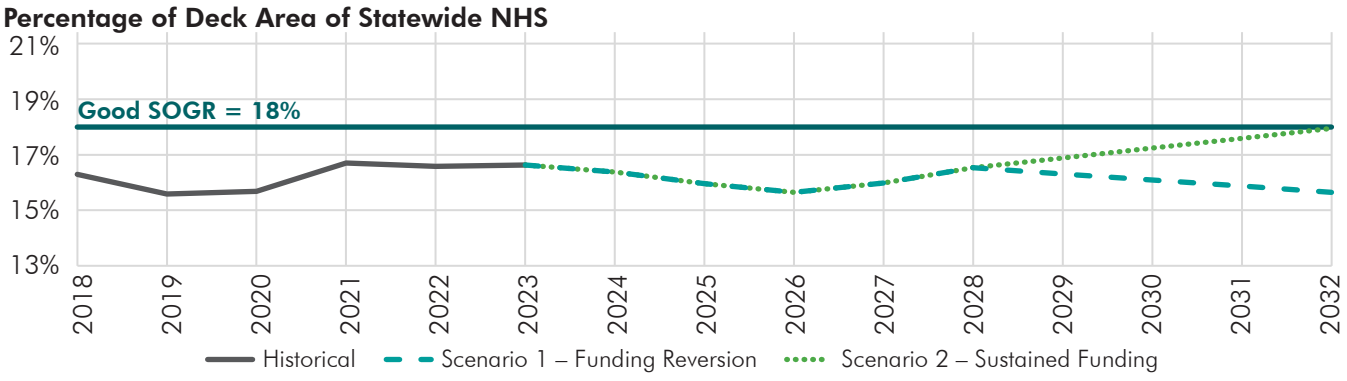


Exhibit 3.8 **Good Bridge Condition on the NHS by Deck Area, 2017-2031**



3.3 Performance Gap Analysis for Bridges

If IIJA funding is continued through the 2022-2031 timeframe, MassDOT projects that it will meet the Federal 10% threshold in 2028 and achieve its 8% SOGR by the early 2030s. As of 2023, MassDOT does not meet the 10% Federal threshold. In practical terms, this means that there is relative high proportion of bridges at end of useful life that require replacement. Nonetheless, MassDOT also recognizes the importance of prioritizing the extension of useful life and minimization of life cycle cost through preservation and maintenance. The future condition of Massachusetts bridges will be determined by MassDOT's ability to balance these needs – replacing structures where useful life has been expended and simultaneously preventing or delaying deterioration across the rest of the network.

Overall, the gap between MassDOT's planned investment in bridges and the investment required to meet SOGR is shown in Exhibit 3.9. Values are estimated to the year of expenditure. A breakdown of planned spending by work type is provided in Exhibit 5.1.

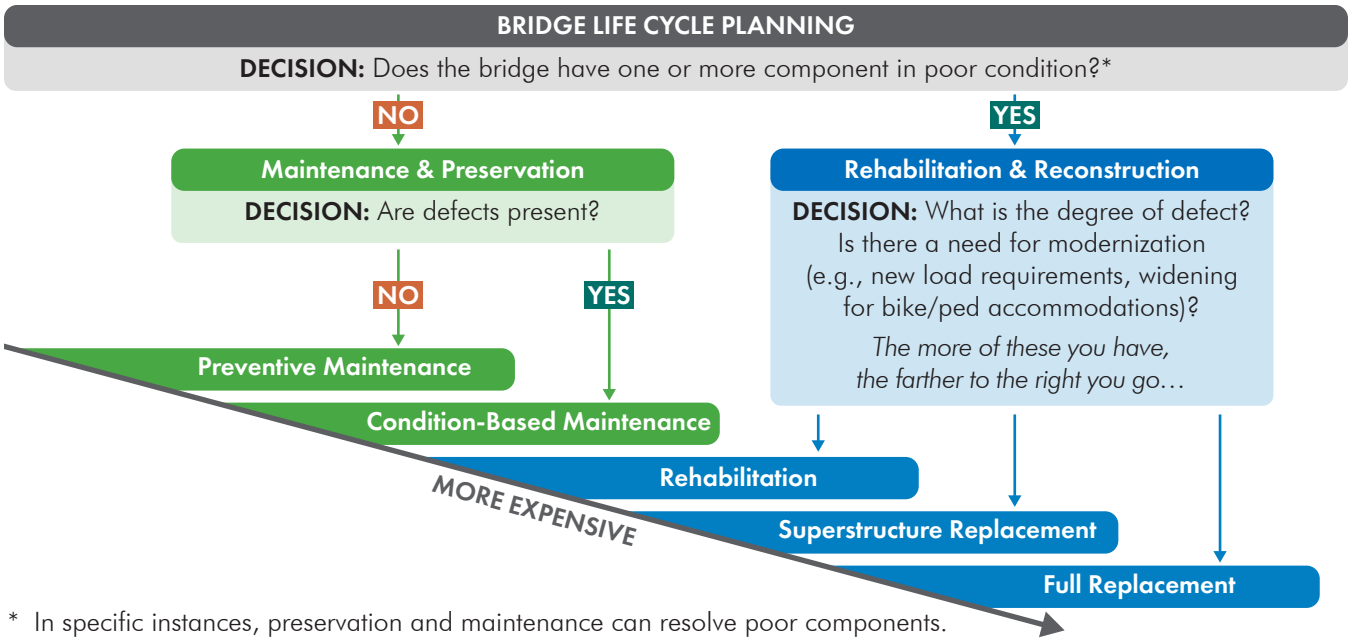
Exhibit 3.9 **MassDOT's Investment Needs on NHS Bridges, 2023-2032 (millions)**

	2023	2024	2025	2026	2027	2028	2029-2032	2023-2032
PLANNED SPENDING	$253.58	$429.17	$658.86	$906.00	$842.91	$556.90	$1,578.14	$5,225.57
SOGR SPENDING	$253.58	$429.17	$658.86	$906.00	$842.91	$750.00	$3,000.00	$6,840.52
GAP	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$193.10**	**$1,421.86**	**$1,614.95**

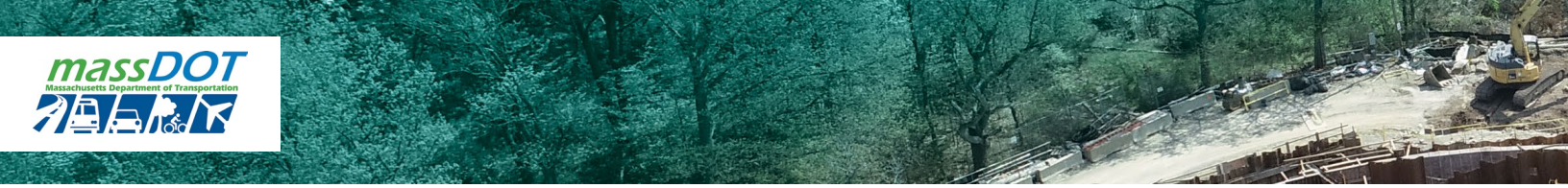
3.4 Life Cycle Planning for Bridges

MassDOT seeks to maximize the useful life of its bridges, while minimizing cost of ownership, with the goal of least life cycle cost. MassDOT employs the life cycle planning process shown in Exhibit 3.10, which is presented with the cost implications of each life cycle intervention. The most effective strategy for management of bridge costs is a robust maintenance and preservation program.

Exhibit 3.10 **MassDOT's Decision-Making Process for Bridge Life Cycle Planning**



* In specific instances, preservation and maintenance can resolve poor components.



MassDOT manages bridges at headquarters and in regional District offices. Generally, the District offices manage the operation and maintenance of bridges, while headquarters manages planning, design, major preservation or rehabilitation, and construction. Inspections are jointly managed between the headquarters-based State Bridge Inspection Engineer and the District Bridge Section. A summary of Bridge Section program governance is provided in Exhibit 3.11.

Exhibit 3.11 **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. • Evaluates and prioritizes overall preservation actions of bridges. • Evaluates scope of projects to be advertised and advertises maintenance projects (various locations and site specific).	• Evaluate inspection reports and identify deficiencies. • Prioritize deficiencies for treatment and select treatment. • Develop candidate projects and work orders. • Manage work order 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) • Review design of capital projects and indicate	• Provide feedback to headquarters on prioritization. • Identify needs and provide candidate projects.
MANAGE BRIDGE DATA	• Develop and maintain state bridge standards and documents. • Administrate, procure, and develop data systems (Bridge Management System, Work Order Tracking System, and Pontis) • Maintain bridge plans and record electronic storage.	• Manage hard copy work orders, work logs, and informal spreadsheet tools.
RATE BRIDGES FOR MAXIMUM LOAD	• Evaluate and recommend load ratings. (Primary) • Evaluate permitted superloads and coordinates with neighboring agencies. • Evaluate and recommend bridge postings or closures. • Recommend actions to remediate and increase load ratings.	• Evaluate and recommend load ratings. (Based on inspection) • Perform actions as necessary to maintain rating and posting.
PROVIDE GEOTECHNICAL AND HYDRAULICS SUPPORT TO PROJECTS	• Perform geotechnical and hydraulic evaluations for capital projects.	• None.
EVALUATE METALS FOR USE ON BRIDGES	• Oversee and approve fabrication, metallurgical procedures, testing, and uses. • Manage and oversee welder certification program. • Perform materials testing on metals for bridge use, evaluate suitability.	• None.

Massachusetts must also contend with the reality of a bridge inventory fifteen years older than the national mean, and a backlog of poor bridges that exceeds the Federal minimum condition threshold. A major reconstruction and rehabilitation investment is necessary to address poor bridges that are beyond the capacity of maintenance and preservation investment, and where these lower cost measures are no longer cost effective. In the case of many of the Commonwealth's poor bridges, the life cycle strategy is clear: bridges at end of useful life must be replaced or reconstructed.

However, MassDOT must concurrently invest in maintenance and preservation or risk a continuous cycle of decline. This plan proposes a dramatic shift in strategy that provides both the investment and internal processes necessary to implement preservation at a meaningful scale.

The following sections build upon Exhibit 3.10 to provide more detail on each type of intervention. Section 3.2 describes how the MassDOT Bridge Condition Model has been built to forecast the effects of actual life-cycle strategies made through the STIP/CIP, including the effects of preservation and maintenance, so that the MassDOT can effectively plan the life cycle of each bridge in its inventory.

3.4.1 Maintenance and Preservation

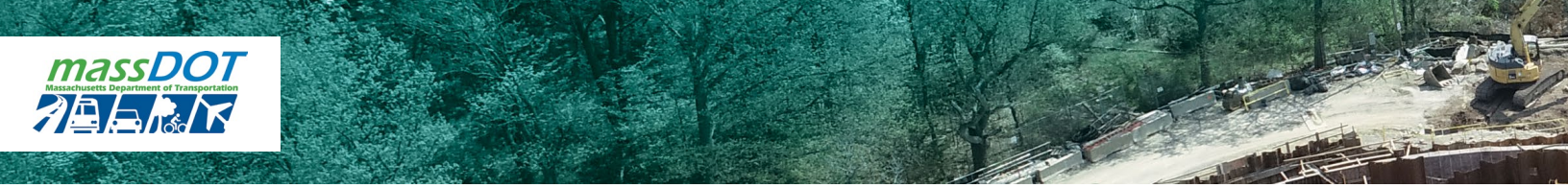
MassDOT's bridge preservation program includes preventative and reactive maintenance (condition-based maintenance) activities:

- **Preventative maintenance** activities are intended to prevent deterioration (e.g., bridge washing to remove deicing chemicals and other materials that could corrode or degrade a structure).
- **Condition-based maintenance** activities are reactive and driven by identified deficiencies and can range from simple to significant repairs.

MassDOT is working to incorporate work order data into capital planning decision-making – for instance, work order data can inform MassDOT of when larger capital investments are needed to keep a fair condition bridge from moving to poor condition. MassDOT is also moving towards a corridor-based or bundling approach to preservation where more structures can be impacted as part of a single contract along the same geographic area to provide a reduction in traffic control, mobilization, and coordination costs.

Additional strategies being implemented to create a consistent preservation program include:

- Use of decision flow charts and guidelines to determine the best course of action and priority for different bridge repair needs to promote uniformity.
- Broadening use of established contract templates for open-ended Bridge Maintenance Contracts.
- Increased utilization of site specific projects to reduce the needs for emergency repair contracts.
- Routine review and updating of eligible criteria for bridge maintenance and preservation projects.
- Incorporation of maintenance considerations in the bridge details of bridge replacement projects.
- Higher preventative maintenance priority for structures for which replacement is infeasible due to site constraints, cost, or traffic interruption and impacts.
- Bundling of site specific bridge maintenance projects by locations or type of work to promote economy and minimize the inconvenience to the public, and coordination of bridge preservation work with future transportation projects.



The preservation strategy promotes uniformity and improvement, building upon historically utilized practices and adapting to the changing needs of the program to reduce the rate at which bridges move into the poor category. Districts can also adapt bridge MassDOT's maintenance best practices as needed.

A summary of unit costs for cyclical and condition-based maintenance activities is provided in Exhibit 3.12. These are the unit costs for contract work and include incidental items outside the activity such as traffic control and mobilization. The costs have been calculated based on recent contracts performed across the Commonwealth and will continue to evolve as contract costs are tracked at a work order level as part of the growth of the bridge preservation program.

Exhibit 3.12 **Preventative and Condition-Based Bridge Maintenance Activities**

	ACTIVITY	TARGET FREQUENCY (FUNDING DEPENDENT)	UNIT COST ($/FT^2)
PREVENTATIVE MAINTENANCE	Bridge washing	Annually	$1.77
	Cleaning and improving drainage systems	Bi-Annually	$3.12
	Coating and sealing concrete surfaces	10 years	$3.93
	Deck sealing, healing, and cracks injections	8–12 years	$16.65
	Lubricate sliding surfaces	5 years	$0.54
	Seal joint—pourable	5–7 years	$0.64
	Replace Joint Seal	12–15 years	$0.29
CONDITION-BASED MAINTENANCE	Clean and paint (full removal)	12-15 years	$57.01
	Clean and paint (overcoat or zone painting)	As needed	$5.70
	Hot Mix Asphalt (HMA) wearing surface with waterproofing membrane	12-15 years	$55.54
	Concrete overlay	20-25 years	$63.42
	Deck Patching	As needed	$51.39
	Deck Replacement	25 -30 years	$377.07
	Repair Joints	As needed	$3.89
	Reconstruct joints	As needed	$8.70
	Replace or repair bearings	As needed	$13.80
	P/S or reinforced concrete beam repairs	As needed	$19.40
	Structural steel repairs	As needed	$60.92
	Substructure repairs	As needed	$4.29
	Scour protection, remediation, or repair	As needed	$85.50

Note: These activities will be fully supported by the MassDOT work order management system this calendar year and will provide an additional input to future TAMPS.

3.4.2 Rehabilitation and Reconstruction

When a bridge has experienced major deterioration and it is no longer feasible to extend useful life through preservation, a more comprehensive investment is needed through the capital program. MassDOT's bridge prioritization process is used to identify state or municipally owned bridge locations for rehabilitation and reconstruction. The ranking system is based on an algorithm using the following four criteria:

- **Condition Loss (CL) |** The percentage difference between a perfect condition rating (nine) 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 (AAHSTOWare BrM) 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) |** FHWA defines scour as "erosion of streambed or bank material due to flowing water; often considered as being localized." ΔHI is scaled up by a factor corresponding to the bridge's scour criticality class. The value varies from 5% (a multiplier of 1.05) for "Category D" to 20% (a multiplier of 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 multiplied by five.

The final rank score is assessed using the formula:

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

Bridges are prioritized for investment based on the rank score, condition ratings, and remediation costs. The list of projects is forwarded to the regional bridge engineers who provide feedback on local priorities and identify structures which require more maintenance resources. Initial rehabilitation and replacement project costs are estimated based on recent project bids. The prioritization process is conducted each year in advance of the spring capital planning cycle.

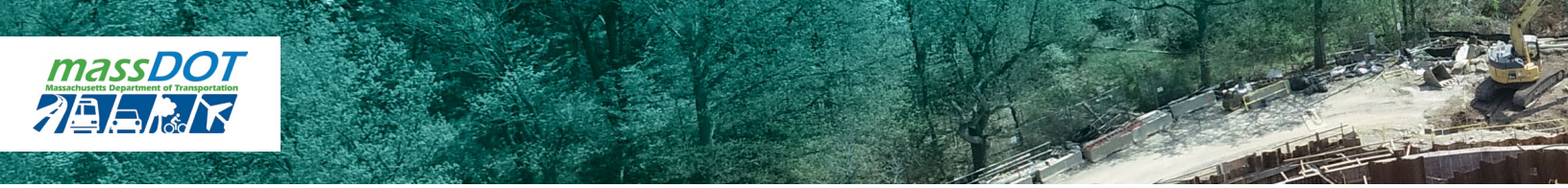
3.5 Risk Management for Bridges

The MassDOT bridge program is subject to internal and external forces with potential to affect outcomes. This section describes risks with a high impact and high likelihood. Chapter 5 holistically discusses enterprise risk management at MassDOT.

3.5.1 Extreme Weather and Resiliency Risks for Bridges

Bridge structures over water are directly vulnerable to the effects of extreme weather. Existing structures are at risk for scour because of increased precipitation, and MassDOT routinely inspects scour-susceptible structures with targeted inspections post-storm. For new water crossings, multi-disciplined scoping ensures that the appropriate criteria and standards are utilized for hydraulic analysis, ensuring new infrastructure is hardened to the climactic challenges of the future.

MassDOT also continues to refine details of bridge designs that can affect long term structure durability. A major contributor to bridge deterioration is infiltration of winter deicing treatment into superstructure and substructure elements. In recent years MassDOT Operations and Maintenance has required "close-loop" systems on all vendor spreaders to limit material overuse. As mitigation to this prevalent risk found in winter climates, MassDOT has increasingly incorporated link slabs and slab-over-backwall details in new bridge construction to ensure the future inventory is more resilient than legacy infrastructure.



3.5.2 Bridge Program Risks

As noted in Section 3.2.2, attainment of long-term bridge state of good repair is contingent upon sustained funding. Aside from the clear funding risk, which this plan attempts to mitigate through magnification, the following risks have been identified by agency personnel and affect day-to-day management of Massachusetts bridges:

- **Maintenance of existing poor bridges** is to be a challenge for some time in the future. Preservation is intended to prevent good or fair bridges from becoming poor, and capital rehabilitation and replacements will address poor bridges and provide others with life cycle "windows" as described in Section 3.2.1. A third category of investment is needed to ensure poor bridges remain in-service until eventual replacement is possible. This work does not register within performance measures but is a necessity to ensure bridges remain safe, passable, open to traffic and free of load restrictions.

- **Over-height vehicles** have been a visible hazard to bridges in recent years. These incidents always require lane closures and traffic disruption for cleanup and inspection, and commonly exact significant damage to structures and can result in restricted use and major repairs. To mitigate this risk the Department has taken steps and will continue to improve permitting processes, industry outreach and enforcement.

- **Coordination with other infrastructure owners** is a necessity within an inter-connected transportation network. MassDOT manages inspections for state and municipally owned structures. This arrangement presents a risk that findings are not reacted to in a timely manner by that asset owner. When deficiencies are encountered, MassDOT notifies municipal officials of critical findings, in advance of and in addition to a full inspection report. MassDOT remains committed to ensuring inspection information is communicated to owners in a timely manner and will continue to collaborate with municipalities to support good repair of non DOT-owned bridges.

  MassDOT also must coordinate with private entities (e.g., utilities and railroads) that own bridges or attached infrastructure. Coordination with railroads is a particular concern and MassDOT actively works to include railroad bridges in its preservation program to keep them out of poor condition.

An additional coordination risk is timely access for inspection of structures over or adjacent to transit infrastructure. These locations often require interruption to service, or off-hour windows, to achieve safe access for inspectors. This planning is critical to timely inspections, and MassDOT will continue to meet with transit owners to manage these inspections in a safe and expedited manner.

3.6 Valuation for Bridges

The value of a bridge is most directly related to replacement cost. MassDOT annually calculates replacement cost based on recent project bids following FHWA guidance. The guidelines exclude specific project cost elements including the demolition of existing structures, maintenance of traffic, right of way, utility relocation, and project contingencies.

Based on the most recent FHWA-published replacement costs (2021),[12] Massachusetts NHS bridges are valued at $15.8 billion, a 13% increase from the 2019 TAMP valuation.

[12] https://www.fhwa.dot.gov/bridge/nbi/sd2021.cfm

4 ENTERPRISE RISK MANAGEMENT

4.1 Identification and Prioritization of Risk

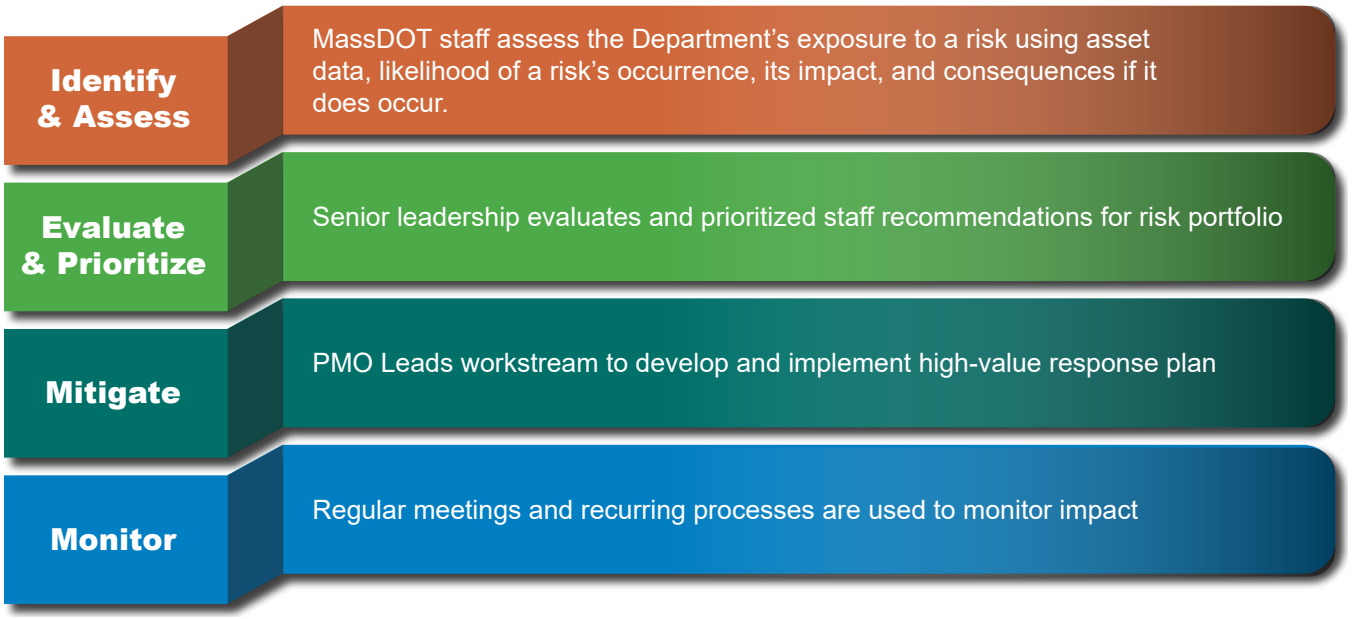
This chapter will discuss two types of risk that MassDOT has prioritized through more than a decade of refining its approach. Specifically, the Department places emphasis on risks where the **consequence** and **likelihood** are both significant. It is generally understood risk management practice to place risks on these two axes as shown in Exhibit 4.1, with priority rising as the event moves further up and to the left on the diagram.

Exhibit 4.1 **Risk Likelihood/Consequence Matrix**

	LIKELIHOOD		UNLIKELY	POSSIBLE	LIKELY	ALMOST CERTAIN
	IMPACT	DESCRIPTION	THE EVENT COULD POSSIBLY OCCUR, BUT IS UNLIKELY AT THIS TIME.	THE EVENT COULD OCCUR UNDER SPECIFIC CONDITIONS AND SOME OF THOSE CONDITIONS ARE CURRENTLY EVIDENCED.	THE EVENT IS MOST LIKELY TO OCCUR IN MOST CIRCUMSTANCES.	THE EVENT IS EXPECTED TO OCCUR IN MOST CIRCUMSTANCES OR IS HAPPENING NOW.
IMPACT	Catastrophic	Potential for multiple deaths & injuries, substantial public & private cost.				
	Major	Potential for multiple injuries, substantial public or private cost and/or foils agency objectives.				
	Moderate	Potential for injury, property damage, increased agency cost and/or impedes agency objectives.				
	Minor	Potential for moderate agency cost and impact to agency objectives.				
	Insignificant or Neutral	Potential impact low and manageable with normal agency practices.				

The MassDOT enterprise risk management process follows a framework within which MassDOT managers and staff assess the Department's exposure to risk, and then make recommendations to senior leadership. Leadership then sets Department priorities based on these recommendations. This process is described in Exhibit 4.2.

Exhibit 4.2 **Framework for Risk Management at MassDOT**



The first set of risks with high likelihood and consequence are those that directly impact capital project delivery. All of MassDOT's investments in assets are made through the CIP. Section 4.2 addresses each of the workstreams of capital project delivery, the significant risks associated with each element, and the methods by which MassDOT seeks to manage (e.g., monitor or mitigate) those risks. MassDOT centralizes enterprise risk management for capital delivery in its PMO.

The second set of risks with high likelihood and consequence are those that address and impact resiliency and climate vulnerability, most commonly manifested through extreme weather events. These risks include increased precipitation, rapid fluctuation of temperature and inland and coastal flooding. Section 4.3 summarizes MassDOT's approach to building resiliency into Massachusetts infrastructure. Section 4.4 satisfies 23 CFR Part 667: "Periodic Evaluation of Facilities Repeatedly Requiring Repair and Reconstruction Due to Emergency Events."

4.2 Management of Capital Delivery Risks

The PMO, established in 2021, works across MassDOT to evolve and refine how process improvement projects are evaluated and how accomplishments, challenges, and opportunities are reported. The PMO connects planning and approvals at the management level with project execution, ensuring that investment strategies are linked to goals, objectives, and priorities while considering sources of uncertainty.

To prepare for new IIJA funding and mandates and in recognition of the hazards and uncertainty described in the 2019 TAMP and other documents, the PMO has developed workstreams that directly monitor and mitigate the highest priority risks identified by senior leadership (i.e., the Administrator, the Chief Engineer, and their deputies).

Exhibit 4.3 presents each workstream, the types of risks addressed in that workstream, and how MassDOT has assessed the likelihood and consequence of each of these risks.

Exhibit 4.3 **Risk Register for Capital Delivery Risks by PMO Workstream**

RISKS	LIKELIHOOD	CONSEQUENCE	MITIGATION
TRAFFIC CONTROL			
Unsafe work zones are a hazard to safety	Possible	Major	The goals of the Traffic Control Workstream are to reduce reliance on the Massachusetts State Police for construction details and improve work zone safety for all roadway users. The Workstream seeks alternatives to details and/or other interventions such as traffic control devices, and to increase efficiency between partners (police, contractors, MassDOT, etc).
Poor project harmonization leads to redundant traffic disruptions.	Likely	Minor	Ongoing work within the Workstream includes initiating a Work Zone Management and Scheduling Application pilot in District 3 that was created to increase operations efficiency within construction work zones.
RISK BASED DESIGN AND REVIEW			
MassDOT cannot efficiently deliver its capital program due to delays in project design.	Possible	Moderate	The goal of the Risk-Based Design and Review Workstream is to evaluate and streamline risk within the design process. This Workstream reviews processes and works to establish improvements and tools to decrease design duration timeline. A risk register model and implementation strategy are currently being developed. The purpose of the risk register is to identify projects whose designs could be accelerated using qualitative risk ratings. Accomplishments include conducting mini workshops for projects and confirming a "home" for the Model in the Pre-25% Scoping Procedure as well as drafting revisions for this scoping procedure. The Pre-25% Scoping Procedure will continue to be refined in the future. Upcoming goals include finalizing the model, creating a High-Level Risk Evaluation Team to use the model and score projects during the Pre-25% process, and conducting two real risk evaluations during scoping meetings for several Pre-25% projects.
Projects experience "scope creep" during the design process, raising costs and challenging delivery.	Possible	Moderate	

RISKS	LIKELIHOOD	CONSEQUENCE	MITIGATION
ENVIRONMENTAL			
Redundant environmental reviews add time and expense to project development.	Possible	Moderate	The main goal of the Environmental Workstream is to streamline environmental processes and permitting to support the Advertisement Program and IIJA. This includes focusing on refining internal environmental workflows to improve the quality and completeness of design submissions and reducing duplicative Environmental reviews. The Workstream also includes hiring and developing staff and improving communication with leadership on the success of the environmental permitting program. Several major products have already been created through this Workstream, including an Environmental Dashboard in Power BI to improve transparency on environmental permitting timeframes and to enhance communication on the delivery of the Advertisement Program. Other products include a new "Environmental Review Checklist" that will streamline a variety of environmental clearances and permits, and new Environmental Workflows such as a MEPA/NEPA Unit that is taking on Scoping and Design Reviews, increasing the capacity of the Wetlands and Stormwater units to fulfill their roles and responsibilities. Future steps for the Environmental Workstream include developing Quality and Completeness Checklists for several environmental applications as well as developing additional Environmental Clearance and Permitting Charts in the Environmental Dashboard.
RIGHT OF WAY			
Project development and delivery are bottlenecked in right-of-way processes and negotiations.	Possible	Moderate	The main goal of the Right of Way Workstream is to identify bottlenecks and accelerate project advertisement. This is being implemented in the development of new workload management systems that have already proven effective as well as new Standard Operating Procedures (SOPs) to help prevent construction delays and to promote better coordination. A new hiring plan has also been set in place. The ROW Workstream moving forward will continue to work on development of an implementation of a ROW Power BI Dashboard that will give MassDOT leadership and project managers a snapshot of the overall workload and individual project status. A Municipal Project Tracker with similar workflow attributes to the State Project Tracker will also continue to be developed.
DISTRICT BRIDGE MAINTENANCE CONTRACTING			
MassDOT cannot effectively spend IIJA funds using existing district-level bridge maintenance contract mechanisms.	Almost Certain	Moderate	The Workstream is developing new chapters of the Bridge M&P Manual to provide more guidance and updating SOPs and key project development components to create documented consistent practices. Moving forward, additional updates will be developed along with implementation of two alternative delivery contracting methods and possible legislative change. The Workstream will continue to re-evaluate original gaps and identify additional areas to address as gaps begin to move to the implementation stage.
ALTERNATIVE PROJECT DELIVERY			
MassDOT could achieve more efficient project delivery through use of (and experience with) new models of project delivery.	Almost Certain	Major	The Alternative Project Delivery Workstream aims to complete a top to bottom review of the program processes to identify bottlenecks and interventions that will expedite projects to construction. This includes new training for Design-Build Project Execution, the development of a Design-Build manual focusing on Project Development and Management, improving the Design Build Quality Assurance Program and updating several SOPs. The completion of the Design-Build Manual is an ongoing goal of the Workstream.

RISKS	LIKELIHOOD	CONSEQUENCE	MITIGATION
WORKFORCE			
MassDOT experiences difficulty hiring needed technical staff for project delivery.	Almost Certain	Major	To respond to the challenges of the pandemic while continuing to fulfill core functions, MassDOT has adopted new technologies, team strategies and work schedules. The Workforce Workstream was established to continue this process and adapt MassDOT's workforce to new challenges including increased levels of investment and new demands on our infrastructure. Several initiatives are underway to facilitate workforce development and training as well as evaluate current and future workforce needs. One of these initiatives includes planning ahead for talent demand and strengthening targeted recruitment. Due to trends in mobility and technology, asset management and traffic engineering have been identified as areas where demand for talent will likely rise. Moreover, MassDOT will likely need additional skills in asset analytics over time. MassDOT is working on filling critical skill gaps in the workforce by offering training, leveraging partners and vendors, and supporting employees through on-the-job instruction and mentorship. MassDOT recognizes that in addition to analytical skills, it may need to develop skills in change management to help the organization evolve. Improving how different types of work are managed and delivered by the current workforce is another way this initiative is being supported, with an example being enhancing the project management function.
MassDOT does not possess and must hire technical and administrative skills to deliver capital projects using best practice methods.	Almost Certain	Major	
MassDOT loses staff with key insight and expertise to retirement, creating the need for knowledge retention.	Almost Certain	Major	

4.3 Management of Resiliency and Vulnerability Risks

The 2019 TAMP described studies MassDOT had undertaken on coastal vulnerability to flooding, including the Coastal Transportation Vulnerability Assessment and the Coastal Flood Exceedance Probability Maps, both utilizing the Boston Harbor Flood Risk Model (BH-FRM). MassDOT has also completed detailed assessments using the BH-FRM of risk and depth of water from storm surge-induced coastal flooding for the tunnels of the Metropolitan Highway System and other major Boston-area highways.

Additionally, the 2019 TAMP demonstrated MassDOT's commitment to monitoring and mitigating inland stream and river crossing vulnerability. The Department partnered with the University of Massachusetts Amherst to pilot methods to identify and prioritize culverts at risk from increased severity of riverine flooding and has extended these methods statewide to estimate the vulnerability of all bridges and culverts to inform priority of inspection and replacement programs.

MassDOT has formed a Resiliency Task Force in partnership with the Massachusetts Department of Environmental Protection, the Division of Ecological Restoration, and the Division of Fisheries and Wildlife (the latter two from the Massachusetts Department of Fish and Game). The Resilience Task force is charged with developing a mission and vision for the resilience program; leading a Strategic Resilience Assessment funded by the Transportation Research Board (TRB); providing transparency for MassDOT's resiliency work; identifying stakeholders and partner agencies for resiliency efforts; and developing a resiliency capital planning strategy in line with this TAMP.

IIJA13 has created new regulations for States to consider resiliency and extreme weather in asset management plans. In addition to the planning studies described above, Exhibit 4.4 presents the mitigation strategies MassDOT has identified for vulnerability risks bearing the greatest likelihood and consequence.

[13] 23 U.S.C. 119(e)(4)(D) § 11105

Exhibit 4.4 **Risk Register for Resiliency and Vulnerability Risks**

RISKS	LIKELIHOOD	CONSEQUENCE	MITIGATION
ADDRESSING KNOWN VULNERABILITIES			
Extreme rainfall events lead to failure of inland culverts.	Possible	Major	The day-to-day operation of MassDOT infrastructure is managed by the six Highway Division District offices. District maintenance and operation forces monitor weather to prepare for storm events, patrol during events, and repair damage left in the wake. To implement the MassDOT resiliency program, the District offices were thus canvassed to begin the process of addressing today's needs, and from this effort a list of priorities of projects across the Commonwealth was created. The PMS is reviewing these locations in concert with environmental colleagues, with the goal of initiating projects for design, programming, and remediation through construction. Proposed projects include: the replacement of culverts vulnerable to failure due to poor condition or insufficient hydraulic capacity, embankment or slope stabilization for areas subject to severe erosion or failure during heavy precipitation events, and improved drainage systems to more efficiently manage stormwater for improved roadway operational safety and environmental quality.
Extreme rainfall events lead to failure of inland slopes.	Possible	Major	
Extreme rainfall events lead to flooded and impeded roadways due to poor or overwhelmed drainage systems.	Likely	Major	
EVALUATION OF CURRENT AND NEW PROJECTS			
MassDOT misses opportunities to address vulnerable assets or improve resiliency in through capital projects due to poor internal coordination.	Possible	Moderate	MassDOT has implemented fully collaborative project initiation and scoping processes which provide the opportunity to include resiliency-building scope within projects of every priority. Many working groups within the Highway Division participate in projection initiation, and the process is further aided using the geographic information – based screening tool MAPIT (Massachusetts Project Initiation Tool), which automatically screens proposed project locations against environmental, hydrological, system condition, equity and safety layers. Once a project has been initiated, scope development in advance of preliminary design (pre-25% scoping) presents an additional opportunity to review project location for vulnerability and determine if there are opportunities to improve resiliency within the design. MassDOT will use these existing processes to ensure state projects are hardening infrastructure in conjunction with other goals.
DETERMINATION OF FUTURE VULNERABILITIES			
Increasing extreme weather events and sea level rise due to climate change catch MassDOT off guard, threatening unexpectedly vulnerable assets.	Possible	Catastrophic	MassDOT is conducting a flood risk assessment to understand future flood related threats to a range of critical transportation infrastructure. The statewide, multimodal planning-level assessment named the Climate Adaptation Vulnerability Assessment (CAVA) seeks to identify transportation assets which are at risk of riverine and coastal flooding over the coming decades. This study focuses on NHS roadways, bridges, and large culverts. The analysis models stream flows for future climate conditions and predicts floodplain and erosion mapping, asset damage and detour modeling, through a probabilistic simulation of future outcomes. In addition to identifying which assets are exposed to damage under various time horizons, return periods and climate scenarios, the work ultimately quantifies risk to MassDOT and our customers as do-nothing-costs: expected costs if no resiliency actions are taken. The results of this work – to be discussed in the upcoming Resilience Improvement Plan – will support MassDOT's ability to initiate and prioritize investments that improve transportation system resiliency.

4.4 Report on Vulnerable Assets (Part 667)

As required by the Final Rule, MassDOT has conducted a study of assets damaged in declared emergencies[14] between January 1, 1997 and December 31, 2021, pursuant to 23 CFR Part 667. 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.

Massachusetts was subject to between 30 and 40 (depending on how duplicates and multipart emergencies are counted) declarations of emergency during the study period. These covered storms, flooding, infrastructure failures, terrorism, and the COVID-19 pandemic.

Of these events, only five produced damage to MassDOT assets (impacting any given asset only once):

- 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).
- Superstorm Sandy (October 2012).

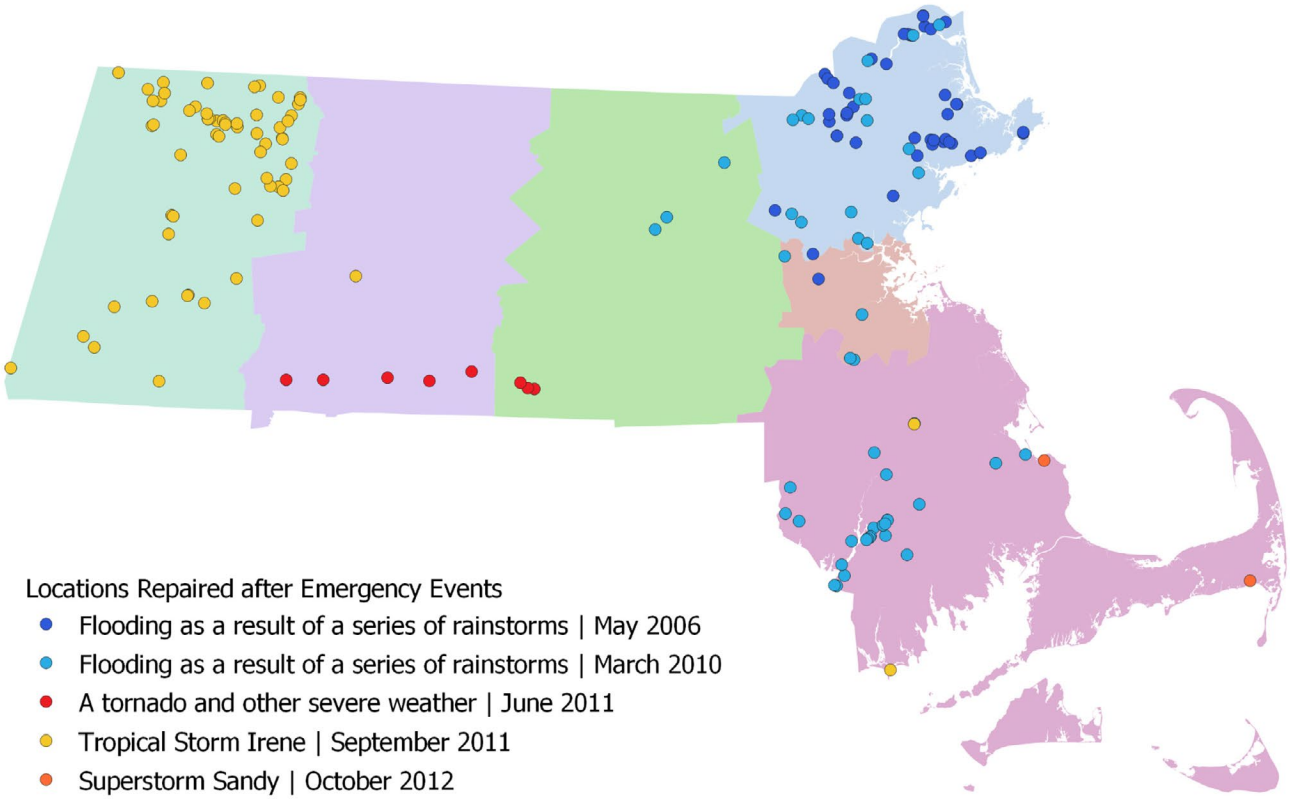
MassDOT's Highway Districts report 161 locations had requested State or Federal reimbursement under disaster declarations for repairs on highway pavement and bridges. Only one location was cited more than once.

MA-18 at the Matfield River was cited twice, first after the March 2010 flooding event and again in 2011 for Tropical Storm Irene. MassDOT has since reconstructed the roadway and built best practice management for drainage.

A map of all locations cited, by event, is provided in Exhibit 4.5.

[14] 23 CFR Part 667

Exhibit 4.5 **Locations Cited for State or Federal Disaster Reimbursement, 1997-2021**



5 FINANCIAL PLAN

5.1 Cost of Future Work

As noted in Section 1.2, the CIP is the authoritative documentation of investments in the NHS and other MassDOT-owned infrastructure. The CIP is a rolling five-year plan produced annually by State fiscal year (July 1 through June 30). MassDOT staff collaborate with transportation stakeholders on each occasion to both add a new fifth year to the CIP and to update investments for the first four years. For pavement and bridge assets, the investment strategies described in Chapter 2 and Chapter 3 of the TAMP inform the development of the CIP.

MassDOT's individual projects are funded through programs assigned to one of three priorities: reliability, modernization, and expansion. The CIP aligns programs with specific outcomes; for reliability programs, outcomes are tied to asset condition and system performance. FHWA classifies work into four categories: maintenance, preservation, rehabilitation, and reconstruction.

Exhibits 5.1, 5.2, and 5.3 provide forecasted spending for Interstate pavements, non-Interstate NHS pavements, and NHS bridges. The years 2023-2028 are summarized from the CIP, while the years 2029-2032 are estimated based on planned investments in the CIP. Values are estimated to the year of expenditure.

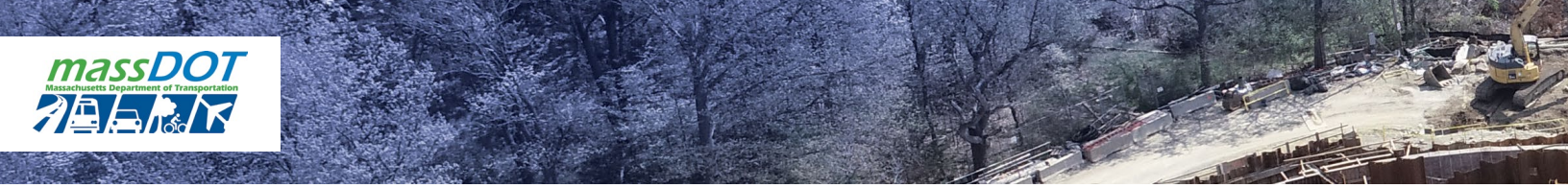


Exhibit 5.1 **NHS Interstate Pavement Spending by FHWA Work Type, 2023-2032 (millions)**

WORK TYPES	2023	2024	2025	2026	2027	2028	2029-2032	2023-2032
Maintenance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Preservation	$13.42	$26.35	$26.82	$28.31	$22.92	$21.90	$96.70	$236.42
Rehabilitation	$31.64	$72.73	$82.00	$76.22	$43.13	$66.01	$291.54	$663.27
Reconstruction	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total	$45.06	$99.08	$108.82	$104.53	$66.05	$87.91	$388.24	$899.69

Exhibit 5.2 **NHS Non-Interstate Pavement Spending by FHWA Work Type, 2023-2032 (millions)**

WORK TYPES	2023	2024	2025	2026	2027	2028	2029-2032	2023-2032
Maintenance	$26.43	$19.48	$14.34	$20.08	$20.08	$20.89	$92.24	$213.55
Preservation	$47.90	$31.49	$17.03	$13.44	$4.86	$13.94	$74.18	$202.85
Rehabilitation	$53.20	$50.43	$77.48	$101.27	$85.31	$62.93	$350.86	$781.47
Reconstruction	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total	$127.53	$101.41	$108.84	$134.79	$110.25	$97.76	$517.29	$1,197.87

Exhibit 5.3 **NHS Bridge Spending by FHWA Work Type, 2023-2032 (millions)**

WORK TYPES	2023	2024	2025	2026	2027	2028	2029-2032	2023-2032
Maintenance	$75.00	$76.50	$78.03	$79.59	$81.18	$82.81	$348.12	$821.23
Preservation	$73.50	$114.26	$116.04	$111.50	$131.49	$75.96	$185.66	$808.41
Rehabilitation	$25.40	$140.61	$247.46	$276.45	$209.57	$103.19	$348.12	$1,350.79
Reconstruction	$79.68	$97.80	$217.33	$438.46	$420.67	$294.95	$696.24	$2,245.14
Total	$253.58	$429.17	$658.86	$906.00	$842.91	$556.90	$1,578.14	$5,225.57

5.2 Anticipated Funding Levels

The CIP uses both Federal Aid and State moneys to fund the delivery of projects from preliminary design to completion. Project delivery costs include project planning and design; environmental planning and mitigation; right-of-way acquisition; utility relocation; construction contract costs; and construction engineering. The CIP also provides for statewide operations, equipment, and materials, as well as for the Municipal Bridge Program, the Municipal Pavement Program, the Complete Streets Program; the Shared Streets and Spaces Program; and the Local Bottleneck Reduction Program, all grant-based programs administered by MassDOT.

Exhibit 5.4 provides total revenue for the years 2022-2031.

Exhibit 5.4 **MassDOT's Capital Revenue, 2022-2031 (millions)**

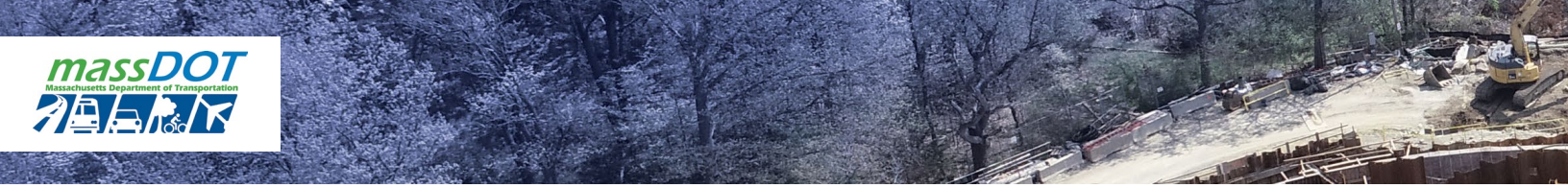
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Federal	$1,031	$949	$950	$937	$941	$850	$866	$882	$898	$915
State	$990	$1,179	$1,289	$1,326	$1,462	$1,335	$1,373	$1,373	$1,162	$1,173
Total	$2,021	$2,113	$2,239	$2,263	$2,403	$2,185	$2,239	$2,255	$2,916	$2,088

5.2.1 *Anticipated Funding Levels for Federal Aid*

The Federal portion of the CIP is contained within the STIP. The STIP is compiled annually by the Office of Transportation Planning (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 at the same time as the CIP, the STIP identifies how 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:

- **The National Highway Performance Program (NHPP) |** The NHPP provides support for the condition and performance of the NHS, provides 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 the targets in the TAMP.
- **The Surface Transportation Block Grant Program (STBG) |** The STBG promotes flexibility in State and local transportation decisions and provides flexible funding to best address State and local transportation needs.
- **Congestion Mitigation/Air Quality (CMAQ) |** The CMAQ program provides a flexible funding source to State and local governments for transportation projects and programs to meet the requirements of the Clean Air Act.
- **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.
- **Carbon Reduction Program (Carbon) |** A new program authorized in IIJA that will provide funding for projects to reduce transportation emissions or the development of carbon reduction strategies.
- **Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation Program (PROTECT) |** A new program authorized in IIJA that will provide funding for Planning, resilience improvements, community resilience and evacuation routes, and at-risk coastal infrastructure.
- **National Electric Vehicle Infrastructure Program (NEVI) |** A new program authorized in IIJA that will provide funding for strategic deployment of electric vehicle charging infrastructure and establish an interconnected network to facility data collection, access, and reliability.
- **Bridge Formula Program (HIP Bridge) |** A new program authorized in IIJA under the Highway Infrastructure program that will provide funding for projects to replace, rehabilitate, preserve, protect, and construct bridges on public roads.



The estimate for Federal-aid revenues assumes the new Federal apportionments available for Massachusetts that were authorized in IIJA. The assumptions assume that MassDOT will receive 87% of the total apportionments authorized as our obligation limit and available to be programmed in the annual STIP. MassDOT's Federal revenue for the years 2022-2031 is projected in Exhibit 5.5.

Exhibit 5.5 **MassDOT's Federal Revenue, 2022-2031 (millions)**

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Total Federal	$1,031	$949	$950	$937	$941	$850	$866	$882	$882	$915

Approximately one-third of the annual STIP budget is distributed among the MPOs based on a formula that currently considers road mileage and population (it may be updated in 2024). The formula is developed by the Massachusetts Association of Regional Planning Agencies (MARPA). The remainder is budgeted for statewide investments identified by MassDOT (i.e., maintenance, preservation, rehabilitation and reconstruction) and enterprise activities (i.e., design and asset, performance, and risk management).

5.2.2 Anticipated State Funding Levels

The three primary State sources for highway infrastructure capital investment are revenues derived from the issuance of General Obligation Bonds and Special Obligation Bonds and fees collected on tolled facilities. Projected State capital revenue for 2022-2031 is provided in Exhibit 5.6.

Exhibit 5.6 **MassDOT's State Capital Revenue, 2022-2031 (millions)**

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Bond Cap	$704	$807	$898	$865	$875	$803	$815	$827	$840	$853
Tolls (Capital)	$257	$225	$253	$266	$280	$279	$260	$248	$278	$276
CARM	$26	$27	$48	$38	$16	$5	$0	$0	$0	$0
Other	$3	$120	$90	$157	$291	$248	$298	$298	$44	$44
Total	$990	$1,179	$1,289	$1,326	$1,462	$1,335	$1,373	$1,373	$1,162	$1,173

State Bond Cap

MassDOT is funded by two types of bonds:

» **General Obligation (GO) Bonds |** MassDOT receives approximately $900 million annually in GO bonds, of which approximately $700 million (including $200 million per year for the Chapter 90 program) is targeted for the Highway Division. GO bonds are used to match Federal Aid as well as to 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 several innovative and Federally-mandated programs including the Accelerated Bridge Program, the Next-Generation Bridge Program, the Positive Train Control program, and the Rail Enhancement Program.

The Executive Office for Administration and Finance (ANF) as part of their annual capital plan guidance (circulated in January of each fiscal year) provides MassDOT with an estimate of bond cap by fiscal year for the upcoming five-year period (e.g., 2023-2027). The total annual amount of bond cap available is determined per the recommendations of the Commonwealth's Capital Debt Affordability Committee (DAC), which was established by Chapter 165 of the Acts of 2012, Section 60B. DAC was established by the Legislature for the purposes of reviewing on a continuing basis the amount and condition of the Commonwealth's tax-supported debt, as well as the debt of certain State authorities. The recommended amount of annual bond cap that can be prudently issued is submitted to the Governor and the Legislature on or before December 15 of each fiscal year.

OTP reviews prior the CIP and bond cap spending programmed by each Division to determine and allocate the baseline bond cap for the next five-year plan by Division by fiscal year. Beyond the five-year period bond cap is assumed to increase 2% annually. OTP works with each Division to determine the additional bond cap or other funding needed to support changes to five-year CIP program budgets and/or to support new programs. Requests for additional bond cap to support new programs/initiatives are submitted by OTP as part of our formal capital plan submissions to ANF and part of the Secretary-Secretary (DOT/ANF) discussions typically held in March of each year.

Tolls

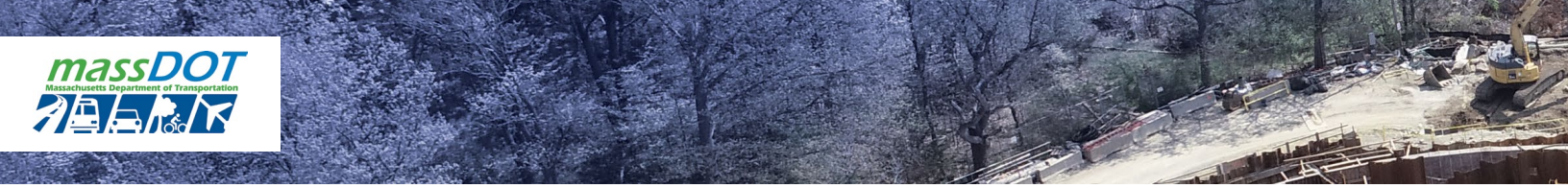
MassDOT collects tolls on two facilities. Tolls from each facility are collected in a separate revenue stream. MassDOT is required to spend toll revenue solely on the facility on which it was collected. Capital sources from toll revenue are determined by first ensuring that operating expenses on the facility are fully funded, and that for the MHS specific annual debt service is paid.

MassDOT's two tolled facilities are:

» **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) |** 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. Of these facilities, all are tolled except for those on I-93.

MassDOT and ANF develop a fiscal year operating budget each year that includes estimates for revenues and expenses split between the toll and non-toll funded operations. OTP works with MassDOT Fiscal Office to develop an estimate of toll revenues available for capital based on the annual toll-funded portion of the operating budget. The Fiscal Office provides an update in January of the expected revenues and expenses by each facility for the current fiscal year and a preliminary budget for the next fiscal year.



MassDOT's traffic and revenue consultant provides an estimate of annual and projected toll revenues for each of the toll facilities for use in developing the operating budget and multi-year projections of toll revenues. OTP works with fiscal on assumptions for the other non-toll revenues and expenses to develop a multi-year projection of net toll revenues available for capital. Toll revenue projections for the CIP are updated in coordination with development of the operating budget that is submitted to the MassDOT Board of Directors for approval in June of each year.

The Central Artery Repair and Maintenance Fund (CARM)

For tunnels constructed through the Central Artery/Tunnel Project (also known as "the Big Dig"), some needs may be eligible for funding through the Central Artery Repair and Maintenance Fund (CARM). This account is managed by FHWA and was created through a settlement with consultants, contractors and material providers involved in the project. Where a defect or deteriorated element can be attributed to a design or construction shortcoming, this fund can be used for design and construction of remediation.

A DEFINITIONS AND TERMINOLOGY

The Federal Highway Administration (FHWA), seeking to satisfy Federal Law in the Fixing America's Surface Transportation (FAST) Act of 2015 and the IIJA of 2021, has required that the TAMP:

- Comply with 23 CFR 515, which sets the content required for a risk-based transportation asset management plan (TAMP) to be updated every four years beginning in 2018.
- Summarize MassDOT's progress toward data and risk-based management of its pavements and bridges on the National Highway System (NHS).
- Describe how MassDOT considers extreme weather and resilience in life-cycle planning, investment strategy, and risk management.

Asset management plan means a document that describes how a State DOT will carry out asset management[15] as defined in this section. This includes how the State DOT will make risk-based decisions from a long-term assessment of the National Highway System (NHS), and other public roads included in the plan at the option of the State DOT, as it relates to managing its physical assets and laying out a set of investment strategies to address the condition and system performance gaps.

This document describes how the highway network system will be managed to achieve State DOT targets for asset condition and system performance effectiveness while managing the risks, in a financially responsible manner, at a minimum practicable cost over the life cycle of its assets.

The term asset management plan under this part is the risk-based asset management plan that is required under 23 U.S.C. 119(e)[16] and is intended to carry out asset management as defined in 23 U.S.C. 101(a)(2).[17]

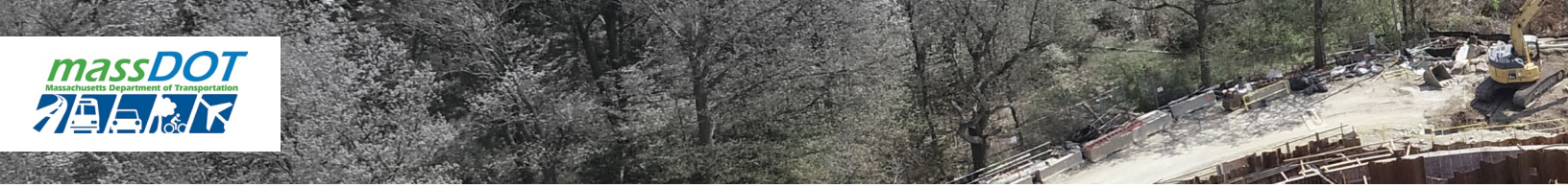
In addition, the Final Rule defined the following terms:

- **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).

[15] https://www.ecfr.gov/current/title-23/chapter-I/subchapter-F/part-515

[16] https://www.govinfo.gov/link/uscode/23/119

[17] https://www.govinfo.gov/link/uscode/23/101



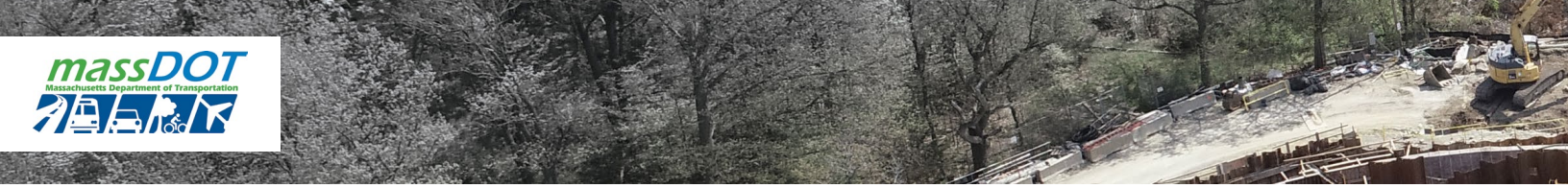
- **Critical Infrastructure:** Facilities having the incapacity or failure of which would have a debilitating impact on national or regional economic security, national or regional energy security, national or regional public health or safety, or any combination of those matters.
- **Financial Plan:** 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**
BIL	**Bipartisan Infrastructure Law of 2021 (also known as the IIJA):** The most recent Federal transportation enabling legislation to pass Congress.
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.
CHAPTER 90	A statutory funding program that distributes $200 million per year to Massachusetts cities and towns for a variety of transportation infrastructure projects.
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.
CMAQ	**The Congestion Mitigation and Air Quality Program:** Provides a flexible funding source to State and local governments for transportation projects and programs to meet the requirements of the Clean Air Act.
DTIMS	**Deighton Total Infrastructure Management System:** MassDOT's pavement management software, which projects pavement condition and recommends schedules of treatment.
FAPRO	**MassDOT Federal Aid Programming and Reimbursement Office**
FAST ACT	**The Fixing America's Surface Transportation Act of 2015:** The second-most-recent Federal transportation enabling legislation to pass Congress.

FHWA	**The Federal Highway Administration**
GO	**General Obligation Bonds:** MassDOT receives approximately $900 million annually in GO bonds, of which approximately $700 million (including $200 million per year for the Chapter 90 program) is targeted for the Highway Division. GO bonds are used to match Federal Aid as well as to support State-funded projects and local transportation grant programs. These bonds are backed by the full faith and credit of the Commonwealth.
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.
HSIP	**The Highway Safety Improvement Program:** Targets a significant reduction in traffic fatalities and serious injuries on all public roads, including non-State-owned public roads.
IBC	**Incremental Benefit/Cost Ratio:** A 0 to 100 value used in dTIMS to analyze the value of potential pavement treatments.
IRI	**International Roughness Index:** A statistic used to estimate the amount of roughness in an MPO measured longitudinal profile of roadway pavement.
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.
MHS	**Metropolitan Highway System:** A system of Interstate highways in Boston and immediate neighbors. It 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. Of these facilities, all are tolled except for those on I-93.
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.
NEVI	**National Electric Vehicle Infrastructure Program:** Provides funding for strategic deployment of electric vehicle charging infrastructure and establish an interconnected network to facility data collection, access, and reliability.
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.
OPMI	**The MassDOT Office of Performance Management and Innovation**
OTP	**The MassDOT Office of Transportation Planning**
PSI	**Pavement Serviceability Index:** MassDOT's day-to-day condition measure for pavement, incorporating roughness, raveling, and three types of cracking.
PROTECT	**The Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation Program:** Provide funding for Planning, resilience improvements, community resilience and evacuation routes, and at-risk coastal infrastructure.
RF	**Ranking Factor:** MassDOT's prioritization score for bridges, incorporating condition loss, highway effectiveness factor, scour criticality factor, and projected health index.
RIP	**Resilience Improvement Plan:** A voluntary, risk-based assessment of vulnerable transportation assets in immediate and long-term transportation planning that demonstrates a systemic approach to surface transportation system resilience.
SCF	**Scour Criticality Factor:** A multiplier applied to the bridge ranking factor to represent the danger posed by scour.



STBG	**The Surface Transportation Block Grant Program:** Promotes flexibility in State and local transportation decisions and provides flexible funding to best address State and local transportation needs.
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**
USACE	**United States Army Corps of Engineers:** An engineer formation of the United States Army that has three primary mission areas – engineer regiment, military construction, and civil works. Under the last of these, they own and operate the Bourne and Sagamore Bridges over the Cape Cod Canal.
USC	**United States Code:** A consolidation and codification by subject matter of the general and permanent laws of the United States.
WT	**Western Turnpike:** The segment of I-90 from the New York state line to Weston.

Exhibit A.2 **NHS Pavement by System and Condition, 2021 (PSI)**

	TOTAL LANE MILES	EXCELLENT/GOOD		FAIR		POOR	
		LANE MILES	%	LANE MILES	%	LANE MILES	%
INTERSTATE	**3,204**	2,905	91%	259	8%	39	1%
NON-INTERSTATE NHS	**7,319**	4,548	62%	1,502	21%	1,251	17%
MASSDOT NON-NHS	**1,867**	1,156	62%	478	26%	233	12%

Exhibit A.3 **NHS Pavement by Jurisdiction and Condition, 2021 (PSI)**

	TOTAL LANE MILES	EXCELLENT/GOOD		FAIR		POOR	
		LANE MILES	%	LANE MILES	%	LANE MILES	%
TOTAL NHS	**7,319**	**4,566**	**62%**	**1,502**	**21%**	**1,251**	**17%**
MASSDOT NHS	**4,528**	3,329	73%	798	18%	401	9%
MUNICIPAL NHS	**2,791**	1,237	44%	704	25%	850	31%

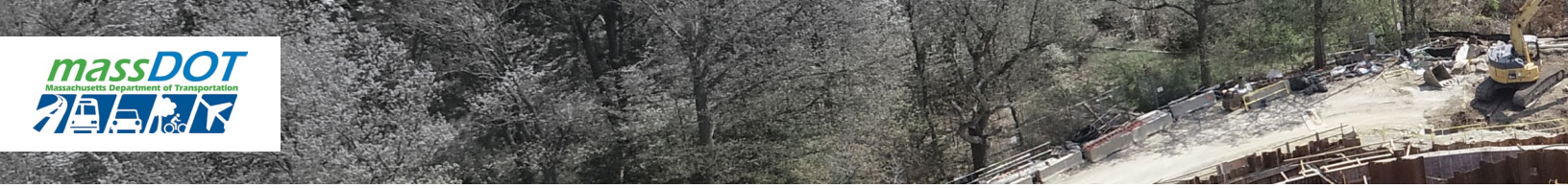
B LANE-MILES OF NHS PAVEMENT OWNED BY MUNICIPALITY

Note: Towns with no NHS mileage were included for completeness, and so that readers from all parts of the Commonwealth could easily use this reference.

CITY OR TOWN	NHS LANE MILEAGE
Abington	3
Acton	15
Acushnet	0
Adams	5
Agawam	12
Alford	0
Amesbury	0
Amherst	17
Andover	15
Arlington	16
Ashburnham	1
Ashby	0
Ashfield	0
Ashland	6
Athol	5
Attleboro	22
Auburn	0
Avon	0
Ayer	6
Barnstable	25
Barre	8
Becket	0
Bedford	0
Belchertown	17
Bellingham	18
Belmont	11
Berkley	10
Berlin	8
Bernardston	0
Beverly	7
Billerica	7
Blackstone	0
Blandford	0
Bolton	17
Boston	256

CITY OR TOWN	NHS LANE MILEAGE
Bourne	0
Boxborough	0
Boxford	2
Boylston	0
Braintree	8
Brewster	5
Bridgewater	4
Brimfield	0
Brockton	32
Brookfield	0
Brookline	15
Buckland	0
Burlington	0
Cambridge	39
Canton	13
Carlisle	0
Carver	4
Charlemont	0
Charlton	0
Chatham	5
Chelmsford	9
Chelsea	4
Cheshire	0
Chester	0
Chesterfield	15
Chicopee	14
Chilmark	0
Clarksburg	0
Clinton	7
Cohasset	0
Colrain	15
Concord	12
Conway	0
Cummington	7
Dalton	2

CITY OR TOWN	NHS LANE MILEAGE
Danvers	7
Dartmouth	4
Dedham	14
Deerfield	0
Dennis	11
Dighton	10
Douglas	0
Dover	1
Dracut	5
Dudley	0
Dunstable	9
Duxbury	4
East Bridgewater	1
East Brookfield	0
East Longmeadow	11
Eastham	0
Easthampton	5
Easton	20
Edgartown	6
Egremont	0
Erving	1
Essex	0
Everett	7
Fairhaven	0
Fall River	6
Falmouth	29
Fitchburg	20
Florida	0
Foxborough	0
Framingham	16
Franklin	2
Freetown	6
Gardner	7
Aquinnah	0
Georgetown	10



CITY OR TOWN	NHS LANE MILEAGE
Gill	0
Gloucester	7
Goshen	0
Gosnold	0
Grafton	4
Granby	0
Granville	17
Great Barrington	5
Greenfield	10
Groton	15
Groveland	5
Hadley	10
Halifax	0
Hamilton	0
Hampden	0
Hancock	0
Hanover	0
Hanson	9
Hardwick	13
Harvard	13
Harwich	12
Hatfield	0
Haverhill	20
Hawley	0
Heath	0
Hingham	0
Hinsdale	0
Holbrook	9
Holden	3
Holland	0
Holliston	6
Holyoke	27
Hopedale	2
Hopkinton	8
Hubbardston	16
Hudson	10
Hull	0
Huntington	0
Ipswich	2
Kingston	9
Lakeville	0

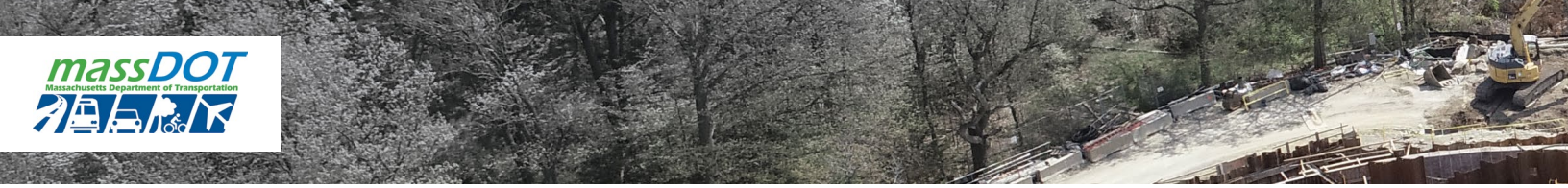
CITY OR TOWN	NHS LANE MILEAGE
Lancaster	16
Lanesborough	0
Lawrence	13
Lee	1
Leicester	0
Lenox	0
Leominster	19
Leverett	0
Lexington	18
Leyden	0
Lincoln	5
Littleton	0
Longmeadow	7
Lowell	33
Ludlow	2
Lunenburg	9
Lynn	23
Lynnfield	0
Malden	18
Manchester	0
Mansfield	11
Marblehead	11
Marion	0
Marlborough	6
Marshfield	0
Mashpee	14
Mattapoisett	0
Maynard	12
Medfield	17
Medford	9
Medway	16
Melrose	7
Mendon	0
Merrimac	0
Methuen	2
Middleborough	0
Middlefield	0
Middleton	0
Milford	14
Millbury	0
Millis	8

CITY OR TOWN	NHS LANE MILEAGE
Millville	0
Milton	18
Monroe	0
Monson	3
Montague	0
Monterey	0
Montgomery	0
Mount Washington	0
Nahant	0
Nantucket	0
Natick	17
Needham	9
New Ashford	0
New Bedford	23
New Braintree	0
New Marlborough	0
New Salem	0
Newbury	0
Newburyport	6
Newton	37
Norfolk	0
North Adams	6
North Andover	3
North Attleborough	0
North Brookfield	0
North Reading	0
Northampton	13
Northborough	0
Northbridge	0
Northfield	0
Norton	6
Norwell	10
Norwood	4
Oak Bluffs	5
Oakham	0
Orange	7
Orleans	0
Otis	0
Oxford	0
Palmer	13
Paxton	0

CITY OR TOWN	NHS LANE MILEAGE
Peabody	17
Pelham	0
Pembroke	7
Pepperell	19
Peru	0
Petersham	0
Phillipston	0
Pittsfield	24
Plainfield	0
Plainville	0
Plymouth	11
Plympton	0
Princeton	8
Provincetown	13
Quincy	39
Randolph	5
Raynham	0
Reading	6
Rehoboth	22
Revere	2
Richmond	0
Rochester	0
Rockland	0
Rockport	0
Rowe	0
Rowley	9
Royalston	0
Russell	0
Rutland	11
Salem	20
Salisbury	0
Sandisfield	1
Sandwich	7
Saugus	12
Savoy	0
Scituate	2
Seekonk	0
Sharon	10
Sheffield	0
Shelburne	5
Sherborn	16

CITY OR TOWN	NHS LANE MILEAGE
Shirley	0
Shrewsbury	9
Shutesbury	0
Somerset	0
Somerville	12
South Hadley	11
Southampton	0
Southborough	0
Southbridge	7
Southwick	14
Spencer	3
Springfield	115
Sterling	9
Stockbridge	3
Stoneham	9
Stoughton	13
Stow	14
Sturbridge	0
Sudbury	8
Sunderland	0
Sutton	0
Swampscott	5
Swansea	9
Taunton	7
Templeton	0
Tewksbury	4
Tisbury	3
Tolland	11
Topsfield	0
Townsend	12
Truro	0
Tyngsborough	0
Tyringham	0
Upton	0
Uxbridge	6
Wakefield	13
Wales	0
Walpole	8
Waltham	24
Ware	4
Wareham	0

CITY OR TOWN	NHS LANE MILEAGE
Warren	0
Warwick	0
Washington	0
Watertown	13
Wayland	18
Webster	0
Wellesley	13
Wellfleet	0
Wendell	0
Wenham	0
West Boylston	0
West Bridgewater	6
West Brookfield	9
West Newbury	0
West Springfield	14
West Stockbridge	1
West Tisbury	0
Westborough	1
Westfield	25
Westford	13
Westhampton	0
Westminster	6
Weston	0
Westport	0
Westwood	8
Weymouth	1
Whately	0
Whitman	5
Wilbraham	1
Williamsburg	4
Williamstown	3
Wilmington	3
Winchendon	10
Winchester	5
Windsor	0
Winthrop	0
Woburn	11
Worcester	106
Worthington	9
Wrentham	1
Yarmouth	7



C NUMBER AND SQUARE FOOTAGE OF NHS BRIDGES OWNED BY MUNICIPALITY

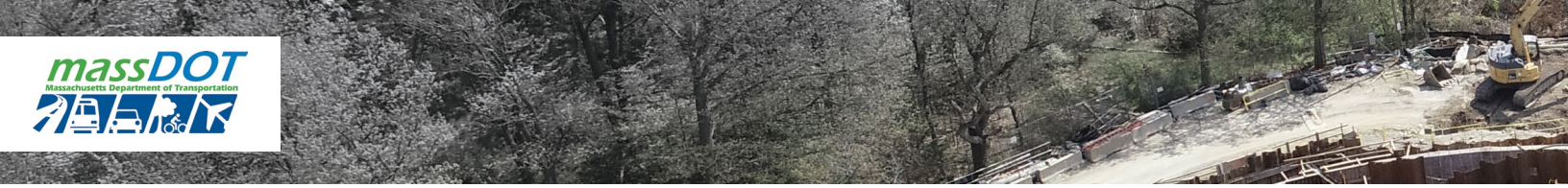
Note: Towns with no NHS bridges were included for completeness, and so that readers from all parts of the Commonwealth could easily use this reference.

CITY OR TOWN	NHS BRIDGES OWNED	NHS SQUARE FOOTAGE OWNED
Abington	0	0
Acton	0	0
Acushnet	0	0
Adams	0	0
Agawam	0	0
Alford	0	0
Amesbury	0	0
Amherst	1	4,014
Andover	0	0
Arlington	1	918
Ashburnham	0	0
Ashby	0	0
Ashfield	0	0
Ashland	0	0
Athol	0	0
Attleboro	1	3,043
Auburn	0	0
Avon	0	0
Ayer	0	0
Barnstable	0	0
Barre	0	0
Becket	0	0
Bedford	0	0
Belchertown	1	1,817
Bellingham	0	0
Belmont	0	0
Berkley	0	0
Berlin	0	0
Bernardston	0	0
Beverly	0	0
Billerica	1	3,042
Blackstone	0	0
Blandford	0	0

CITY OR TOWN	NHS BRIDGES OWNED	NHS SQUARE FOOTAGE OWNED
Bolton	0	0
Boston	22	465,499
Bourne	0	0
Boxborough	0	0
Boxford	0	0
Boylston	0	0
Braintree	0	0
Brewster	0	0
Bridgewater	0	0
Brimfield	0	0
Brockton	3	6,097
Brookfield	0	0
Brookline	0	0
Buckland	0	0
Burlington	1	2,062
Cambridge	0	0
Canton	2	3,586
Carlisle	0	0
Carver	0	0
Charlemont	0	0
Charlton	0	0
Chatham	0	0
Chelmsford	0	0
Chelsea	0	0
Cheshire	0	0
Chester	0	0
Chesterfield	1	971
Chicopee	0	0
Chilmark	0	0
Clarksburg	0	0
Clinton	0	0
Cohasset	0	0
Colrain	0	0

CITY OR TOWN	NHS BRIDGES OWNED	NHS SQUARE FOOTAGE OWNED
Concord	0	0
Conway	0	0
Cummington	0	0
Dalton	0	0
Danvers	0	0
Dartmouth	0	0
Dedham	1	2,685
Deerfield	0	0
Dennis	0	0
Dighton	2	1,418
Douglas	0	0
Dover	0	0
Dracut	0	0
Dudley	0	0
Dunstable	0	0
Duxbury	0	0
East Bridgewater	0	0
East Brookfield	0	0
East Longmeadow	0	0
Eastham	0	0
Easthampton	1	2,319
Easton	0	0
Edgartown	0	0
Egremont	0	0
Erving	0	0
Essex	0	0
Everett	0	0
Fairhaven	0	0
Fall River	0	0
Falmouth	0	0

CITY OR TOWN	NHS BRIDGES OWNED	NHS SQUARE FOOTAGE OWNED
Fitchburg	0	0
Florida	0	0
Foxborough	0	0
Framingham	0	0
Franklin	0	0
Freetown	2	2,723
Gardner	1	1,411
Aquinnah	0	0
Georgetown	0	0
Gill	0	0
Gloucester	0	0
Goshen	0	0
Gosnold	0	0
Grafton	0	0
Granby	0	0
Granville	0	0
Great Barrington	0	0
Greenfield	0	0
Groton	0	0
Groveland	0	0
Hadley	0	0
Halifax	0	0
Hamilton	0	0
Hampden	0	0
Hancock	0	0
Hanover	0	0
Hanson	0	0
Hardwick	0	0
Harvard	0	0
Harwich	0	0
Hatfield	0	0
Haverhill	0	0
Hawley	0	0
Heath	0	0
Hingham	0	0
Hinsdale	0	0
Holbrook	0	0
Holden	0	0
Holland	0	0
Holliston	0	0
Holyoke	0	0
Hopedale	0	0
Hopkinton	0	0
Hubbardston	0	0
Hudson	0	0
Hull	0	0
Huntington	0	0
Ipswich	1	2,496
Kingston	0	0
Lakeville	0	0
Lancaster	0	0
Lanesborough	0	0
Lawrence	1	10,929
Lee	0	0
Leicester	0	0
Lenox	0	0
Leominster	0	0
Leverett	0	0
Lexington	1	2,648
Leyden	0	0
Lincoln	0	0
Littleton	0	0
Longmeadow	0	0
Lowell	4	106,269
Ludlow	0	0
Lunenburg	0	0
Lynn	0	0
Lynnfield	0	0
Malden	0	0
Manchester	0	0
Mansfield	2	5,612
Marblehead	0	0
Marion	0	0
Marlborough	0	0
Marshfield	0	0
Mashpee	0	0
Mattapoisett	0	0
Maynard	1	6,631
Medfield	0	0
Medford	0	0
Medway	0	0
Melrose	0	0
Mendon	0	0
Merrimac	0	0
Methuen	0	0
Middleborough	0	0
Middlefield	0	0
Middleton	0	0
Milford	0	0
Millbury	0	0
Millis	0	0
Millville	0	0
Milton	1	2,416
Monroe	0	0
Monson	1	1,257
Montague	0	0
Monterey	0	0
Montgomery	0	0
Mount Washington	0	0
Nahant	0	0
Nantucket	0	0
Natick	0	0
Needham	0	0
New Ashford	0	0
New Bedford	0	0
New Braintree	0	0
New Marlborough	0	0
New Salem	0	0
Newbury	0	0
Newburyport	0	0
Newton	0	0
Norfolk	0	0
North Adams	1	36,693
North Andover	0	0
North Attleborough	0	0



CITY OR TOWN	NHS BRIDGES OWNED	NHS SQUARE FOOTAGE OWNED
North Brookfield	0	0
North Reading	0	0
Northampton	0	0
Northborough	0	0
Northbridge	0	0
Northfield	0	0
Norton	0	0
Norwell	0	0
Norwood	0	0
Oak Bluffs	0	0
Oakham	0	0
Orange	1	3,207
Orleans	0	0
Otis	0	0
Oxford	0	0
Palmer	0	0
Paxton	0	0
Peabody	0	0
Pelham	0	0
Pembroke	0	0
Pepperell	0	0
Peru	0	0
Petersham	0	0
Phillipston	0	0
Pittsfield	0	0
Plainfield	0	0
Plainville	0	0
Plymouth	0	0
Plympton	0	0
Princeton	0	0
Provincetown	0	0
Quincy	1	33,497
Randolph	0	0
Raynham	0	0
Reading	0	0
Rehoboth	0	0
Revere	0	0
Richmond	0	0
Rochester	0	0
Rockland	0	0
Rockport	0	0
Rowe	0	0
Rowley	0	0
Royalston	1	758
Russell	0	0
Rutland	1	1,010
Salem	0	0
Salisbury	0	0
Sandisfield	0	0
Sandwich	0	0
Saugus	0	0
Savoy	0	0
Scituate	0	0
Seekonk	0	0
Sharon	0	0
Sheffield	0	0
Shelburne	0	0
Sherborn	0	0
Shirley	0	0
Shrewsbury	0	0
Shutesbury	0	0
Somerset	0	0
Somerville	0	0
South Hadley	0	0
Southampton	0	0
Southborough	0	0
Southbridge	0	0
Southwick	0	0
Spencer	0	0
Springfield	3	23,204
Sterling	0	0
Stockbridge	0	0
Stoneham	0	0
Stoughton	0	0
Stow	0	0
Sturbridge	0	0
Sudbury	0	0
Sunderland	0	0
Sutton	0	0
Swampscott	0	0
Swansea	0	0
Taunton	0	0
Templeton	0	0
Tewksbury	0	0
Tisbury	0	0
Tolland	0	0
Topsfield	0	0
Townsend	1	276
Truro	0	0
Tyngsborough	0	0
Tyringham	0	0
Upton	0	0
Uxbridge	0	0
Wakefield	0	0
Wales	0	0
Walpole	0	0
Waltham	1	14,768
Ware	1	487
Wareham	0	0
Warren	0	0
Warwick	0	0
Washington	0	0
Watertown	0	0
Wayland	1	4,431
Webster	0	0
Wellesley	0	0
Wellfleet	0	0
Wendell	0	0
Wenham	0	0
West Boylston	0	0
West Bridgewater	0	0
West Brookfield	0	0
West Newbury	0	0
West Springfield	0	0

CITY OR TOWN	NHS BRIDGES OWNED	NHS SQUARE FOOTAGE OWNED
West Stockbridge	0	0
West Tisbury	0	0
Westborough	0	0
Westfield	0	0
Westford	0	0
Westhampton	0	0
Westminster	0	0
Weston	0	0
Westport	0	0
Westwood	0	0
Weymouth	0	0
Whately	0	0
Whitman	0	0
Wilbraham	0	0
Williamsburg	0	0
Williamstown	0	0
Wilmington	0	0
Winchendon	0	0
Winchester	1	2,420
Windsor	0	0
Winthrop	0	0
Woburn	0	0
Worcester	3	13,674
Worthington	0	0
Wrentham	0	0
Yarmouth	0	0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