pennsylvania
DEPARTMENT OF TRANSPORTATION

Pennsylvania Department of Transportation

Transportation Asset Management Plan 2019

June 28, 2019

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June 28, 2019

Dear Fellow Pennsylvanians:

PennDOT is pleased to present its 2019 Transportation Asset Management Plan. Pennsylvania's transportation assets—our roads, bridges, and other vital infrastructure that comprise our transportation system—represent a tremendous investment by taxpayers over many decades. Much like the cars we drive on them, these assets need regular maintenance, sometimes require major repairs, and eventually must be replaced. Just as a timely oil change can prevent or delay costlier engine trouble and make a vehicle last longer, completing the right maintenance or treatment at the right time on Pennsylvania's roadways and bridges helps infrastructure last longer and enables us to squeeze the most value from our transportation dollars.

That is the essence of asset management—performing the right treatment at the right time. While it is straightforward in principle, achieving that ideal is complex due to the sheer volume of transportation assets statewide owned by PennDOT and other entities, the myriad factors that contribute to their wear and tear, and the reality that needs consistently exceed available funding.

We have made significant progress in improving our transportation system, especially since Act 89 of 2013, but more investment is necessary to keep up with funding challenges and increasing costs. However, that plan envisioned meaningful investment from the federal government in our most heavily traveled assets, which has not yet occurred. Without additional investment, more of our limited resources will need to go to the Interstate system, which will reduce investments on other parts of our system and worsen conditions. The federal government—a critical partner, especially for Interstates and other high-traffic roadways—needs to join the states in significantly investing in infrastructure.

This Transportation Asset Management Plan, as required by the federal FAST Act, illustrates our commitment to and formal definition of asset management. Further, it projects needed levels of future investment to meet asset condition targets, contrasted with expected funding levels. The passage of Pennsylvania Act 89 provided a much-needed additional investment in the transportation system; however, it was not a long-term funding solution. This TAMP shows that while proper planning and operations are critical, they can only get us as far as our funding allows. It is time for our federal partners to take action and deliver on past promises of infrastructure investment. We look forward to continued conversations and collaboration to move toward that goal.

Sincerely,

Leslie S. Richards
Secretary, Pennsylvania Department of Transportation

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1. Introduction

Asset management provisions enacted in the Moving Ahead for Progress in the 21st Century Act (MAP-21) and continued by the Fixing America's Surface Transportation Act (FAST Act) require each state department of transportation to develop and implement a risk-based asset management plan in accordance with 23 U.S.C. 119. The intent is to encourage states to achieve and sustain a state of good repair over the life cycle of transportation assets—regardless of ownership—and to preserve or improve the condition of the National Highway System (NHS).

This document satisfies the requirements of the Federal Highway Administration (FHWA) rulemaking 2125-AF57, which provides detailed guidance on developing and implementing state Transportation Asset Management Plans (TAMPs).

The Pennsylvania Department of Transportation's (PennDOT's) TAMP demonstrates that its asset management practices are consistent with federal requirements. This document:

- Establishes targets for NHS pavement and bridge condition;
- Summarizes Pennsylvania's inventory of NHS pavement and bridge assets by structure type, class, owner, and condition;
- Forecasts NHS asset condition by year for at least a 12-year planning horizon at current funding levels; and
- Outlines Pennsylvania's asset management processes, which are integrated into long-range planning, project programming, financial planning, and risk assessment processes.

This 2019 edition of the TAMP analyzes NHS pavement and bridge assets only, as data is not yet available to fully analyze all assets that comprise Pennsylvania's complete surface transportation system. However, this document does discuss NHS assets in the context of the complete transportation system—an accurate fiscally constrained asset condition analysis and projection must consider all the financial responsibilities of a DOT and its state and local partners.

PennDOT continues to work toward including additional transportation assets in future editions of the TAMP, as data and asset management processes develop. In addition to an expanded pavement and bridge inventory to include non-NHS pavements and bridges, the following NHS and non-NHS assets are being considered for subsequent TAMP updates:

- Roadway signs
- Retaining walls
- High mast lighting
- Traffic signals
- Guiderail and end treatments
- Traffic counting devices (weigh-in-motion (WIM), continuous automatic vehicle classification (CAVC), and automatic traffic recorders (ATR))
- Intelligent transportation systems (ITS)

As PennDOT systematically expands the scope of its asset management tools and processes to analyze an increasing percentage of Pennsylvania's transportation assets, asset management practices will become more fully integrated into the operations of asset owners statewide. This will result in continually refined project selection processes, with more in-depth and accurate cost and condition projections providing a clear picture of the current and needed level of investment to maintain Pennsylvania's complete transportation system at the current state of repair.

The 2019 TAMP was developed by the Asset Management Division, Bureau of Maintenance and Operations, Pennsylvania Department of Transportation.

2. Objectives

Why Asset Management is a PennDOT Priority

Asset management-based decision making is key to fulfilling PennDOT's mission, which is to provide a sustainable transportation system and quality services that are embraced by our communities and add value to our customers. Proper asset management—simply defined as performing the right treatment at the right time—enables roads and bridges to last longer, saves money, and keeps the overall transportation system in a state of good repair. This business practice ensures that the citizens of the Commonwealth and the motoring public receive the most value from their investment in transportation infrastructure, directly aligning with PennDOT's mission.

In more technical terms, asset management can be described as a data-based decision framework applied to project selection that helps achieve and sustain the desired state of good repair for transportation assets by providing decision tools to select the right treatment at the right time. This methodology allows assets to be managed to specific condition targets and to the lowest practical life-cycle cost (LLCC).

The transition to asset management-based planning and programming marks a promising new chapter for Pennsylvania transportation. The approach ties into other initiatives, such as PennDOT Connects, aimed at developing the most effective project for the community. Asset management-based planning and programming also helps each project stay consistent with regulations, state priorities, and LLCC-based preservation, rehabilitation, and replacement decisions.

Objective A: Sustain a Desired State of Good Repair over the Life Cycle of Assets

A transportation system in good overall condition is a key enabler of economic activity and is central to quality of life in Pennsylvania. Timely, appropriate preservation and rehabilitation treatments are required to maintain roadway pavement, bridges, and other transportation infrastructure in a state of good repair.

Pennsylvania defines its desired state of good repair as meeting the FHWA minimum condition thresholds for pavements and bridges: no more than 5 percent of NHS Interstate lane-miles shall be rated in poor condition (23 CFR part 490.315(a), Subpart C) and no more than 10 percent of total NHS bridge deck area shall be rated as poor (previously classified as structurally deficient or SD) (23 U.S.C. 119(f)(1)). Pennsylvania's desired state of good repair for NHS non-Interstate pavements is also defined as having no more than 5 percent of lane-miles be rated in poor condition.

The asset management decision framework is the key to making data-driven decisions on which treatments (e.g., roadway resurfacing, bridge painting) are needed and what time interval is appropriate to achieve the desired state of good repair, recognizing that projects must be planned and added to PennDOT's program in a fiscally constrained manner. Fiscal constraint means that the total cost of planned projects—no matter how urgently needed—cannot exceed reasonably forecasted federal and state funding.

Objective B: Achieve the Lowest Practical Life-Cycle Cost for Assets

Transportation needs have historically and consistently exceeded available funding in Pennsylvania. For this reason, as well as PennDOT's commitment to good stewardship and delivering value, it is imperative to derive the greatest value from every infrastructure dollar invested. The intent of a lowest life-cycle cost (LLCC) asset management framework is to allow for prioritization of all work types and scopes to ensure that the full life of an asset is achieved by balancing timely and appropriate maintenance and preservation needs with immediate rehabilitation and replacement requirements. This data-driven decision-making, along with updated management matrices, will allow the life of assets to be extended and reduce the overall cost of maintaining them in the desired state of good repair.

Objective C: Achieve National Goals

The asset management framework is a central tool in Pennsylvania's support of the following national transportation goals, identified in [23 U.S.C. 150(b):]

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

Objective D: Achieve State Goals

National goals shape PennDOT's statewide planning initiatives, specifically the Department's:

- Long Range Transportation Plan (LRTP);
- Comprehensive Freight Movement Plan (CFMP); and
- Strategic Highway Safety Plan (SHSP).

These plans guide investment in Pennsylvania's transportation system. PennDOT's asset management targets, tools, and processes, which provide a data-driven basis for prioritizing projects through the lens of each plan's area of emphasis, are integral to achieving the plans' goals and objectives.

State goals are listed below by plan.

PA On-Track: PA's Long-Range Transportation & Comprehensive Freight Movement Plan (2016) includes the following goals:

- System Preservation
- Safety
- Personal and Freight Mobility
- Stewardship

Pennsylvania Strategic Highway Safety Plan (2017) includes the following goal:

- Reduce average fatalities and serious injuries to support the national effort of ending fatalities on our nation's roads within the next 30 years.

3. Measures and Targets

Overview

The FHWA final rule for the *National Performance Management Measures; Assessing Pavement Condition for the National Highway Performance Program and Bridge* was published in the Federal Register (82 FR 5886) on January 18, 2017, and became effective on February 17, 2017. This final rule established a set of performance measures for state departments of transportation (state DOTs) and metropolitan planning organizations (MPOs) to use as required by MAP-21 and the FAST Act.

MAP-21 and the FAST Act require state DOTs to use the FHWA performance measures to carry out the National Highway Performance Program (NHPP) and to assess the condition of the following in their state:

- NHS Interstate pavements;
- NHS non-Interstate pavements; and
- NHS bridges, including on- and off-ramps connected to the NHS.

The NHPP is a core Federal-Aid highway program that provides support for the condition and performance of the NHS and the construction of new facilities on the NHS. The NHPP also ensures that investments of Federal-Aid funds in highway construction support progress toward performance targets for the NHS established in a state's asset management plan. This final rule establishes regulations for the new performance aspects of the NHPP that address measures, targets, and reporting. The FHWA issued this final rule based on Section 1203 of MAP-21, which identifies national transportation goals and requires the U.S. Secretary of Transportation to promulgate rules to establish performance measures and standards in specified Federal-Aid highway program areas.

Pursuant to this rule, state DOTs are required to establish targets in coordination with MPOs for all the measures in this rule. Note that PennDOT holds the state’s Rural Planning Organizations (RPOs) to the same standards as MPOs. PennDOT coordinated with the MPOs/RPOs to set statewide targets, which are detailed on the following pages. Pennsylvania’s MPOs/RPOs elected to adopt the State-established targets. Baseline conditions were reported as of October 1, 2018, and near-term performance was projected as shown in Table 2 and Table 3.

Pavement Condition

Measures

Pavement performance measures required for FHWA reporting include four distress components:

- International Roughness Index (IRI) – Quantifies how rough the pavement is by measuring the longitudinal profile of a traveled wheel track and generating a standardized roughness value in inches per mile.
- Cracking – Measures the percentage of pavement surface that is cracked.
- Rutting – Measures the depth of ruts (surface depression) in bituminous pavement in inches.
- Faulting – Quantifies the difference in elevation across transverse concrete pavement joints in inches.

These distress measurements translate to good, fair, or poor condition scores. Table 1 summarizes the pavement condition metrics for IRI, cracking percentage, rutting, and faulting.

Table 1: Pavement Condition Rating System

Pavement Condition Measure	Rating		
	Good	Fair	Poor
IRI (inches/mile)	<95	95–170	>170
Cracking Percentage (%)	<5	CRCP: 5–10 Jointed: 5–15 Asphalt: 5–20	CRCP: >10 Jointed: >15 Asphalt: >20
Rutting (inches)	<0.20	0.20–0.40	>0.40
Faulting (inches)	<0.10	0.10–0.15	>0.15

Source: 23 CFR 490.313

IRI and cracking apply to both bituminous and concrete pavements, while rutting is exclusively for bituminous and faulting is exclusively for concrete. A pavement segment is considered in good condition if all three of its distress components are rated as good, and in poor condition if two or more of its three distress components are rated as poor.

Note that the FHWA pavement condition measures evaluate the wearing surface only, and do not reflect system age, the condition of the underlying roadway structure, or the existing backlog of reconstruction needs.

FHWA Minimum Condition Threshold

23 CFR part 490.315(a), Subpart C, requires that no more than 5 percent of a state's NHS Interstate lane-miles be in poor pavement condition.

Pennsylvania Condition Targets

PennDOT has adopted the FHWA minimum condition thresholds for NHS Interstate and non-Interstate roadways as its desired state of good repair. As presented in Table 2, near-term conditions are expected to meet or exceed that threshold. Table 3 provides condition targets for NHS non-Interstate pavements.

Table 2: NHS Interstate Pavement Condition Thresholds, Baseline, and Targets

Measure	FHWA Minimum Condition Threshold	2017 PM2 Baseline	2021 PM2 4-Year Target
Percentage in Good Condition	none	67.2%	60.0%
Percentage in Poor Condition	5.0%	0.4%	2.0%

Table 3: NHS Non-Interstate Pavement Condition Thresholds, Baseline, and Targets

Measure	FHWA Minimum Condition Threshold	2017 PM2 Baseline	2019 PM2 2-Year Target	2021 PM2 4-Year Target
Percentage in Good Condition	none	36.8%	35.0%	33.0%
Percentage in Poor Condition	none	2.3%	4.0%	5.0%

Appendix G describes the methodology used for pavement condition targets.

PennDOT's pavement condition targets are consistent with its asset management objectives of maintaining the system at the desired state of good repair, meeting the federal minimum condition threshold of having no more than 5 percent of NHS Interstate pavements rated poor, managing to LLCC, and achieving national and state transportation goals.

Bridge Condition

Measures

Similar to pavements, the FHWA final rulemaking established performance measures for all mainline NHS Interstate and NHS non-Interstate bridges regardless of ownership or maintenance responsibility, including bridges on ramps connecting to the NHS and NHS bridges that span a state border.

Separate bridge structure condition ratings are collected for deck, superstructure, and substructure components during regular inspections using the National Bridge Inventory

Standards. For culvert structures, only one condition rating is collected—the culvert rating. A rating of 9 to 0 on the FHWA condition scale is assigned to each component. Based on its score, a component is given a good, fair, or poor condition score rating.

Table 4 summarizes the FHWA scoring system for bridge condition metrics for deck, superstructure, substructure, and culvert components.

Table 4: FHWA Bridge Condition Rating System

Bridge Component	Rating		
	Good	Fair	Poor
Deck	≥7	5 or 6	≤4
Superstructure	≥7	5 or 6	≤4
Substructure	≥7	5 or 6	≤4
Culvert	≥7	5 or 6	≤4

Source: 23 CFR 490.411

A structure's overall condition rating is determined by the lowest rating of its deck, superstructure, substructure, and/or culvert. If any of the components of a structure qualify as poor, the structure is rated as poor.

FHWA Minimum Condition Threshold

23 CFR 490.411(a) requires that no more than 10 percent of a state's total NHS bridges by deck area be in poor condition.

Pennsylvania Condition Target

Pennsylvania has adopted the federal minimum condition threshold as its desired state of good repair: No more than 10 percent of Pennsylvania's total NHS bridge by deck area shall be in poor condition. Table 5 presents baseline conditions and forecasts for PA NHS bridges.

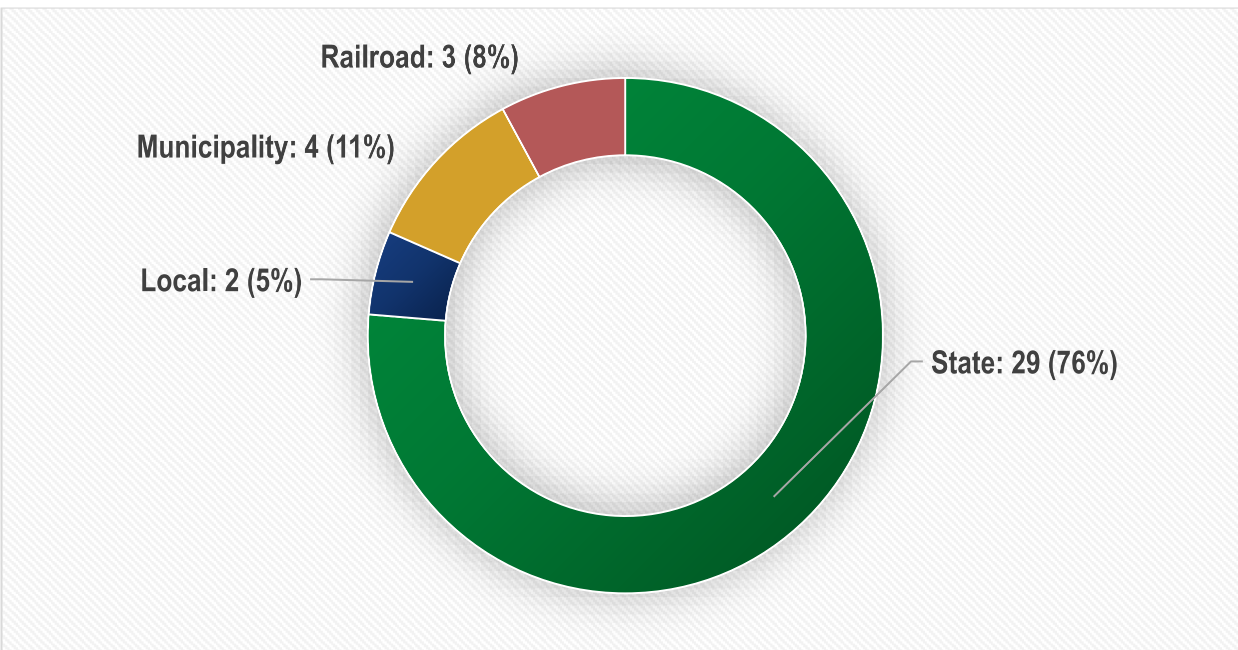
Table 5: NHS Bridge Condition Thresholds, Baseline, and Targets

Measure	FHWA Minimum Condition Threshold	2017 PM2 Baseline	2019 PM2 2-Year Target	2021 PM2 4-Year Target
Percentage of Total Bridge Deck Area in Good Condition	none	25.6%	25.8%	26.0%
Percentage of Total Bridge Deck Area in Poor Condition	10%	5.5%	5.6%	6.0%

Appendix G describes the methodology used for bridge condition targets.

In addition to the FHWA-required minimum condition threshold, PennDOT has set a voluntary target of having zero NHS Interstate bridges be weight-restricted (posted). As shown on Figure 1, there were 38 posted bridges on the NHS in Pennsylvania as of December 2018; 29 are state-owned.

Figure 1: Owners of PA Posted Bridges



Source: BMS2 data, End of Year (EOY) 2018

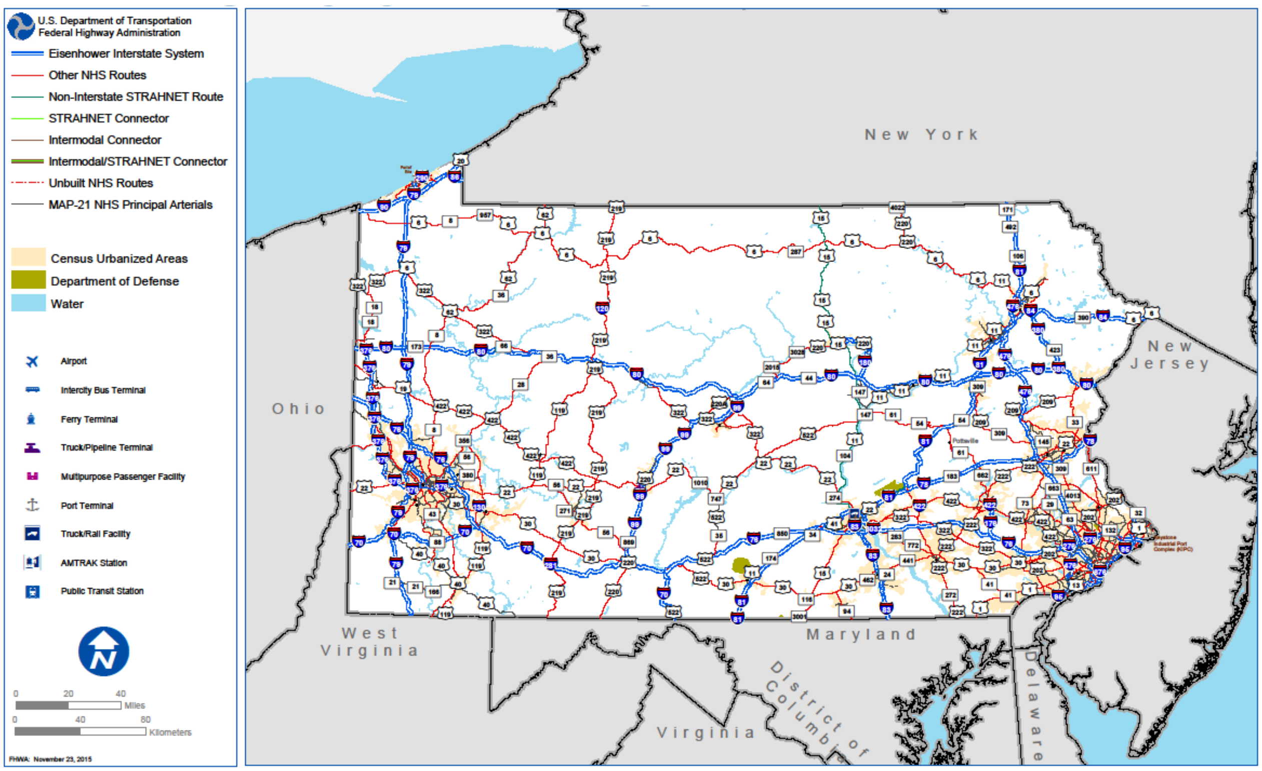
4. NHS Pavement and Bridge Inventory and Condition

Inventory

National Highway System

The National Highway System (NHS) is the federal designation of the network of roads and bridges that are vitally important to the nation's economy, mobility, and security. Pennsylvania's NHS network is shown on Figure 2.

Figure 2: National Highway System Roadways in Pennsylvania



Source: FHWA

In Pennsylvania, 54 different entities own portions of the NHS. There are three major roadway owners, six major bridge owners, and four "other" owners. As shown on Table 6 and Table 7, PennDOT owns 88 percent of the NHS lane-miles and more than 80 percent of the bridge deck area in Pennsylvania. The Pennsylvania Turnpike Commission (PTC) owns, operates, and maintains approximately 10 percent of these assets. The remaining portion of the NHS network is owned, operated, and maintained by other (mainly local) entities. Detailed NHS inventory and ownership information by PennDOT District is provided in Appendix B.

Table 6: NHS Pavement Owners

Asset Owner	Lane-Miles	Percentage of Total Lane-Miles
State Highway Agency (PennDOT)	20,332	88
State Toll Authority (PTC)	2,283	10
City, Municipal Highway Agency, or Borough	519	2
Total	**23,134**	**100**

Source: PennDOT Roadway Management System (RMS), June 2019

Appendix Figure F.1 and Appendix Figure F.2 indicate the age of these roadways, charting NHS Interstate and NHS non-Interstate pavements by year constructed.

Table 7: NHS Bridge Owners by Category

Asset Owner	Bridge Count	Percentage of Total Count	Deck Area	Percentage of Total Deck Area
State Highway Agency (PennDOT)	5,077	86.85%	72,112,442	81.16%
State Toll Authority (PTC)	598	10.23%	9,763,704	10.99%
City, Municipal Highway Agency, or Borough	45	0.77%	544,665	0.61%
County Highway Agency	39	0.67%	1,227,967	1.38%
Local Toll Authority	42	0.72%	4,691,098	5.28%
Railroad	31	0.53%	347,219	0.39%
Town or Township Highway Agency	6	0.10%	13,714	0.02%
Private (other than Railroad)	6	0.10%	44,962	0.05%
Other Local Agencies	1	0.02%	1,000	<0.01%
Other State Agencies	1	0.02%	110,208	0.12%
Total	**5,846**	**100.00%**	**88,856,979**	**100.00%**

Source: BMS2 Extract, EOY 2018

Appendix Figure F.3 indicates the age of these assets, charting NHS bridges and culverts by year constructed.

Interstate Highway System

The Interstate Highway System is part of the NHS. Table 8 details the ownership of Interstate highways in Pennsylvania.

Table 8: NHS Interstate Highway Owners

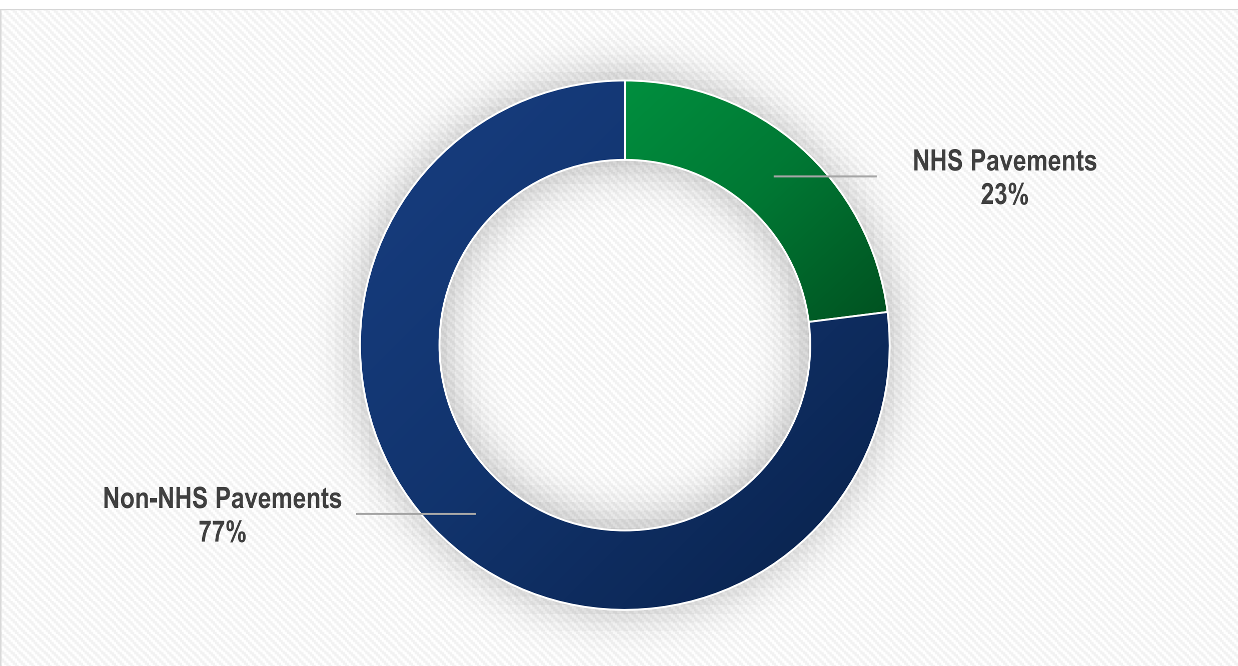
Asset Owner	Lane-Miles	Percentage of Total Lane-Miles
PennDOT	5,822	74
Pennsylvania Turnpike Commission	2,012	26
Total	**7,834**	**100**

Source: RMS, June 2019

Non-NHS Roadways and Bridges

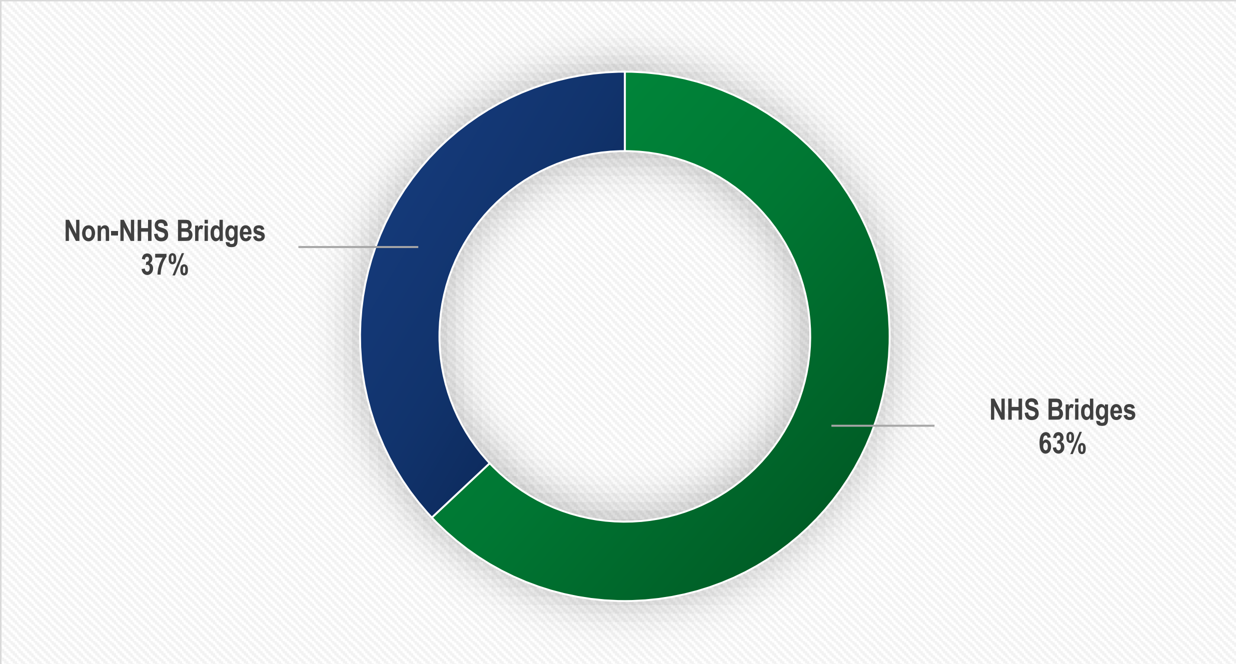
As noted previously, this TAMP submission is limited to NHS assets. However, it is important to understand the complete state-managed surface transportation system. As shown on Figure 3 and Figure 4, the NHS only represents 23 percent of the lane-miles and 63 percent of the bridge deck area that PennDOT owns and maintains. In addition to PennDOT, other local owners maintain bridges and roadways that are used every day by the traveling public.

Figure 3: NHS Pavements as a Percentage of Total PennDOT-Managed Lane-Miles



Source: RMS, June 2019

Figure 4: NHS Bridges as a Percentage of Total PennDOT-Managed Bridge Deck Area



Source: BMS2 data, EOY 2018

Roads and bridges are managed and categorized among four business plan networks (BPNs), outlined in Table 9. A detailed breakdown of this information by PennDOT District is provided in Appendix B.

Table 9: Pennsylvania Pavement and Bridge Inventory by Business Plan Network

Owner	Description	Bridge Count	Bridge Deck Area (square feet)	Lane-Miles
PennDOT	NHS Interstate	1,629	30,694,481	5,565
PennDOT	NHS Non-Interstate	3,490	46,069,792	15,155
PennDOT	Non-NHS with Average Daily Traffic (ADT) ≥ 2,000	4,139	22,713,259	23,222
PennDOT	Non-NHS with ADT < 2,000	6,285	16,523,129	44,171
Local	Locally owned roads and bridges	6,488	15,971,866	4,243
PTC	Turnpike-owned roads and bridges	631	9,951,737	2,283
DCNR	DCNR-owned roads and bridges	273	272,004	–
Total		**22,935**	**142,196,268**	**94,639**

Sources: Bridge data from BMS2, EOY 2018; pavement data from RMS, June 2019

Appendix Figure F.4 indicates the age of these assets, charting all Pennsylvania bridges and culverts by business plan network and year constructed.

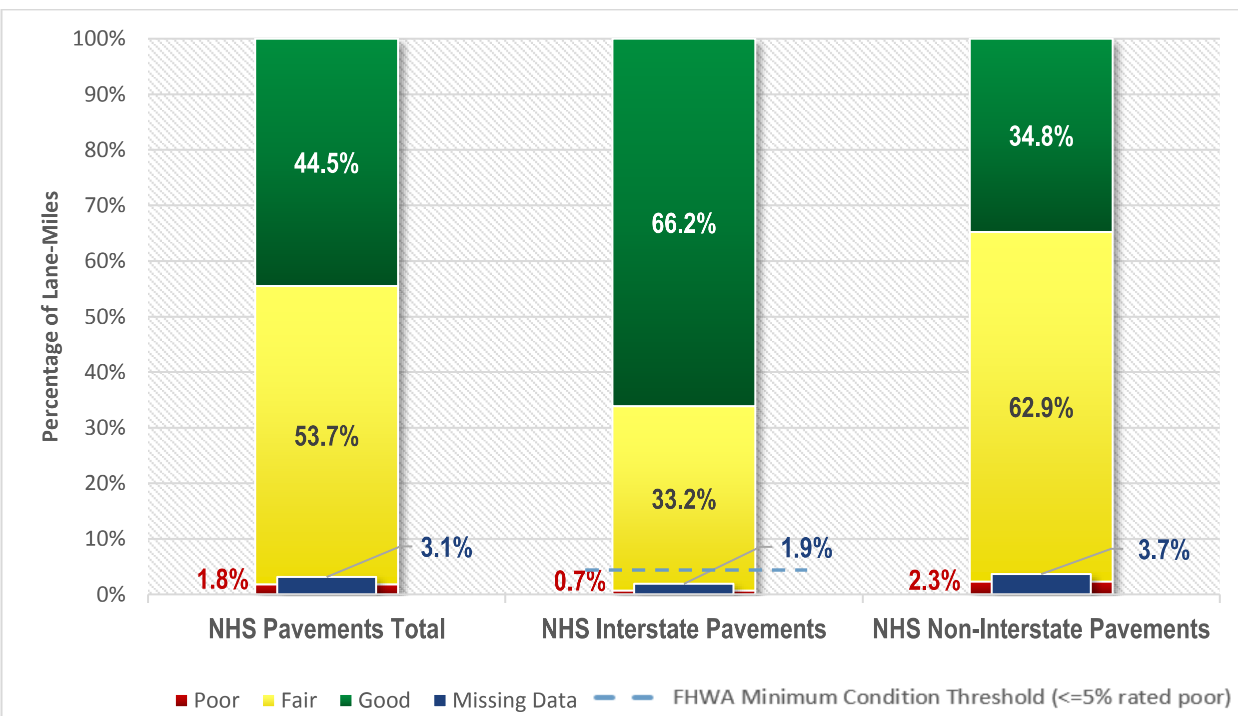
While this TAMP focuses only on NHS pavements and bridges, Pennsylvania's residents and businesses depend on the full network of roadways and bridges that connect people and goods with homes, employers, retailers, schools, medical facilities, etc., not only the major routes through the state. PennDOT and its state, regional, and local partners recognize the importance of maintaining all roads and bridges appropriately to minimize life-cycle cost. Maintaining the existing complete network to its current condition requires adequate funding at all network levels. If budgets are inadequate to maintain all roadways appropriately, prioritizing NHS roadways to meet federal requirements will cause lower-level network roadways to degrade to a lower condition state.

Condition

2018 NHS Pavement Condition Status

Figure 5 shows the condition of all NHS roadways regardless of ownership, based on 2018 tenth-mile data. The chart also shows the breakdown between NHS Interstate and NHS non-Interstate pavement conditions. Current baseline conditions meet the FHWA minimum condition threshold of having no more than 5 percent pavement rated as poor.

Figure 5: 2018 NHS Pavement Condition



Source: Based on EOY 2018 RMS data

Note: 23 CFR 490.313(b)(4)(i) requires the total mainline lane-miles of missing, invalid, or unresolved sections for Interstate System and non-Interstate NHS shall be limited to no more than 5 percent of the total lane-miles. A section is missing if any one of the data requirements specified in §§490.309 and 490.311(c) are not met or that reported section does not provide sufficient data to determine its overall condition.

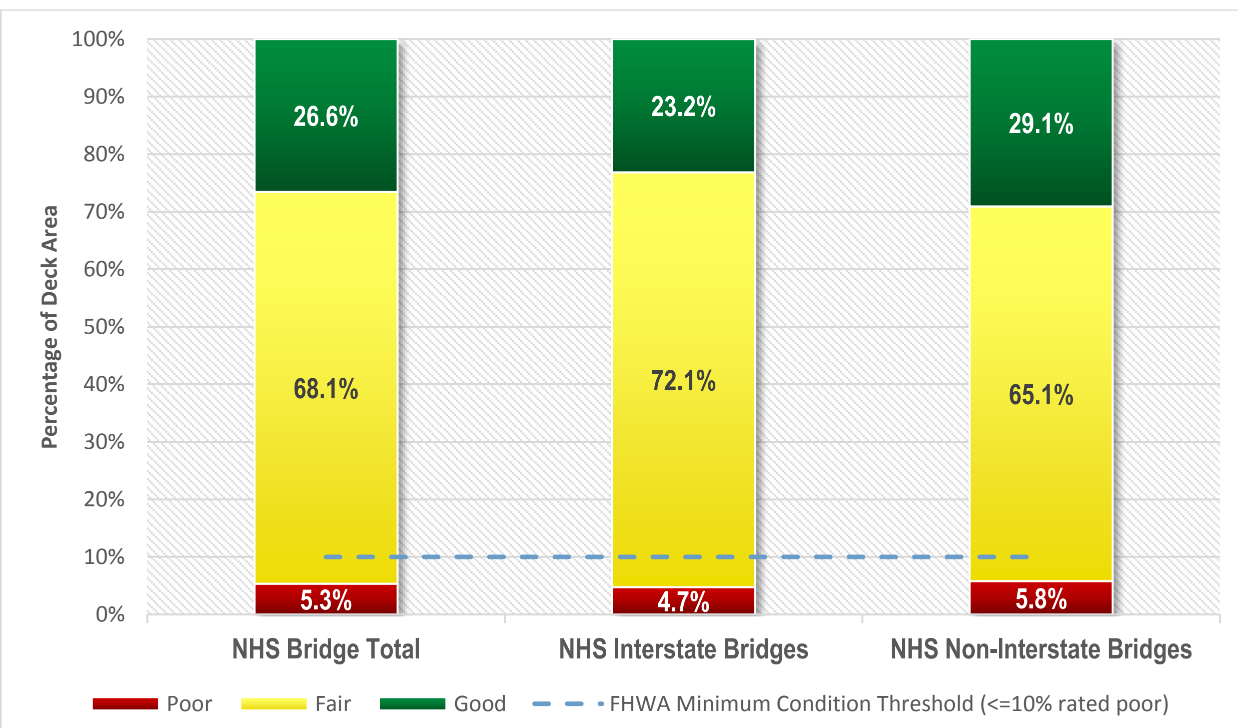
Determining pavement condition requires rigorous data collection. In the past, all PennDOT data was collected for each half-mile roadway segment. Federal rulemaking 23 U.S.C. 119 requires that all distress component information be collected for one-tenth-mile increments. PennDOT and its partners have adjusted their pavement data collection to meet FHWA requirements. Data collection at the tenth-mile increment level was adjusted in 2017 for cracking, rutting, and faulting.

Note that the FHWA pavement condition measures evaluate the wearing surface only, and do not reflect system age, the condition of the underlying roadway structure, or the existing backlog of reconstruction needs.

2018 NHS Bridge Condition Status

Figure 6 shows the condition of all NHS bridge deck area. The baseline conditions meet the FHWA minimum condition threshold of having no more than 10 percent of NHS bridges by deck area be in poor condition.

Figure 6: 2018 Condition Rating of NHS Bridges by Deck Area



Source: EOY 2018 BMS2 data

5. Performance Gap Analysis

PennDOT TAMP Performance Gap Analysis Process Description

PennDOT's process for conducting its asset management performance gap analysis is designed to identify any areas where asset condition is not meeting or is forecasted to not meet the FHWA minimum condition thresholds, and to develop strategies to address the deficiencies. PennDOT's Asset Management Division facilitates the annual TAMP performance gap analysis with the Asset Management Steering Committee, which comprises representatives of PennDOT Central Office and executive leadership, the Pennsylvania Turnpike Commission, and FHWA.

The major steps of PennDOT's performance gap analysis follow.

Step 1: Collect and Store Condition Data

PennDOT uses a long-term data collection process and database to collect and house current and historical condition information on pavements and bridges. Data from other owners is collected and submitted to PennDOT.

Pavements

As noted in Chapter 4, PennDOT and its partners have adjusted their data collection processes to collect pavement distress component data at tenth-mile increments, as currently required by 23 CFR 490.

Condition data on PennDOT-owned pavements is collected by a contracted vendor. PennDOT performs quality assurance surveys using its own staff and equipment. Each year, the vendor collects data on 100 percent of NHS pavements and 50 percent of the non-NHS PennDOT-owned system, thus completing data collection on all non-NHS assets every two years. This schedule translates to approximately 28,500 segment-miles surveyed per year. Survey data is collected using transverse and single-point laser profilers, as well as high-definition video images. The system generates semi-automated condition ratings for pavement distresses.

The pavement data is batch-uploaded into PennDOT's Roadway Management System (RMS) after sections are completed, data is post-processed, and Quality Assurance / Quality Control (QA/QC) checks are performed. PennDOT's Pavement Asset Management System (PAMS) pulls data from RMS annually, because a complete survey season is needed for pavement modeling and forecasting.

For more information on data collection from local owners, please see Chapter 10.

Bridges

Condition data on PennDOT-owned bridges is collected by certified bridge inspectors from both an in-house and consultant workforce. The inspections are typically performed biennially, depending on structure condition. Inspection frequencies may be extended for certain structures in good condition and are shortened for all structures in poor condition. Inspection data is captured using an in-house mobile platform called iForms and is uploaded to PennDOT's custom Bridge Management System version 2 database (BMS2). This database serves as PennDOT's system of record for all bridge inspection data and history, and is the core database for PennDOT's bridge asset management system, Bridge Care. BMS2 is also integrated with PennDOT's SAP-based maintenance system and can push recorded inspection issues to maintenance personnel.

BMS2 houses inspection data for:

- All PennDOT-owned bridges greater than 8 feet long;
- All structures greater than 20 feet long that are owned by other state entities (PTC, Department of Conservation and Natural Resources [DCNR], etc.);
- Locally owned structures greater than 8 feet long; and
- Other assets that require inspections regardless of owner, such as high mast lights, retaining walls, noise walls, and tunnels.

Step 2: Forecast Pavement and Bridge Condition

Pavement and bridge condition forecasts through the next 12 years are generated by PennDOT's Asset Management Division using its enterprise Pavement Asset Management System and Bridge Asset Management System. The projections are based on current condition data housed in PennDOT databases and the improved conditions expected as a result of future projects. Planned transportation system investments are derived from financial information provided in PennDOT's General Procedural Guidance document and lists of programmed projects from the Multi-modal Project Management System (MPMS).

While every effort is made to minimize errors in these projections, both systems (PAMS and BAMS) are relatively new to PennDOT; maximum accuracy will be achieved over time. Further, there are inherent minor variabilities in projections that cannot be accounted for, so there will always be some small level of error in future projections. In summary, although the sophisticated tools PennDOT uses are designed to minimize projection errors, portions of the software still need minor annual adjustments as PennDOT continually improves its condition forecasting.

Step 3: Analyze Current and Future Conditions

As noted in Chapter 3, PennDOT has included its targets as part of this 2019 TAMP submission (Table 2, Table 3, and Table 5). Pennsylvania's 2021 condition targets are:

- NHS Interstate pavements – 2 percent in poor condition
- NHS non-Interstate pavements – 5 percent in poor condition
- NHS bridges – 6 percent in poor condition

PennDOT's Asset Management Division facilitates the annual TAMP performance gap analysis with the Asset Management Steering Committee. The Asset Management Division calculates the percentage of good and poor assets from the respective pavement and bridge databases on an annual basis. It then compares current condition data with condition targets to identify current performance gaps, if any.

The Asset Management Division similarly compares forecasted pavement and bridge conditions over the next 12 years to the FHWA minimum condition thresholds. It identifies projected performance gaps and/or undesirable trends, if any.

Current and projected performance gaps, if any, are reported annually and reviewed with the Asset Management Steering Committee.

Step 4: Develop Strategies to Address Deficiencies

If any deficiencies or undesirable trends are identified that may threaten Pennsylvania's ability to achieve asset condition targets, PennDOT's Asset Management Division interacts with PennDOT's Center for Program Development and Management (CPDM) to identify necessary corrective actions to close any performance gaps.

Performance Gap Analysis Results

NHS Pavement and Bridge Performance through FY 2021-22

As shown in Table 2 and Table 5 of Chapter 3, and the condition forecast graphs that follow in this chapter, there is no current or near-term (within the first four-year performance period) performance gap between PA condition targets and actual pavement and bridge conditions.

NHS Pavement and Bridge Performance, FY 2022-23 and Beyond

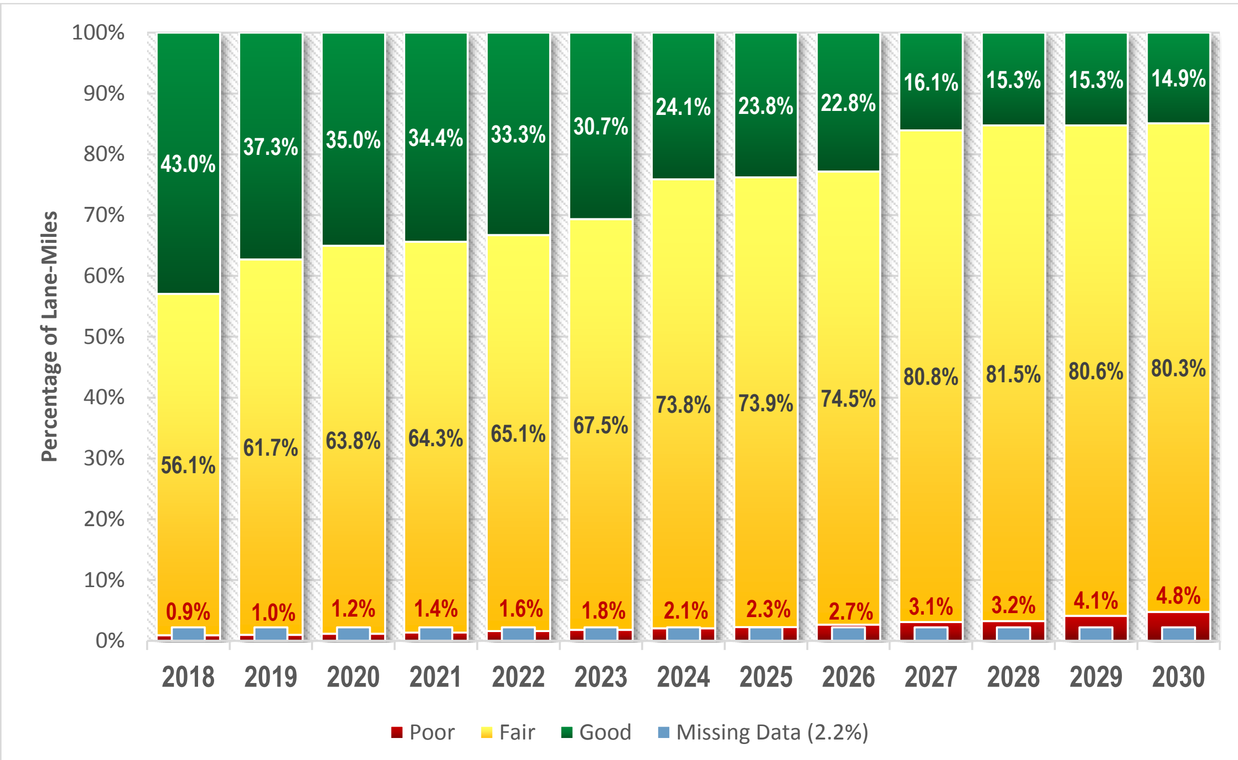
In the long term, PennDOT projections indicate that a performance gap can be expected. As shown on the following series of figures, both NHS pavements and bridges are expected to deteriorate, significantly increasing the amount of fair pavement (vs. good) and reaching the FHWA minimum condition threshold and PA target for bridges by 2023 when using LLCC project selection methodology. These projected results are likely due to a combination of three factors:

- Funding is inadequate to keep pace with rehabilitation and replacement projects that are needed to keep the system in optimal condition;
- The increased age of Pennsylvania's infrastructure minimizes the benefit of continual preservation treatments; and
- The results of underinvestment may be slightly exaggerated, as the models are not yet precise enough to yield highly reliable forecasts of conditions in the 5- to 12-year range.

While NHS Interstate pavement condition forecasts appear to indicate that the FHWA minimum condition thresholds will be met throughout the forecast period, the results are deceptive. The

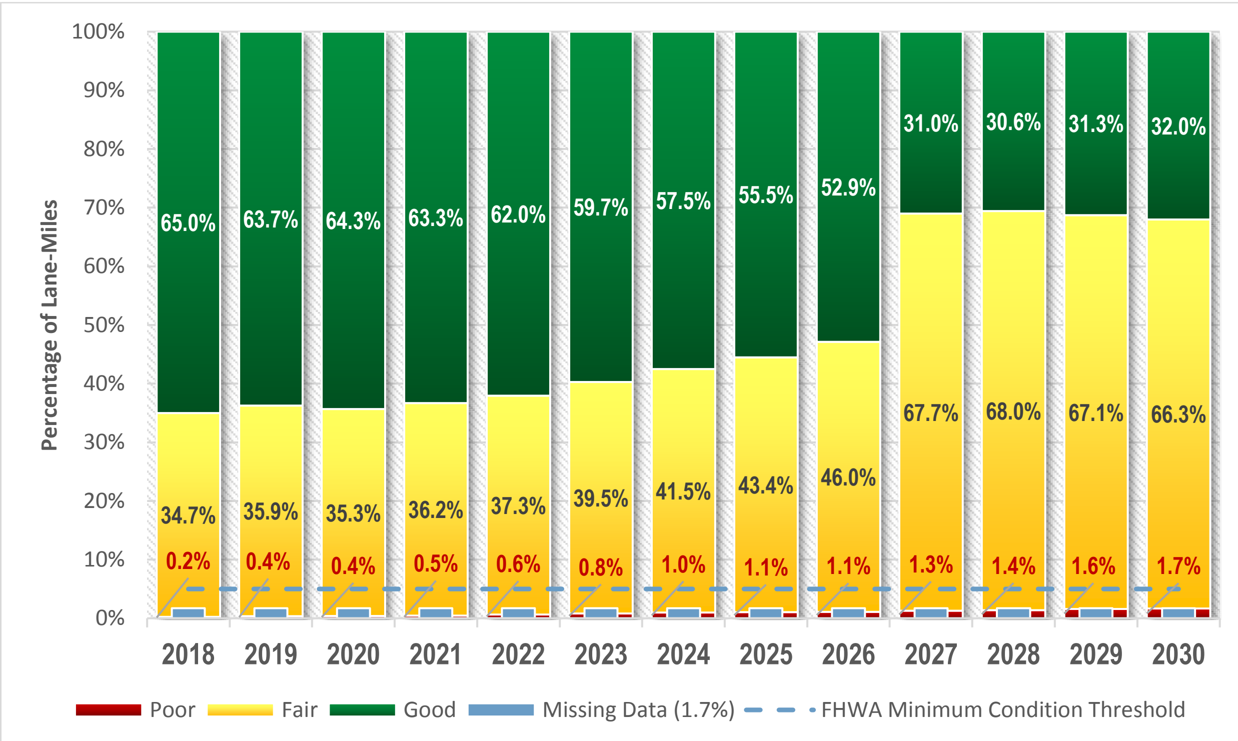
FHWA pavement condition measures are based on surface condition, and do not account for roadway age, the condition of the underlying pavement distresses, or the backlog of roadway reconstructions. Detailed analysis of pavement history would show many more pavements requiring costly reconstruction due to the shortening life of preservation or rehabilitation treatments. PennDOT's PAMS is being implemented to project more realistic future conditions based on LLCC.

Figure 7: Forecasted Total NHS Pavement Condition



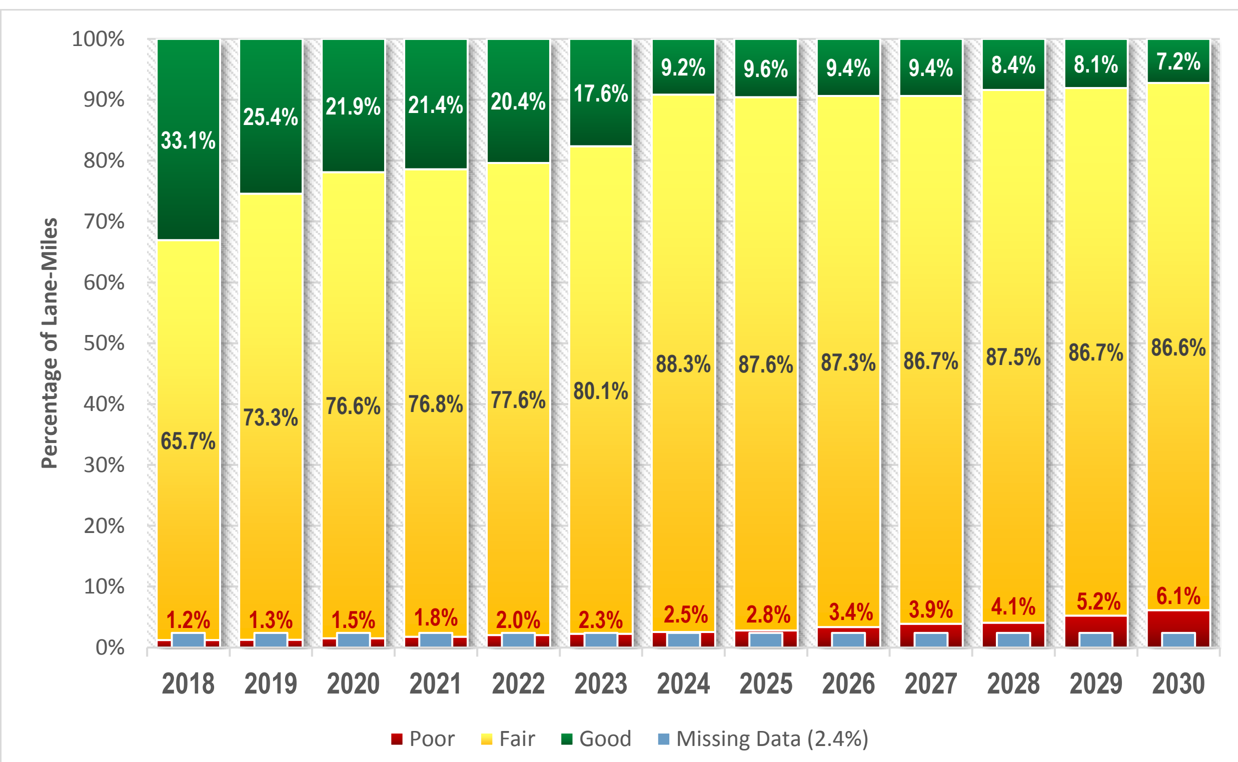
Source: PAMS, based on EOY 2018 RMS segment-level data

Figure 8: Forecasted NHS Interstate Pavement Condition



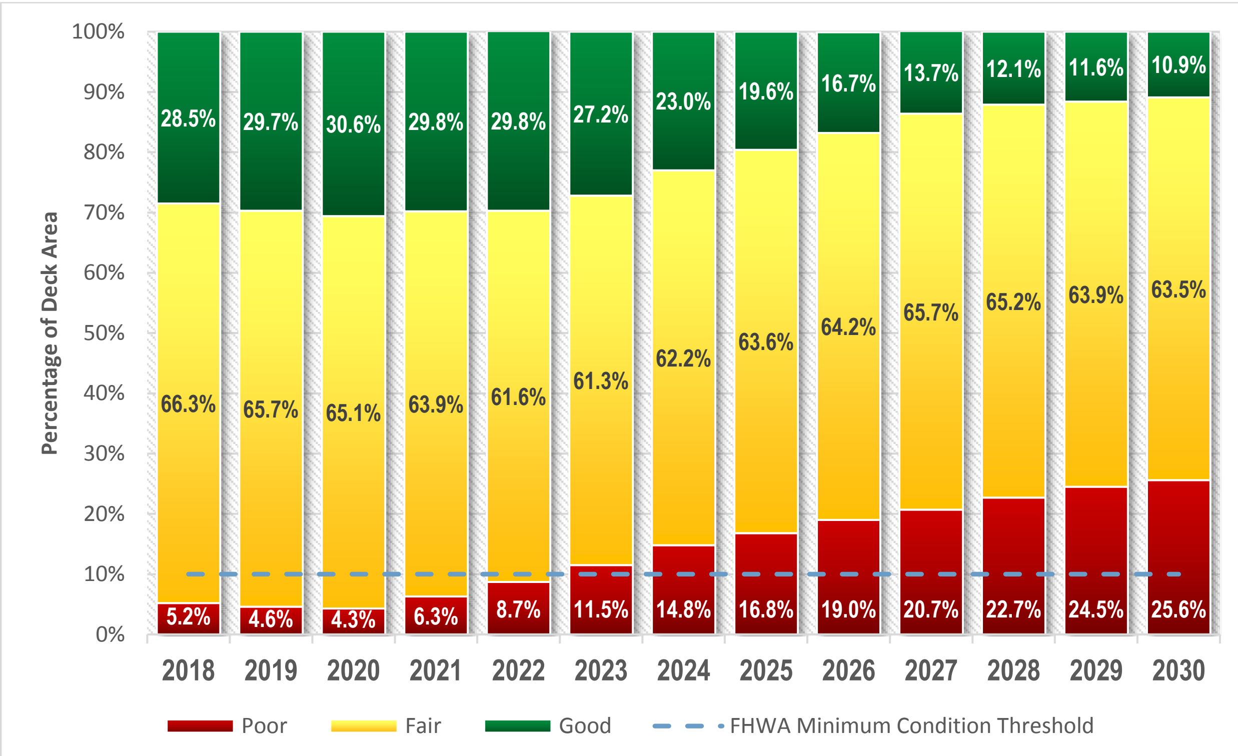
Source: PAMS, based on EOY 2018 RMS segement-level data

Figure 9: Forecasted NHS Non-Interstate Pavement Condition



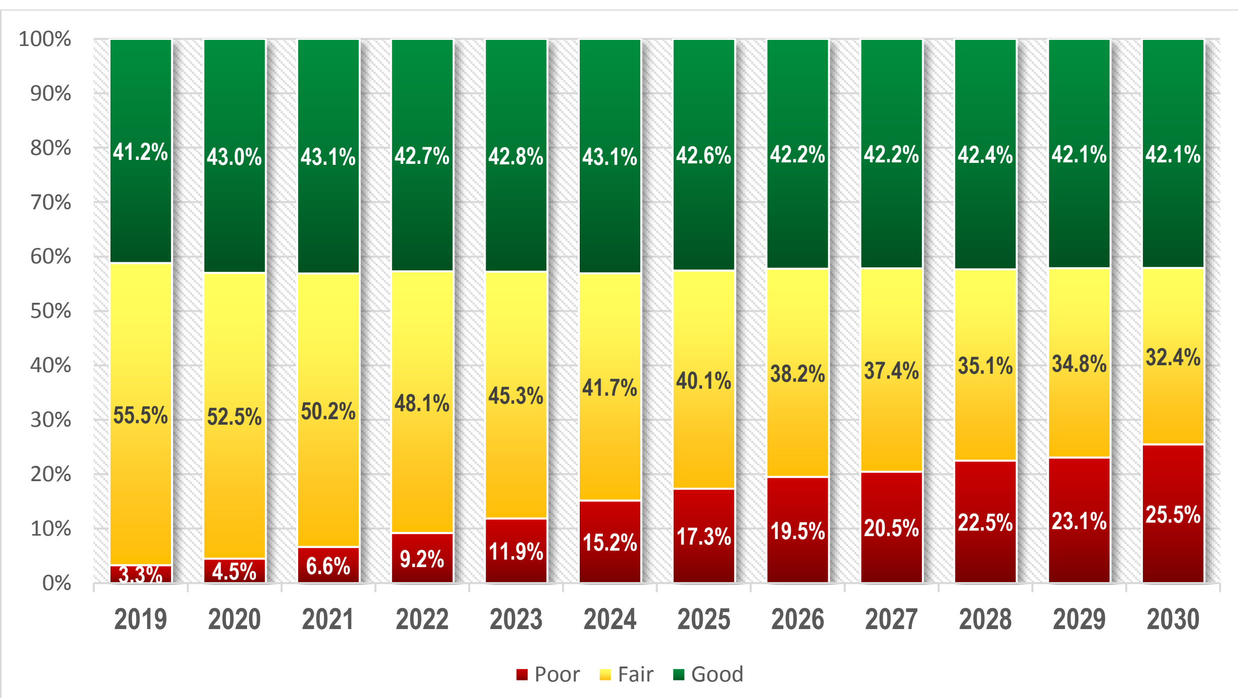
Source: PAMS, based on EOY 2018 RMS segment-level data

Figure 10: Forecasted Total NHS Bridge Condition by Deck Area



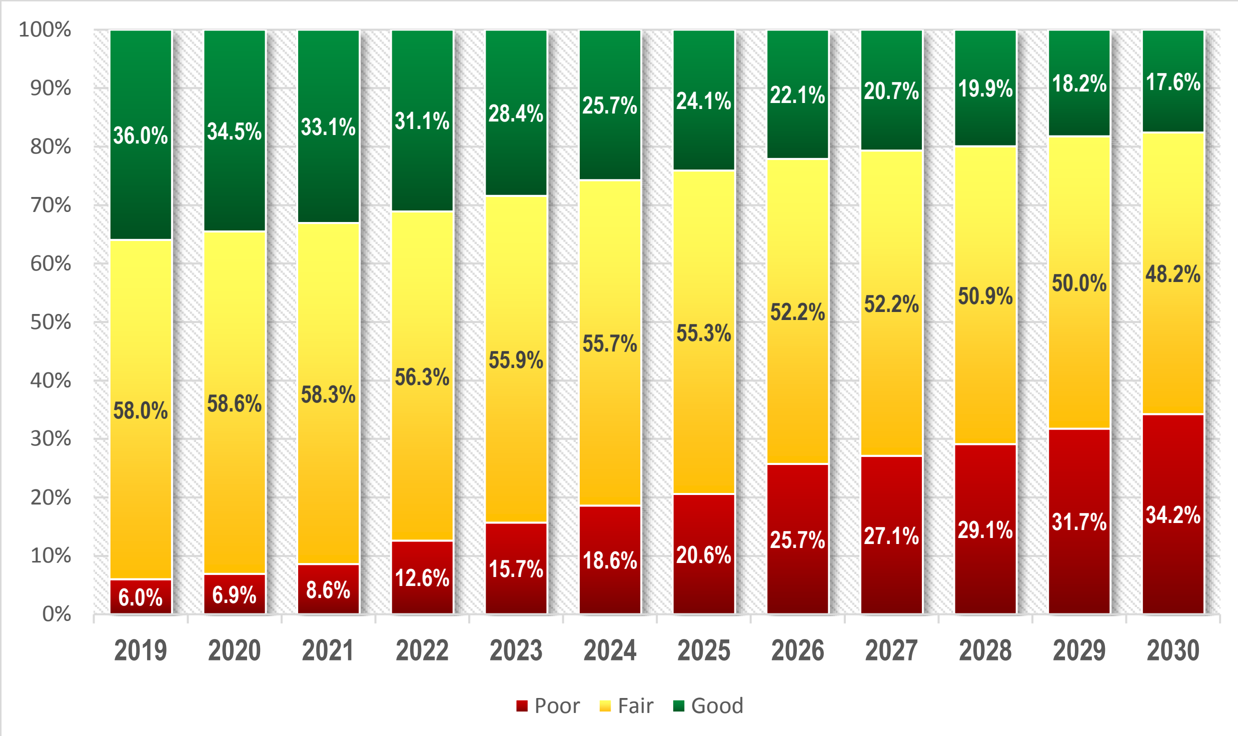
Source: BAMS data, based on EOY 2018 BMS2 data

Figure 11: Forecasted NHS Interstate Bridge Condition by Deck Area



Source: BAMS, based on EOY 2018 BMS2 data

Figure 12: Forecasted NHS Non-Interstate Bridge Condition by Deck Area



Source: BAMS, based on EOY 2018 BMS2 data

Forecasted Non-NHS Pavement and Bridge Performance

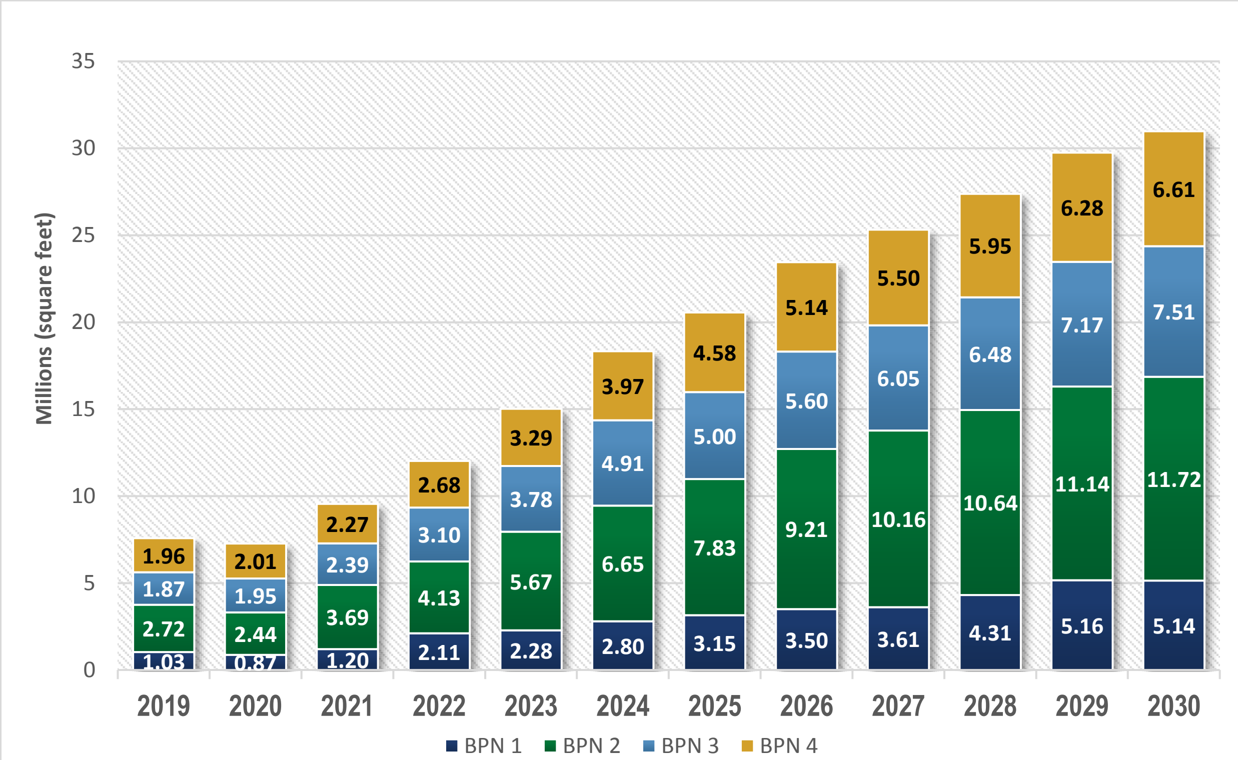
As a result of PennDOT's practice of maintaining the NHS at the expense of the non-NHS system, the proportion of non-NHS system pavement in poor condition would steadily increase.

Prioritizing NHS bridges at the expense of non-NHS bridges, demonstrated in Figure 13, results in non-NHS bridges rated poor (by bridge deck area) nearly tripling by 2030, while the NHS non-Interstate poor deck area would still quadruple. In this scenario, the percentage of each network's poor deck area would be as follows:

- BPN 1 – 9 percent
- BPN 2 – 14 percent
- BPN 3 – 22 percent
- BPN 4 – 24 percent

A continuing funding shortfall will result in rougher secondary roads, increased on-demand (unplanned) maintenance costs, and a greater number of weight-restricted bridges and roads, hampering mobility and potentially impacting local commerce.

Figure 13: Forecasted Poor Bridges by Deck Area by Business Plan Network



Source: BAMS, based on EOY 2018 BMS2 data

Strategies to Address Forecasted Deficiencies

Identifying forecasted performance gaps enables PennDOT to develop corrective actions to improve pavement and bridge conditions and prevent any actual performance gaps.

As discussed previously, LLCC-only based methodology shows a performance gap by 2023. If funding remains inadequate, meeting the FHWA minimum condition thresholds and preventing a performance gap from materializing would require non-LLCC, worst-first project selection—contrary to PennDOT's commitment to develop future State Transportation Improvement Plans (STIPs) based on LLCC methodology.

PennDOT has adopted the following strategies to address the forecasted performance gap while continuing to transition to LLCC:

1. Manual assessment and tracking of projections versus condition thresholds to verify actual gap. This strategy will allow PennDOT's Asset Management Division to actively engage with CPDM and District Planning and Programming staff to identify the correct mix of work types and the projects within those work types to achieve the FHWA minimum condition thresholds.
2. Evaluate funding allocation of pavements versus bridges to address system-level deficiencies. However, while the performance measures forecast more deficiencies for

bridges than pavements, that should not in itself lead to the conclusion that funding can be shifted from pavements to bridges. The pavement measures are based on surface condition and do not reflect system age, condition of the underlying pavement structure, or the existing backlog of reconstruction needs.

3. Reallocation of a portion of funding from non-NHS pavements and bridges to NHS pavements and bridges, subject to the limits described in the following paragraph.
4. Identify and evaluate potential new revenue sources.

Effectiveness of the NHS

The current practice of prioritizing NHS assets over other networks has had a positive impact on the effectiveness of the NHS system, as both bridge and pavement conditions are below (better than) FHWA minimum condition thresholds. However, the financial burden of maintaining the NHS at the mandated condition levels for pavements and bridges will create a shortfall for the rest of the surface transportation system, as PennDOT does not receive sufficient funding to maintain NHS and non-NHS pavements and bridges to a state of good repair. When conditions degrade on the non-NHS system such that funding can no longer be diverted from it to the NHS, or there is no longer support to supplement NHS funding, the effectiveness of the NHS will be compromised.

6. Life-Cycle Planning

PennDOT TAMP Life-Cycle Planning Process Description

PennDOT's life-cycle planning process is led by the Asset Management Steering Committee and is integrated into Pennsylvania's statewide and regional planning and programming processes. These processes are supported by software systems that project condition and performance of the assets.

Strategy for Managing Assets to LLCC

PennDOT's policies, management strategies, and planning and programming process (discussed in the following section) are focused on managing assets to the **lowest practical life-cycle cost** as described in Chapter 2, Objective B.

PennDOT's management strategy is to prioritize preservation activities to extend asset life. This strategy reflects PennDOT's asset management slogan and guiding principle: "The right treatment at the right time." It is PennDOT's overall implementation and investment strategy and philosophy for achieving its asset condition targets, sustaining the performance of the NHS, and supporting progress toward the national goals identified in 23 U.S.C. 150(b) (23 CFR 515.13(b)(2)).

In addition, PennDOT limits capacity-adding projects in order to devote maximum funding to preserving existing infrastructure. PennDOT limits its investment in capacity-adding projects to 5 percent of its budget maximum and aims to hold the amount at 3 percent.

PennDOT's asset management systems use data processing and analysis tools to create data-driven project selections based on preservation, rehabilitation, and replacement work types that ultimately support lower life-cycle cost investments. These systems are based on deterioration models—work and cost matrices by asset family that allow the appropriate repair or replacement to be recommended based on family, age, condition, and expected duration and cost of repair.

These tools inform the project programming process, which is data-driven yet based on strategic decision-making by professionals familiar with real-world conditions on the local system as well as state and regional priorities. The combination of forecasts and in-depth data with professional judgment representing various viewpoints allows the optimal choices to be made in order to maintain the system to LLCC.

Pennsylvania Project Planning and Programming Process

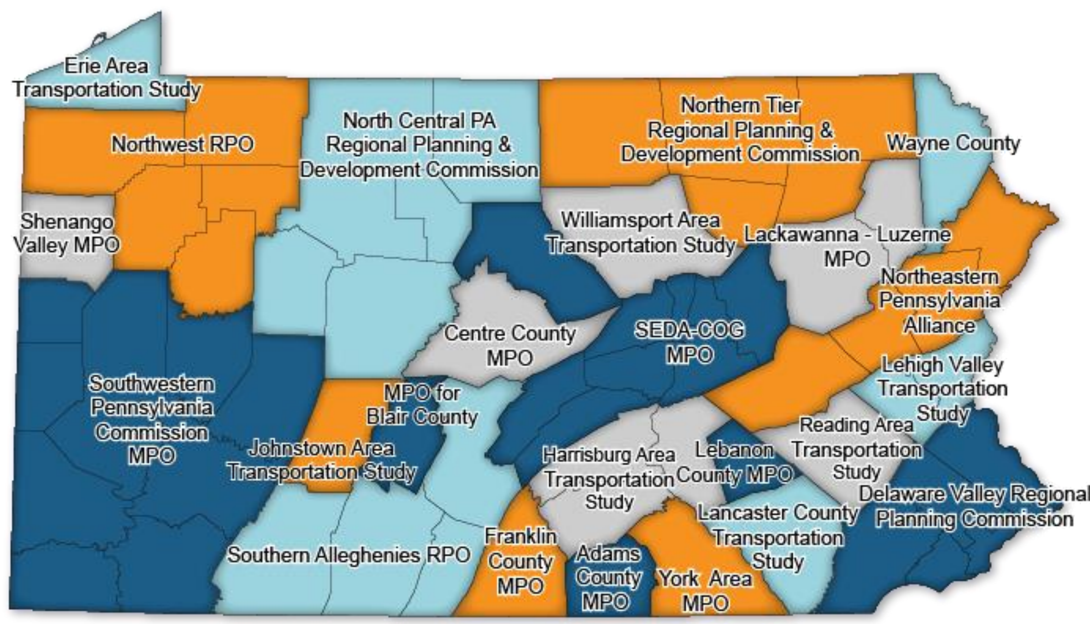
Pennsylvania's process for identifying, prioritizing, and selecting transportation projects has been developed to adhere to state and federal law, align with cohesive state goals, constrain planned spending to expected budgets, encourage public participation, and support regional planning entities with state-level expertise and resources, including asset management tools.

In addition, the PennDOT Connects policy formally fosters collaboration among state, regional, and local entities well in advance of planned projects, maximizing efficiencies and helping to ensure that the resulting projects best meet communities' needs and priorities.

A statewide vision and supporting goals and objectives are established through Pennsylvania's statewide Long-Range Transportation Plan (LRTP), which has a 20-year planning horizon and aligns with federal transportation goals. PennDOT's Center for Program Development and Management (CPDM) leads development of the LRTP. The statewide LRTP sets policy and direction for the state but does not list specific projects. PennDOT also leads development of a Comprehensive Freight Movement Plan and a Strategic Highway Safety Plan, which articulate a statewide vision, goals, and objectives pertinent to those focus areas.

Project-level planning and programming is a coordinated effort led by the state's MPOs/RPOs. Figure 14 maps Pennsylvania's 19 MPOs, four RPOs, and one independent county.

Figure 14: Pennsylvania's Regional Planning Organizations



Each MPO/RPO leads the development of a regional LRTP. Plans are consistent with the goals of the statewide LRTP, are based on extensive public and stakeholder involvement, and include a list of fiscally constrained projects supportive of regional goals and objectives. PennDOT has developed and is currently updating a Developing Regional Long Range Plans guidebook (PUB 575) to assist MPOs/RPOs in effective, inclusive, compliant, performance-based planning.

The programming process refines, selects, and prioritizes projects, and is also characterized by extensive public and stakeholder outreach. It considers a 12-year planning horizon, therefore the result is known as the Twelve-Year Program (TYP). The TYP is required by state law (PA Act

120 of 1970) and comprises the mid-range of investments for the regional LRTPs. Regional portions of the TYP are developed locally by PennDOT Districts and the MPOs/RPOs and are approved by the State Transportation Commission (STC). The TYP must be fiscally constrained, meaning the expected total cost of projects must not exceed total anticipated funding—so prioritization is essential.

PennDOT and the MPOs/RPOs evaluate candidate projects based on statewide and regional LRTP goals and recommendations; statewide policy, plans, and goals; PennDOT Connects outreach; and asset management targets, data, and guidance provided by PennDOT Central Office and its Engineering Districts. The first four years of the TYP are the Transportation Improvement Program (TIP)—a federally required, fiscally constrained list of projects that are expected to be undertaken within the next four federal fiscal years (FFY).

PennDOT's Interstate network is managed by the Interstate Steering Committee. An Interstate Management TIP is developed, LLCC projects are selected, and priorities are set in generally the same manner, but independent of, the regional TIPs.

The regional and Interstate Management TYPs are compiled into a statewide TYP. After the statewide TYP is adopted by the STC, the federally required Statewide Transportation Improvement Program (STIP—the first four years of the TYP) is submitted to FHWA and the Federal Transit Administration (FTA) for approval in accordance with federal law (49 U.S.C.5304 (g)). This multi-agency approval process ensures that state and federal government investments in Pennsylvania's transportation system are data-driven and aligned with federal, state, and regional/local goals. Discussion of the TYP and STIP in this document is limited to NHS bridges and pavements, however the full TYP and STIP are multimodal and include networks beyond the NHS.

Pennsylvania updates the TYP, which includes the STIP/TIPs, every two years. As part of each update, workgroups representing PennDOT CPDM, BOMO, PennDOT Districts, MPOs/RPOs, and FHWA cooperatively develop two guidance documents that are used for program development. The Financial Guidance document lays out the anticipated federal and state funding and formulas for distribution to the statewide programs and regional Planning Partners. The General and Procedural Guidance document informs how the funding should be invested and what requirements must be met. The current guidance documents can be found at: https://www.talkpatransportation.com/transportation-planning/STIP.

MAP-21/FAST Act performance-based planning and programming requirements, Transportation Performance Management, and the TAMP requirements are incorporated into PennDOT's General and Procedural Guidance. Information from the Asset Management Steering Committee, the Asset Management Division, BAMS, and PAMS are included in the guidance documents prepared in 2019 for the FFY 2021 TYP update to provide enhanced support for project programming to achieve LLCC. CPDM will work with the Asset Management Division to provide each MPO/RPO with a list of recommended projects by work type based on LLCC projections derived from PennDOT's pavement and bridge asset management systems, based on funding allocations from the Financial Guidance document. The document has been updated to include an Asset Management Factor (AMF), which allows for adjusted funding in areas that demonstrate greater need. The AMF formula is provided in Appendix I.

The Pennsylvania Turnpike Commission independently manages the Pennsylvania Turnpike system, with separate funding sources.

As PennDOT transitions to LLCC, projects currently included in regional LRTPs, the TYP, and the STIP/TIPs will be evaluated and possibly reprioritized as part of the two-year update cycle. Programs will be refined to reflect current asset condition data and funding levels as well as shifting needs, including changes in demand and needs related to extreme weather events, to move toward managing the overall network at LLCC while achieving performance targets.

Pennsylvania's transportation planning and programming process is illustrated in a step-by-step guide on the STC website at http://www.talkpatransportation.com/2019TYP/infographic/. More information on Pennsylvania's MPOs/RPOs and the planning and programming process is available at http://www.talkpatransportation.com/planningpartner.html.

Life-Cycle Planning Analysis

Identification of Deterioration Models for Each Asset Class

PennDOT's PAMS and BAMS forecast condition and investment needs by asset class and work type using deterioration models and cost matrices developed for PennDOT infrastructure based on historical data. PennDOT has developed both predictive and deterministic models that support multi-objective decision-making based on current average work costs and estimated treatment lifespans, allowing PennDOT to predict infrastructure investment needs and condition into the future under a range of scenarios.

Potential Work Types and Unit Costs by Asset Class

PennDOT's life cycle planning process is guided by asset management systems that utilize deterioration models and cost matrices across multiple asset classes, families, and work types to generate system-wide forecasts.

PennDOT's PAMS system uses enterprise Deighton dTIMS™ software for projections, and requires that the families, deterioration models, and cost tables be in a specific format.

PennDOT's BAMS in-house (Bridge Care) software also uses structural families and cost matrices with deterioration models. This software uses deterministic models rather than probabilistic models, allowing for the known longer duration of Pennsylvania's bridges in certain condition states and more accurately predicting future conditions.

7. Risk Management Analysis

PennDOT Process for Conducting TAMP Risk Analysis

The PennDOT Asset Management Steering Committee is charged with assessing and addressing overall enterprise risk for PennDOT. The committee evaluates enterprise risks and mitigation strategies for each TAMP submission.

PennDOT's methodology for identifying and prioritizing risks is based on the FHWA risk framework of risk being a function of likelihood and consequence. TAMP risks are identified by the Asset Management Steering Committee and categorized by magnitude—from enterprise to task—and prioritized. At all risk levels, additional dimensions of risk are incorporated into the decision-making process, as risks are not linear or planar, but have multiple attributes or dimensions.

PennDOT looks at risk as having multiple dimensions, as there can be more than one factor or attribute to a given risk, and the risk could be different depending on the context of the evaluation. The two key dimensions that PennDOT has identified in risk are what we are aware of that could go wrong, and what we are unaware of that could still go wrong. For both dimensions, PennDOT considers risk in terms of likelihood and consequence in context of time or duration. PennDOT has distilled the "unknowns" down to two key elements: detectability and timeframe. Both elements were used to create a risk registry; enterprise-level risks are outlined under the Risk Analysis section, which follows.

The standard PennDOT risk prioritization table is presented in Figure 15, and depicts the two risk aspects of severity and likelihood.

Figure 15: PennDOT Risk Prioritization Table

Likelihood	Potential Consequence			
	Low	Moderate	High	Severe
Almost Certain	Medium Risk	High Risk	Very High Risk	Severe Risk
Probable	Medium Risk	Medium Risk	High Risk	Very High Risk
Possible	Low Risk	Medium Risk	Medium Risk	High Risk
Rare	Low Risk	Low Risk	Medium Risk	Medium Risk

Risk Analysis

The Asset Management Steering Committee held its annual TAMP meeting on April 1, 2019. One of the tasks of the meeting was to update the existing enterprise risk register for the TAMP, which is provided in Appendix H. That meeting and subsequent follow-up meetings produced an updated summary of the highest-ranking risks, which follows.

Severe Risks

- Funding Shortfall – Inadequate funding continues to be PennDOT's most severe risk. Current forecasting models show a steadily growing gap between projected revenue and transportation system needs to meet mandatory asset condition targets and maintain the current level of service for capacity. The core risk is that transportation funding will be inadequate to sustain the current level of service due to the combination of declining revenue, increasing materials costs, and increasing construction needs due to infrastructure age. (See Appendix F for age of infrastructure.)
  Mitigation strategies and owner:
  - Innovative financing (Executive Staff)
  - Innovative contracting (P3 Office)
  - Increase funding (Executive Staff)
  - Improve project selection (Asset Management Division)

- Extreme Weather – This was added to the risk register in 2019 because PennDOT experienced unprecedented damage to its infrastructure in 2018 from extreme weather events—primarily flooding and landslides. If this trend continues, it will erode PennDOT's ability to perform regular maintenance activities and impact the Department's ability to let new projects.
  Mitigation strategies and owner:
  - Update PennDOT design manuals to improve resiliency of infrastructure design (Bureau of Project Delivery – BOPD)

- Project Cost Uncertainty – Asset management software uses cost tables based on actual historical costs to optimize project selection with the goal of LLCC, and to forecast asset condition in light of anticipated budgets. However, costs are not static. Inflation and market fluctuations can significantly increase the cost of labor and materials within a short period of time. Further, unforeseen issues during construction can lead to cost over-runs. These items reduce the number of projects that can be undertaken and could threaten PennDOT's ability to meet asset condition targets.
  Mitigation strategies and owner:
  - Improve PennDOT cost-estimating (BOPD)
  - Improve project constructability and maintainability (BOPD)
  - Develop more consistent project scopes (BOPD)
  - Minimize design errors and omissions (BOPD)

- Data Issues and Limited Management Systems – PennDOT has one of the largest and oldest inventories of assets in the U.S. The combination of a wide variety of construction types and asset age makes infrastructure inspection and condition forecasting challenging. Some of the IT systems in place that store the infrastructure data that are relied upon for data-based decisions have been in place for several decades and are out of date or have no capacity to store additional data. In addition, the accuracy and completeness of data collected can be compromised without high attention to quality assurance. Further, if the data sets are not correctly interpreted, the resulting analysis can be misleading.

Mitigation strategies and owner:

- Ensure data integrity in all systems (Highway Administration and CPDM)
- Define and enforce data standards (Asset Management Steering Committee)
- Increase quality assurance awareness and training (Highway Administration and CPDM)
- Increase field verification and integration (Highway Administration and CPDM)
- Strengthen quality assurance (Highway Administration and CPDM)

Very High Risks

- Loss of Institutional Knowledge – PennDOT's workforce is turning over and there are not adequate systems or programs in place to capture the knowledge accumulated by experienced employees. This can be expected to lead to gaps in knowledge and skill sets, which will adversely affect the organization.

  Mitigation strategies and owner:
  - Mentoring, job shadowing, and succession planning (Department-wide)
  - Create and provide needed training (Department-wide)
  - Create and document a knowledge transfer process (Department-wide)
  - Enhance business processes for capturing and storing needed knowledge in existing databases (Department-wide)

High Risks

- Increases in Freight Volume (2018) – If industry trends continue, trucking will continue to grow. Increased heavy truck traffic reduces the service life of roads and bridges, which could deteriorate faster than projected, requiring increased investment to meet asset condition targets.

  Mitigation strategies and owner:
  - Implement advanced technologies in construction materials and data forecasting (Department-wide)
  - Enhance validation of data collection and prediction of conditions and trends (Department-wide)
  - Modify the TYP based on changing needs and priorities (Department-wide)

- Construction Quality – Poor-quality construction and materials leads to shorter asset life and higher life-cycle costs. While most PennDOT contractors perform high-quality work, and although PennDOT rigorously monitors construction materials and methods, there is a risk of PennDOT not detecting poor workmanship or inferior/unproven materials, potentially compromising the quality and ultimately the service life of newly constructed assets.
  Mitigation strategies and owner:
    - Increase inspection frequency (PennDOT Districts)
    - Test and accept new materials (Materials Lab)
    - Monitor substandard asset performance to determine trends and patterns (Asset Management Division)

- Political Influence on Project Selection – Although project selection is primarily data-driven, professional engineering judgment is an important part of the programming process. With the human element of planning and prioritizing comes the potential for bias and political influence to insert projects into PennDOT's program that do not align with LLCC methodology, and/or that add capacity without consideration of subsequent maintenance obligations.
  Mitigation strategies and owner:
    - Develop metrics to indicate the life-cycle cost impact of sub-optimal project selection (Asset Management Division)
    - Develop metrics to indicate short- and long-term impacts on asset condition targets as a result of sub-optimal project selection (Asset Management Division)
    - Develop metrics to indicate short- and long-term impacts on funding requirements as a result of sub-optimal project selection (Asset Management Division)

Monitoring and Mitigation Plan

PennDOT's Asset Management Steering Committee reassesses the Department's enterprise-level risks and mitigation strategies annually, including receiving updates from owners of previously established risks. The information is discussed, analyzed, and scored, and a reprioritized list is produced for the TAMP annually.

Emergency Events – Part 667

The Federal Transportation Asset Management Plan Rulemaking part 667 requires the periodic evaluation of facilities repeatedly requiring repair and reconstruction due to emergency events.

PennDOT has summarized and analyzed the emergency events that occurred from January 1, 1997, through December 31, 2018, and found that while Pennsylvania has had significant damage throughout the state from past named and un-named storms, no individual piece of infrastructure has been substantially repaired or replaced on two or more occasions due to these events. For a complete list of emergency weather events and the locations they have affected, please see Appendix Table E.1. Note that the table lists roadway segments within declared disaster areas by PennDOT District; it is not a list of infrastructure repairs.

In addition to the FHWA requirements of Part 667, PennDOT has independently undertaken extreme weather impact evaluations for future design considerations. The "Phase 1 PennDOT Extreme Weather Vulnerability Study" was completed in Spring 2017. The study describes consequences and potential impacts of extreme weather and identifies funding priorities and strategies to improve transportation system resiliency. Types of climate and weather changes affecting Pennsylvania include temperature extremes, precipitation (primarily flooding), sea-level rise, and hurricanes.

The Extreme Weather Vulnerability Study evaluates historical and future vulnerabilities, develops a framework for addressing climate change impacts, and presents an initial assessment of risks and priorities related to the identified vulnerabilities. Data used for this evaluation includes state DOT adaptation studies, FHWA/National Cooperative Highway Research Program (NCHRP) research documents, and National Oceanic and Atmospheric Administration (NOAA) and other national research and tools.

The output of the Extreme Weather Vulnerability Study is a GIS product that highlights potential future flood risks. Both are available online at http://s3.amazonaws.com/tmp-map/climate/index.html. This information can be used at the preliminary design stages to determine whether increased drainage capacity is needed or warranted.

One outcome of the 2017 Extreme Weather Vulnerability Study was PennDOT's launch of the Resiliency of Design Task Force. The task force is working to reduce the risk to transportation infrastructure due to extreme weather events by enhancing engineering, design, construction, and maintenance practices.

Pennsylvania's primary natural hazard is flooding. PennDOT anticipates updating its hydrologic & hydraulic (H&H) design standards in late 2019 based on analysis being conducted by the task force in conjunction with the PA Department of Environmental Protection and the U.S. Geological Survey (USGS). The project is updating the USGS regression equations and the stream stats database to reflect changes in drainage area characteristics (due to development) and rainfall distribution (due to climate change).

The task force is also recommending design and construction measures such as:

- reinforcing embankments by using geotextiles to wrap fill layers during construction,
- increasing culvert and pipe design sizes (with consideration of downstream impacts),
- requiring U wings instead of flared wings over streams, and
- updating bridge scour countermeasures.

In addition, PennDOT is conducting a pilot study on three bridge sites to:

- assist in evaluating its H&H methods and procedures,

- develop a detailed guide for conducting H&H studies that include climate change impacts, and
- assist in evaluating the planning-level climate flooding forecasts in the 2017 Extreme Weather Vulnerability Study.

Results of the three pilot projects will be submitted to FHWA in August 2019. Ongoing efforts of the Resiliency of Design Task Force include conducting detailed studies to identify locations with a history of flooding, assess historical vulnerabilities, and evaluate adaptation strategies for those locations. Additionally, the task force will focus on forecasting the impacts of climate change and supporting MPOs in conducting resiliency planning to inform project programming for bridge replacements and roadway improvements.

8. Financial Planning

PennDOT TAMP Financial Planning Process Description

The purpose of TAMP financial planning is to estimate the cost of achieving asset condition targets over at least the next decade and compare the needed investment to expected funding levels.

PennDOT's CPDM is responsible for financial planning and works closely with the Asset Management Division, PennDOT Districts, and regional MPOs/RPOs to develop detailed forecasts of needed projects, estimate the future cost of work, and compare need with expected funding levels. Pennsylvania's Secretary of Transportation leads efforts to maximize efficiency and secure adequate funding for PennDOT to properly meet its responsibilities.

2019 TAMP Financial Planning

The cost of future programmed work to implement the investment strategies outlined in this asset management plan, and expected levels of funding, are discussed in this chapter to illustrate PennDOT's financial planning over a 12-year period. Note that PennDOT assumes annual inflation at 3.00 percent in its projections and expense models.

The following commentary encompasses all NHS assets regardless of owner, but it is essential to remember that NHS assets are only a small portion of PennDOT's transportation asset responsibility. While needs and funding appear to align in the following sections for the first four-year performance period, it is only because Interstate pavements and NHS bridges receive priority funding in order to meet federally mandated condition thresholds, as stated earlier in this document. As funding levels stagnate or decline and NHS needs and costs increase, both the NHS and non-NHS systems will not be able to be maintained to the current level of service, with or without management to LLCC.

As noted previously, future TAMP editions are expected to include figures for all transportation assets, not only NHS infrastructure, providing a more complete picture of needed investment.

Estimated Cost of Future Work

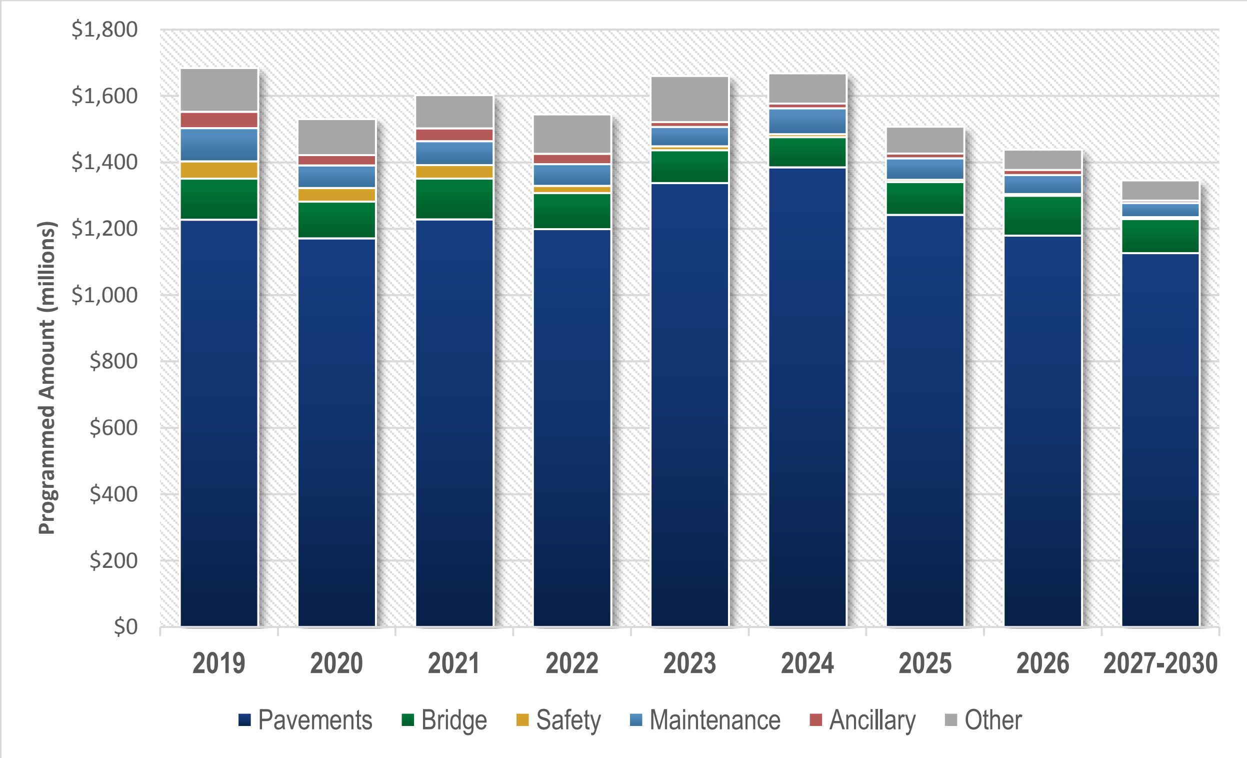
To implement the investment strategies contained in this asset management plan and achieve established asset condition targets for the first four-year performance period, PennDOT must invest—at minimum—the amounts shown on Figure 16, which have been estimated based on anticipated funding levels.

PennDOT's investment activities comprise approximately 39 programs, including Bridge Restoration, Highway Reconstruction, General Maintenance, etc. These work activities and associated funding levels (detailed in Appendix Table D.2) are classified into six major work type categories, as summarized in Table 10. Figure 16 illustrates the allocation of funds by work type over the planning period. It should be noted that financial work category labels do not necessarily reflect the exact type of work that is performed, as they are legacy labels from finance. For example, preservation activities for bridges could come from bridge, maintenance, highway, or other work categories.

Table 10: Categories for Phased Program Work Type Classes

Work Category	Description
Ancillary	Work that supports non-bridge/pavement NHS assets such as guiderail, sign structures, and railroad crossings
Bridge	Rehabilitation and replacement of NHS bridge assets
Maintenance	Maintenance efforts that support NHS bridge and pavement assets, such as bridge washing, crack sealing, mowing, and winter maintenance
Other	Work related to but not directly associated with NHS bridge and pavement assets, such as bicycle paths and disaster relief
Pavements	Rehabilitation and replacement of NHS pavement assets
Safety	Work that pertains to the safety of the traveling public on NHS bridge and pavement assets

Figure 16: Estimated Expenditure on the NHS by Federal Fiscal Year and Category



Source: MPMS, June 2019

Note: The last column graphs the average annual value for the years indicated.

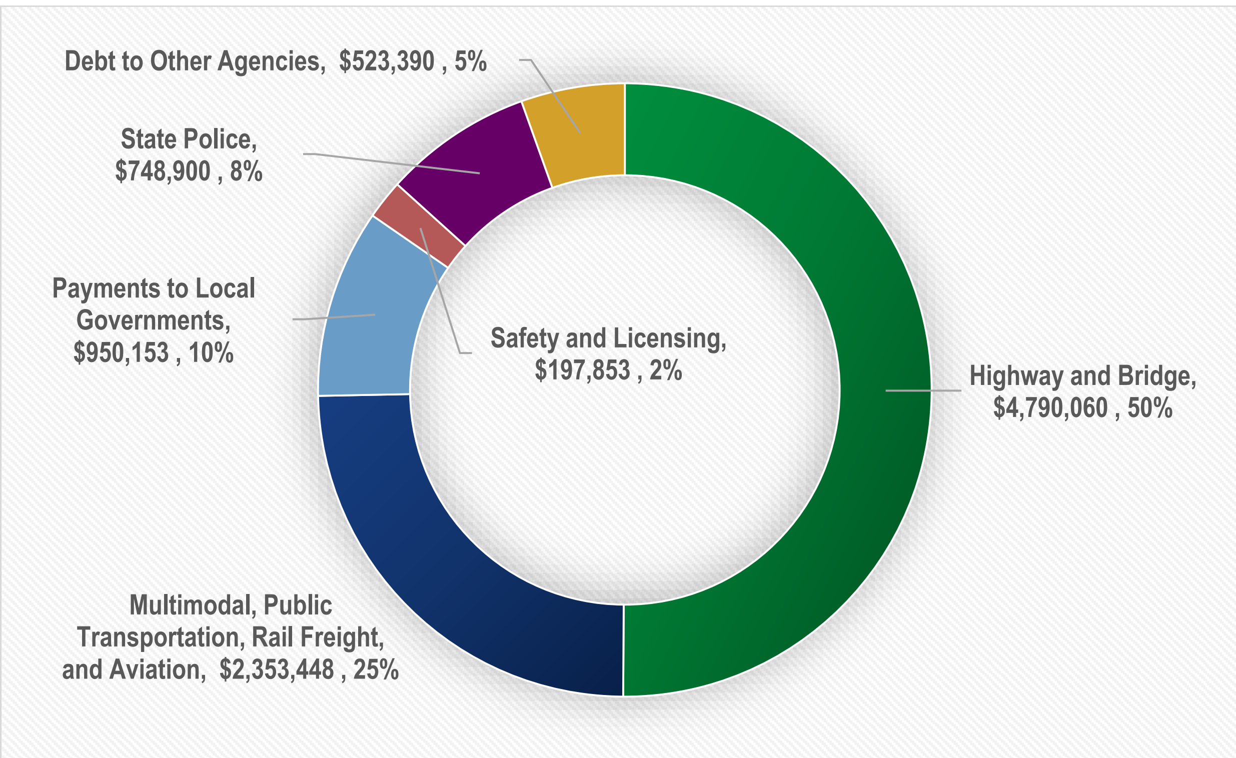
As shown in Figure 16, approximately $1.5 billion is expected to be utilized each year on NHS assets over the next 12 years. Act 89 of 2013 provided a much-needed additional investment in Pennsylvania's multimodal transportation system, with an additional $2.3 billion by the fifth year ($1.3 billion for state-owned roads and bridges), allowing many long-deferred projects to be advanced. However, it is not a long-term funding solution, as shown by the relatively flat projected funding. When accounting for inflation, this overall reduction in buying power tracks with the decline of NHS pavement and bridge assets from their current compliant condition to deteriorating to no longer meet FHWA minimum condition thresholds.

Funding allocated to specific work activities is dictated by funding availability—there are 39 funds that support PennDOT's investment on NHS assets, and monies from each fund may only be used on certain types of projects.

Expected Funding Levels and Sources

PennDOT's overall budget for SFY 2019-20 is approximately $9.56 billion, allocated as shown in Figure 17.

Figure 17: PennDOT FY 2019-20 Budgeted Expenditures (in thousands)



Source: Bureau of Fiscal Management, June 2019

There are currently 39 funds that support PennDOT's spending activities for NHS assets from 2019 through 2030 (see www.talkpatransportation.com for more details). Twelve of these comprise the majority of total program funding and are listed in Table 11. Many of the funds are expected to decrease over the planning horizon.

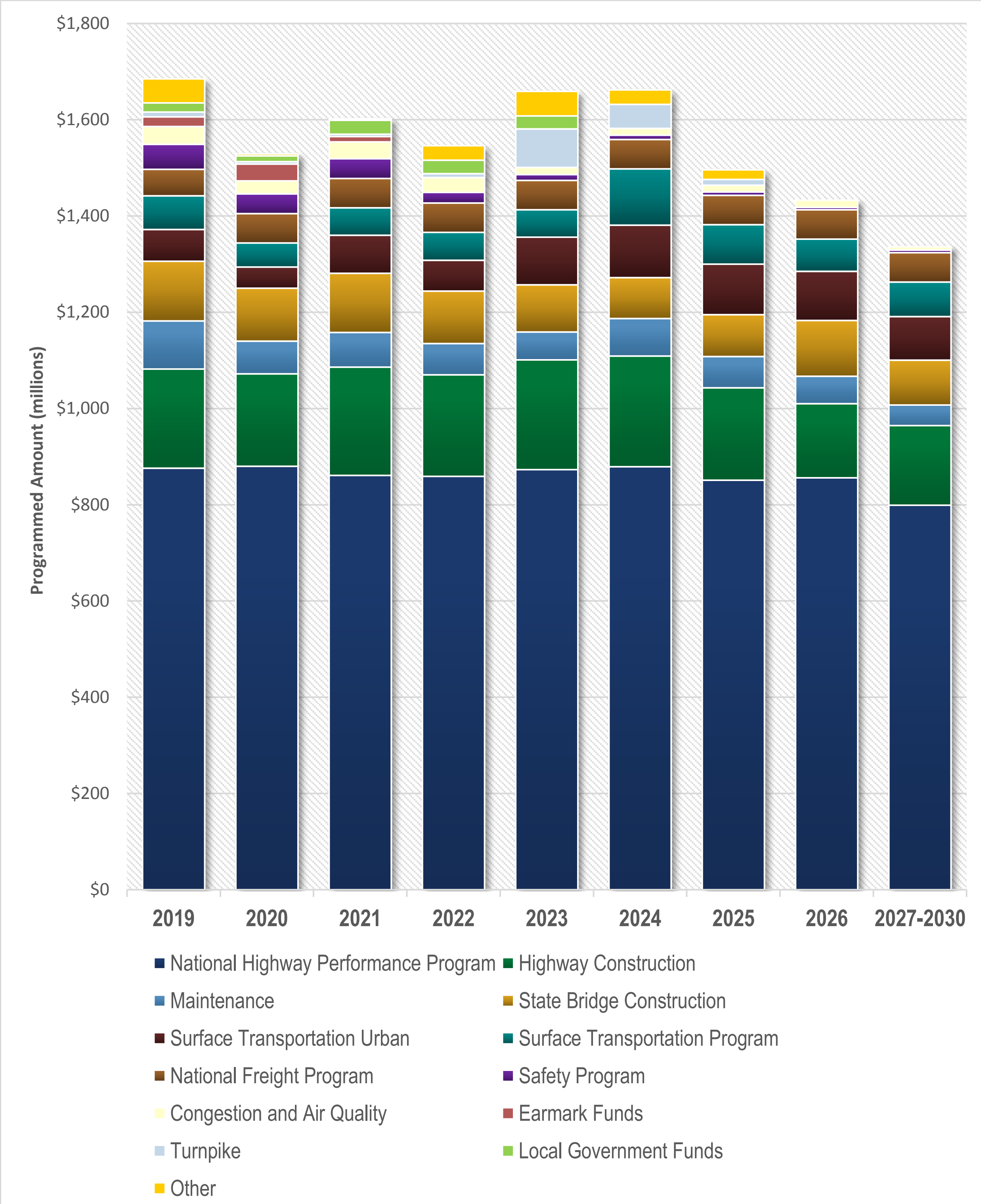
Table 11: Estimated Capital (in millions) by Federal Fiscal Year and Fund

Fund Name	2019	2020	2021	2022	2023	2024	2025	2026	2027 to 2030
National Highway Performance Program	876	880	861	859	873	879	851	856	3,196
Highway Construction	206	192	225	211	228	230	192	154	662
Maintenance	100	68	72	65	58	78	65	57	171
State Bridge Construction	124	110	123	109	98	85	87	116	373
Surface Transportation Urban	66	44	79	64	99	109	105	102	362
Surface Transportation Program	70	50	57	58	57	117	82	67	287
National Freight Program	55	61	61	61	61	61	61	61	244
Safety Program	52	41	41	22	12	9	7	5	22
Congestion and Air Quality	37	27	35	31	15	14	14	15	28
Earmark Funds	20	35	11	–	–	–	–	–	–
Turnpike	10	5	5	8	80	50	12	–	–
Local Government Funds	19	12	29	28	27	0	–	–	–
Other	50	4	3	30	51	30	20	–	–

Source: MPMS, June 2019

Figure 18 charts the levels of funding for NHS assets through 2030. By necessity, the funding levels detailed in Figure 18 and estimated funding by work activity detailed in Figure 16 follow the same trend. The most funding is available in 2019. While funding is expected to stay relatively flat, in future years there will be a decrease in buying power due to inflation.

Figure 18: Levels of NHS Funding by Federal Fiscal Year and Fund



Source: MPMS, 2019

Note: The last column graphs the average annual value for the years indicated.

Risks to Projected Funding

Pennsylvania's projected transportation funding over the next decade is insufficient to meet the state's transportation needs. In fact, the transportation funding gap could widen—the baseline projected funding may not be received due to various funding risks. A 2019 study by the Pennsylvania Transportation Advisory Committee (TAC) evaluated the financial and other impacts of five of the most pressing risks to Pennsylvania transportation funding. The TAC estimated that transportation funding through 2030 could be reduced by a cumulative $18.5 billion if the identified risks materialize.

Estimated Asset Value and Needed Annual Investment to Maintain Value

A valuation of PennDOT's NHS bridge and pavement assets provides insight into the capital investment required to sustain the transportation system. Asset valuation is an estimation of the fair monetary value of infrastructure assets, which, being publicly owned, have no defined market value. An understanding of the current value of infrastructure assets in relation to their replacement costs enables an assessment of infrastructure needs. Further, the gap between current funding and the rate of asset depreciation indicates whether the level of funding is sufficient to maintain the asset in its current condition (see Appendix D for more detailed information and calculations).

The asset valuation and total value of PennDOT's NHS bridges and pavements is presented in Table 12.

Table 12: NHS Pavement and Bridge Valuation Summary

Asset	Current Value	Total Replacement Cost	Difference
Pavement Assets	$8.9 billion	$53.6 billion	$44.7 billion
Bridge Assets	$27.1 billion	$57.8 billion	$30.7 billion
Total	**$36.0 billion**	**$111.4 billion**	**$75.4 billion**

PennDOT is committed to making the best investments of its limited resources to maximize the useful life of its bridges and pavements, however current investment levels are not keeping pace with system deterioration. Currently, PennDOT NHS pavement assets have an average life expectancy of approximately 49 years. This figure is based on 20 years of data comparing the difference between the year of construction and the year of reconstruction of roadway segments. Given a life expectancy of 49 years, the total value of pavement assets depreciates by approximately 2.0 percent per year. In 2017, the average investment was below 1.0 percent of current value—less than the level that is required to maintain pavements at the desired state of good repair.

For NHS bridges, average life expectancy is approximately 85 years. This figure is based on 10 years of data on age of structure at time of replacement. Given a life expectancy of 85 years, the value of bridge assets depreciates at approximately 1.25 percent per year. The 2018 average investment was below 1.0 percent of current value—less than is required to maintain bridges at the desired state of good repair.

Forecasted Funding Need and Potential Additional Sources of Funding

While PennDOT will meet its required condition (the FHWA minimum condition thresholds) for NHS assets in the near term, current revenue streams are projected to be insufficient to maintain the full transportation network at PennDOT's desired state of repair. Cumulative unmet pavement need is $17.8 billion. Cumulative unmet bridge need is $10.4 billion.

PennDOT is actively advancing its planning and programming methodology to achieve lowest overall life-cycle cost, but this transition will not be enough to offset decreasing revenue and the loss of buying power due to inflation. In addition, needed investments are expected to increase due to aging infrastructure. Current projections show that steps must be taken to avoid incurring significant deferred maintenance costs on the non-NHS system within the next three- to five-year timeframe. To reduce this pending deficit, PennDOT has led the following efforts:

- **Motor License Fund Revenue Stabilization** – The Motor License Fund (MLF) has had both a decreasing balance and an increase in usage by other agencies. Fiscal code changes capped the amount of MLF funding diverted to other agencies to preserve a predictable revenue stream to invest into highway and bridge projects.
- **Mileage-based tax** – Federal CAFE standards have increased the fuel economy of cars and trucks, eroding the revenue transportation agencies receive from fuel taxes. In addition to higher overall fleet fuel economy, electric cars are now becoming part of that fleet, and currently there is no financial mechanism for these users to pay their fair share of roadway maintenance costs. To address this problem, PennDOT is participating in an I-95 Corridor Coalition and Delaware DOT study piloting a mileage-based tax system, where a driver would pay a fee based on miles driven in lieu of a per-gallon fuel tax.

Despite these measures, additional predictable sources of transportation funding will be required to sustain desired levels of repair.

Failure to secure adequate funding would have severe impacts on the non-NHS roadway network. In order for PennDOT to commit to meeting its condition the FHWA minimum condition thresholds for Interstate pavements and NHS bridges in the future, emphasis will need to be placed on investing available funding to maintain those assets first. This will result in funds other than NHPP being utilized on NHS needs, leaving even less than the already insufficient current resources to maintain non-NHS pavements and bridges.

9. Investment Strategies

TYP Funding by Work Type

As per 23 CFR 515.13(b)(2)(i), FHWA recognizes five major work types for highway and bridge projects to be addressed in a TAMP:

1. Initial Construction/Capacity-Adding
2. Reconstruction
3. Rehabilitation
4. Preservation
5. Maintenance

Capacity-adding projects are those that add lanes to accommodate more traffic or construct entirely new roadways. One PennDOT strategy to meet asset condition targets within limited funding is to maximize the amount of funding dedicated to maintaining existing infrastructure (vs. expanding the transportation system). Therefore, PennDOT aims to limit capacity-adding projects to 3 percent of its total construction project, with a maximum of 5 percent allowed. The proportion of replacement, rehabilitation, and preservation projects is determined by output of PennDOT's asset management systems combined with professional engineering judgment.

The first four work types are planned and programmed through the TYP and STIP as described in Chapter 6 and in the following section of this chapter. Routine maintenance is programmed and prioritized under a separate program that is much more reactive than the STIP.

Unit costs by work type used for planning purposes are provided in Table 13. TYP-listed project investments by work type, as well as planned maintenance investments, are detailed in Table 14 and graphed in Figure 19.

Table 13: Pavement and Bridge Unit Costs by Work Type

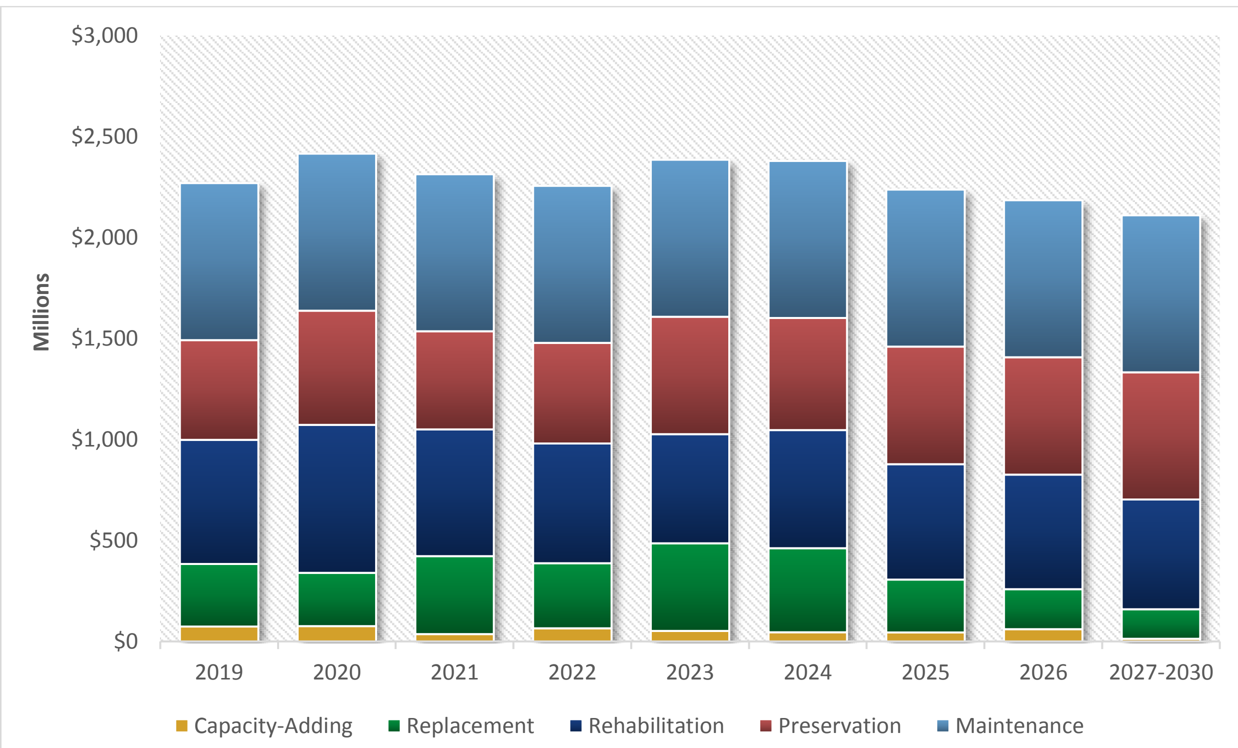
Work Type	Pavements Cost per Square Foot	Bridges Cost per Square Foot
Initial Construction/Capacity-Adding	$190	$850
Reconstruction	$200	$650
Rehabilitation	$35	$350
Preservation	$15	$75
Maintenance	$2	$15

Table 14: Planned Investment by Work Type and Year

Year	Capacity-Adding	Replacement	Rehabilitation	Preservation	Maintenance
2019	$73,901,389	$309,791,750	$614,608,982	$493,749,574	$777,478,826
2020	$75,903,140	$263,772,163	$732,757,670	$565,344,477	$777,478,826
2021	$36,348,191	$385,978,553	$627,730,141	$485,934,449	$777,478,826
2022	$65,105,711	$322,322,582	$592,930,482	$498,057,105	$777,478,826
2023	$52,250,926	$433,833,676	$540,286,852	$581,355,476	$777,478,826
2024	$45,518,000	$416,223,904	$584,861,710	$555,201,007	$777,478,826
2025	$44,681,000	$261,613,770	$571,388,929	$582,237,575	$777,478,826
2026	$60,748,000	$198,068,907	$567,257,494	$581,149,441	$777,478,826
2027-2030	$53,000,000	$584,802,952	$2,174,150,723	$2,518,660,293	$3,109,915,304

Source: MPMS and SAP

Figure 19: Planned Investment by Work Type and Year



Source: MPMS and SAP

Note: The last column graphs the average annual value for the years indicated.

Investment Strategy for 2021 TYP/TIP

As discussed in Chapter 6, PennDOT's General and Procedural Guidance document provides detailed direction for MPOs/RPOs as well as PennDOT staff for selecting projects in a manner that complies with state and federal requirements and is consistent with statewide priorities. PennDOT's 2019 General and Procedural Guidance will be used in developing the 2021 TYP/TIP and introduces the TAMP along with mandatory asset condition targets and the shift from worst-first programming to LLCC. Key elements of the guidance are listed below:

Overview:

To the maximum extent practicable, project selection, evaluation, and prioritization should be a clear and transparent process. PennDOT District and MPO/RPO staff will work together to identify risk-based candidate projects for the highway/bridge portion of the 2021 TYP/TIP that work toward the overarching goals of managing to LLCC and achieving a desired state of good repair, as well as national and state transportation goals.

Project Selection: Carryover Projects

Initial focus should be placed on carryover projects, which must be carried forward onto the 2021 TIP from a previous TIP. These include:

- Projects that are still advancing through the project delivery process
- Projects with unforeseen cost increases
- Projects with anticipated advance construct (AC) conversion

Despite PennDOT's shift in project prioritization discussed below, these previously programmed projects should remain on the TIP to retain the investment already made in their planning and project development.

Highway/bridge carryover project scopes, costs, and schedules will be reviewed and updated based on information obtained through project management and from local input/outreach sources such as the STC Public Survey, MPO/RPO public involvement, PennDOT Connects (PennDOT's municipal outreach initiative), and Environmental Justice Core Elements and Analysis. PennDOT Districts will update this project information in PennDOT's Multimodal Project Management System (MPMS) and share this information with the MPOs/RPOs and PennDOT CPDM.

Project Selection: New Projects

PennDOT District staff and MPO/RPO staff should then cooperatively meet to evaluate highway/bridge project ideas or additional needs that have been identified through the statewide and regional LRTPs, transportation performance measures, the TAMP/PennDOT's asset management systems, and local public involvement. PennDOT CPDM will ensure that adequate coordination meetings are occurring and appropriately documented for the STIP/TIP submission.

Based upon this continued coordination throughout the TIP development process, PennDOT District staff will create project scopes, costs, and schedules in MPMS for the mutually agreed-upon new projects. To allow for open discussion and collaboration, cooperative discussions about candidate projects under consideration should occur between the MPOs/RPOs and the Districts prior to preparation of a fiscally constrained project list.

<u>Pavement and Bridge Condition Performance Measures (PM2)</u>

PennDOT BOMO analyzed PA NHS pavement and bridge data and made overall projections regarding future asset conditions. PennDOT's pavement and bridge condition targets for the NHS system (which match the FHWA mandatory minimum performance thresholds) are established in PennDOT's TAMP, which also documents PennDOT's asset management approach of managing to lowest life cycle cost (LLCC).

The TAMP estimates the levels of future investment necessary to meet the asset condition targets and contrasts them with expected funding levels. This helps PennDOT to make ongoing assessments and to reevaluate data associated with its investment decisions.

While the TAMP and PM2 measures currently only focus on the NHS, PennDOT and the MPOs/RPOs must ensure that projects are selected through LLCC and risk-based methodologies and prioritized for the entire state-owned and locally owned Federal-Aid network. In coordination with PennDOT Districts, the MPOs/RPOs should document how the following items were utilized as part of their program development process:

- regional highway and bridge system assets
- existing conditions on the NHS
- projected future conditions on the NHS
- develop strategies/priorities to continue to improve the system at the LLCC
- plan, program, and implement projects as part of annual budgets

Implementation of improved asset management practices will begin with the Interstate Highway System, then progress to the rest of the National Highway System (NHS) and other state-owned and local networks. This will help PennDOT and the MPOs/RPOs to select and prioritize projects that enhance the overall performance of the entire network.

<u>Transition to LLCC Methodology</u>

In recent years, PennDOT successfully reduced its backlog of Structurally Deficient (SD) bridges through a focused investment strategy that prioritized rehabilitation and replacement projects for SD structures. This approach is known as "worst-first" programming.

While this strategy was successful in terms of reducing the number of SD bridges (now referred to as "poor"), worst-first programming prioritizes work on the poorest-condition structures at the expense of preventative maintenance on other structures in better condition. The previous SD

Bridge Risk Score was not a prioritization tool for network-level risk, but rather a combination of project-level risk and structure condition.

PennDOT is transitioning from the previous focus on poor to a true overall risk-based prioritization and selection of projects based on LLCC. New Pavement and Bridge Risk Scores have been developed to assist in prioritizing preservation, rehabilitation, and replacement projects. These scores do not include condition in the calculation so that risk can be addressed independently, and each asset is ranked on the same scale. It should be noted that risk scores cannot be compared between asset classes at this time. Please see Appendix J for more information regarding the Pavement and Bridge Risk Score calculations.

Additionally, PennDOT is enhancing its BAMS and PAMS to allow the Districts and MPOs/RPOs to review and analyze investment decisions and make condition projections based on available funding levels. PennDOT has adopted a commercial BAMS and PAMS for use in PennDOT's Central Office in order to comply with 23 CFR 515. The Asset Management Division is working to make these systems available to District Bridge Engineers, Pavement Engineers, and MPOs/RPOs.

Until successful roll-out of these systems, Asset Management staff will provide Districts and MPOs/RPOs with BAMS- and PAMS-recommended project selections aimed at meeting asset condition targets within an LLCC approach to the extent budgets allow.

A guidance document for the Districts and MPOs/RPOs regarding the transition to LLCC programming will be developed by PennDOT Central Office Asset Management and CPDM. Key points of the document will include general guidance on:

- Transitioning from worst-first to LLCC.
- Considering new asset condition targets and metrics and how to apply them.
- Maintaining TIP program development (current planned work will be maintained in to order to preserve planning efforts and development dollars).
- Applying the new methodology to TIP adjustments.
- Moving toward "on-cycle" programming with the next TYP.
- Utilizing the PAMS/BAMS tools to assist in TIP/TYP project selection.
- Training on the software systems and interim tools.

Roll-out of the guidance documents will be performed by both PennDOT Asset Management and CPDM through MPO/RPO meetings and calls, BAMS and PAMS implementation meetings, engineering and county maintenance meetings, and workshops as needed.

Anticipated Outcomes of Investment Strategies

The strategies described in this section support objectives stated earlier in this document. In the near-term the strategies will allow PennDOT to achieve a state of good repair, meet stated targets, and support national goals.

The LLCC-based project selection described in this section supports progress toward achieving the national goals described as Objective C in Chapter 2, by following the General and Procedural Guidance for project selection.

These strategies also serve to mitigate the stated risks that were identified as part of the risk analysis described in Chapter 7. The top risks are Funding Shortfall, Extreme Weather, and Project Cost Uncertainty. PennDOT's transition to LLCC effectively mitigates financial risks by maximizing the utility of the funding available. It is recognized that damage from extreme weather events will have to be funded and repaired regardless of planned investment. However, PennDOT has revised its planning and programming processes to mitigate extreme weather event risks, by adding resiliency consideration to programming processes, and undergoing vulnerability assessments.

In the long term, funding levels are projected to be insufficient to maintain PennDOT's defined state of good repair. As discussed in the performance gap analysis, if funding remains inadequate, meeting the FHWA minimum condition thresholds and preventing a performance gap from materializing could require non-LLCC, worst-first project selection. To maintain our defined state of good repair, more than double the current anticipated funding would be needed.

The table below shows the current expected investments from FY 18-19 MPMS programmed projects verses recommended outputs from our BAMS and PAMS. The disparity between the two comes from previous planning prioritization methodology, which is not LLCC. Since these projects are planned and have completed preliminary engineering and, in many cases final design, it would be a significant financial loss to remove them in favor of an immediate transition to LLCC projects. Therefore, it will take approximately 4 years to clear the cue of existing projects before the transition to LLCC methodology can be fully implemented.

Table 15: Consistency Summary Table

Work Type	Pavements		Bridges	
	Expected Investment	RoadCare Selection	Expected Investment	BridgeCare Selection
Maintenance	$26,000,000	$74,000	$3,000,000	$3,000,000
Preservation	$430,958,000	$771,637,000	$80,519,000	$260,888,000
Rehabilitation	$15,564,000	$3,670,000	$126,133,000	$23,537,000
Reconstruction	$84,737,000	$38,721,000	$167,761,000	$89,985,000
New Construction	$256,843,000	–	–	–
TOTAL	$814,102,000	$814,102,000	$377,413,000	$377,410,000

10. Process for Obtaining Data from Other Owners

PennDOT obtains pavement and bridge condition data from multiple other owners, which generally fall into two categories: the Pennsylvania Turnpike Commission (PTC) and local municipal owners. Pavement and bridge information is collected by these entities and shared with PennDOT for reporting requirements and planning use by PennDOT and its MPOs/RPOs.

For the PTC, PennDOT receives pavement data annually via Microsoft Excel spreadsheets. The data is then uploaded into the HPMS system, a sub-system of the Roadway Management System (RMS). Currently, PennDOT only receives the minimum required pavement data items, including Year of Last Improvement, Year of Last Construction, IRI, Rutting, Faulting, and Cracking Percent. PennDOT and the PTC are in the process of implementing an upgrade to PTC's system that will allow them to share more information in future submissions, including Last Overlay Thickness, Structural Thickness of both rigid and flexible pavement, and Base Type Thickness. The PTC also shares its annual budget and cost data so that PennDOT can improve the precision of its asset management models.

For other municipal Local Federal-Aid (LFA) owners, four pavement condition data items are collected for the LFA routes every two years: IRI, Rutting, Faulting, and Cracking Percent. These items are collected by a contractor, currently FUGRO, who uses the same collection method and contract PennDOT uses for the state-owned routes.

11. Use of Best Available Data and Asset Management Systems

Process Description

Effective asset management requires comprehensive, reliable data and advanced databases and software systems. PennDOT collects significantly more data than the minimum required asset condition data, which provides a more complete picture of current asset condition and yields more reliable forecasts.

PennDOT has robust legacy bridge and pavement databases, as well as AASHTOWare software and custom asset management systems that utilize historical data and deterioration modeling to help program future projects at lowest life-cycle cost. The combination of these databases and systems ensures accurate information is maintained for all owners of the NHS and reasonable forecasts of future conditions can be made.

Inventory Data

Pavements

All pavement information is housed in the PennDOT Roadway Management System (RMS). RMS is a legacy database that also contains location referencing, pavement history, condition data, traffic information, as well as other administrative and inventory data for the state-owned roadway network.

QA/QC processes are in place to ensure data integrity and quality for various RMS data elements. Specifically, and most important to pavement asset management, annual QA/QC analysis and reporting is generated for location referencing, pavement history, and condition data.

Bridges

As part of its bridge inspections, PennDOT requires hundreds of data points that are distilled into the basic condition ratings for the deck, superstructure, substructure, and/or culvert.

All bridge information is stored in the Bridge Management System 2 database (BMS2). It is a custom DB2-based platform that houses all current and historical inspection data, as well as various plans and notes. BMS2 contains data on all NHS bridges in Pennsylvania. Certain larger local owners have independent systems that house additional inventory or condition data, but BMS2 is considered the system of record for all structures. BMS2 has no predictive or analytical capabilities.

BMS2 is updated with inspection records from iForms, another in-house software that allows inspectors to perform field inspections and upload the results electronically to BMS2. Collecting inspection data digitally enhances efficiency, reduces human error, and provides an automated means of validating entries.

In December 2006, Publication 590, the Element Coding Guide, was released, leading to PennDOT's data collection program. The collection of PA Core Element Data was completed December 30, 2014. Collection of AASHTO/PennDOT element-level data began on April 24, 2018.

Currently, element-level data has been collected for most state bridges of NBIS length (around 99 percent). This data is either from the data collection program that concluded in 2014 or is newly collected as part of the AASHTO/PennDOT Element program. Some local NBI structures and NHS bridges do not have element-level data currently available.

By May 31, 2020, PennDOT expects to have collected element-level data for all NBI bridges on the NHS. Element-level data collection for all state-owned bridges, including non-NHS structures that are 8 feet and greater in length, is expected to be completed by May 31, 2022.

Asset Management Systems

In order to conduct precise forecasting on the 25,000 state-owned structures and 40,000 linear miles of roadway, PennDOT has deployed Infrastructure Asset Management (IAM), an Applied Research Associates shareware solution that has been customized to meet the needs and data depth of PennDOT. It has been fully developed and is in the initial stages of implementation at PennDOT.

IAM has been configured for bridges and pavements to produce future condition forecasting for PennDOT. As with all asset management systems, IAM generates prioritized lists of recommended preservation, rehabilitation, and replacement projects based on inputs including current condition data, deterioration models, committed projects, budgets, condition targets, and specific network and management priorities. Within those specified parameters, the software evaluates the benefit/cost ratio for feasible treatments and selects a program of treatments that meets targets and criteria most cost-effectively. The system also generates condition forecasts based on that investment scenario.

IAM enables PennDOT to run multiple simulations to evaluate various infrastructure management scenarios, such as managing to LLCC, prioritizing Interstate projects, increasing maintenance budgets, and adjusting asset condition targets. IAM presents the results of these simulations in several ways and creates reports of all the variables used in the simulation on an attribute-by-attribute or year-by-year basis. Maintenance and rehabilitation activities appear in the table at their scheduled times, with their effects on the network being displayed in the budgets, targets, and deficiencies. Selecting a given activity from the table displays a summary of each of the simulation variables with their remaining life, project costs and budget, and benefit/cost ratio.

IAM calculations are based on user-defined guidelines on how to optimize network spending. These include features such as Priorities, Budget Order, Targets, and Deficient. Priorities inform the software of which assets should receive treatment over others. Examples of priorities include criteria such as bridges on NHS routes and/or bridges with daily traffic exceeding 10,000 vehicles. Each priority is criteria-driven and allows a certain portion of the budget to be spent on each priority. PennDOT can enter multiple priorities in a ranked order.

IAM uses benefit/cost as the metric for evaluating the value for a treatment. Calculations of both benefits and costs have been updated in PennDOT's IAM implementation. The benefit of a treatment can be determined using two methods: incremental benefit of a benefit variable and effect on remaining life.

Benefit Calculation

Incremental Benefit Method

The incremental benefit of a given treatment is determined by calculating the difference between the value of the benefit attribute with Treatment and with No Treatment for a duration.

First, the consequence of the treatment is applied (feasible Treatment or No Treatment). New values for all the simulation variables are determined according to the consequences. Next all calculated attributes are re-evaluated according to their criteria-driven equations. The benefit variable is then added to the benefit sum. The benefit variable may be either an attribute with a deterioration equation or a calculated attribute made up of multiple attributes with deterioration equations.

After the treatment's criteria-driven consequences have been applied, all attributes are deteriorated one year into the future. At this time, any committed or scheduled treatment consequences will apply. Both committed and scheduled treatments will be applied, even if the effect is overspending of the applicable budget. If there are no committed or scheduled treatments, the No Treatment consequences will be applied. The calculated attributes are evaluated and a value for Year 2 benefit is summed with the previous year. This iteration of the asset, one year at a time, is performed for the duration of the analysis with the sum stored as the Treatment benefit.

The same calculation is performed by applying the No Treatment consequences, using the same application of the criteria-driven deterioration curves and the same application of committed projects. The result of this is the calculated No Treatment benefit.

The difference between the Treatment benefit and the No Treatment benefit is the incremental benefit of the benefit attribute. This value is stored for each asset and each treatment and is available in the output report of a simulation run.

Remaining Life Method

IAM also supports remaining life analysis as an alternative to incremental benefit. The remaining life of an asset is the duration of time before the value for a deteriorating attribute falls below the user-defined deficient value. PennDOT has established the following deficient targets: only 10 percent of NHS bridges may have a score less than 5, and no more than 5 percent of NHS pavement lane-miles may be in poor condition.

As with the incremental benefit analysis, each treatment consequence is applied. Calculated attributes are evaluated and the following-year deterioration is applied. Committed and scheduled project consequences are applied. From these calculations, the number of years each deteriorating attribute remains above the deficient level is determined. The asset's remaining life is the number of years before the first deteriorating attribute becomes deficient.

The current version of IAM allows the use of calculated attributes as benefit variables and now allows multiple deterioration attribute optimizations.

Cost Calculation

IAM determines costs by applying all feasible criteria costs to a treatment. If multiple costs are valid for a given treatment, all are applied. This allows the software to calculate cost on a project-by-project basis. For example, an analysis can calculate the cost of deck replacement based on deck area, the cost of traffic control based on number of lanes and daily traffic, and the cost of substructure based on whether the bridge is over water or not.

Costs of the initial treatment and future scheduled treatments are summed into a single cost score. Both the cost and benefit calculations use current value dollars for an accurate ratio.

Project Selection

Different analyses in IAM select projects using different methods. In a Budget Permits analysis, all feasible projects are ranked according to their benefit/cost ratios. The program then selects the highest benefit/cost project, meeting priority and budget-order constraints. The system continues to do so until the budget is exhausted. The forecasted deficient levels for each year are calculated and output to the simulation report.

In a Targets and Deficient analysis, the treatments are ordered from the highest to lowest benefit/cost ratio with an added constraint. If a treatment would cause a target to be met, a multiplier is added, giving it a higher priority. If a treatment does not help meet any target it will never be selected, even if it has a high benefit/cost ratio.

When selecting treatments, all scheduled and committed projects are evaluated and their cost is summed. The benefit of all future treatments is calculated. The result is that very few projects will be selected in the years before a committed project, as the benefit and cost of the project have already been accounted for.

Deterioration Modeling

The PennDOT deterioration modeling process is used to determine how long a given attribute is likely to last in a given condition state. Several methodologies were investigated during the development of this process, including modified versions of both the Weibel and Markov models. Ultimately, PennDOT determined that the most appropriate approach for modeling overall deterioration is through a combination of deterministic and probabilistic means. This combined approach allows PennDOT to visualize the data in specific condition intervals and choose the best-fit percentile within the data set for each condition state. This approach facilitates the best combination of data-driven decisions and engineering judgement.

The core deterministic model uses a summary of condition data, as well as information from PennDOT's planning tool (MPMS), its workforce tracking tool (SAP), and its contract management tool (ECMS) to determine how long each asset has lasted in a given condition state.

This information is then represented graphically showing the number of instances a particular asset has lasted for a given duration. The human aspect (engineering judgement) of this is to look at the graphs and determine what cumulative percentage best represents the average duration for the given asset and condition state. The sum of these cumulative percentages is then utilized in IAM to project the duration of these condition states into the future.

12. Glossary

Asset – All physical highway infrastructure located within the right-of-way corridor of a highway. The term asset includes all components necessary for the operation of a highway including pavements, highway bridges, tunnels, signs, ancillary structures, and other physical components of a highway.

Asset class – Assets with the same characteristics and function (e.g., bridges, culverts, tunnels, pavements, or guiderail) that are a subset of a group or collection of assets that serve a common function (e.g., roadway system, safety, Intelligent Transportation System (ITS), signs, or lighting).

Asset condition – The actual physical condition of an asset.

Asset management – A strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on both engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the life cycle of the assets at minimum practicable cost.

Asset management plan – A document that describes how a state DOT will carry out asset management. 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. An asset management plan 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 is the risk-based asset management plan that is required under 23 U.S.C. 119(e) and is intended to carry out asset management as defined in 23 U.S.C. 101(a)(2).

Asset sub-group – A specialized group of assets within an asset class with the same characteristics and function (e.g., concrete pavements or asphalt pavements).

Financial plan – A long-term plan spanning 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.

Investment strategy – A set of strategies that result from evaluating various levels of funding to achieve state DOT targets for asset condition and system performance effectiveness at a minimum practicable cost while managing risks.

Life-cycle cost – The cost of managing an asset class or asset sub-group for its whole life, from initial construction to its replacement.

Life-cycle planning – A process to estimate the cost of managing an asset class, or asset sub-group, over its whole life with consideration for minimizing cost while preserving or improving the condition.

Minimum practicable cost – The lowest feasible cost to achieve the objective.

Performance of the NHS – the effectiveness of the National Highway System in providing for the safe and efficient movement of people and goods where that performance can be affected by physical assets. This term does not include the performance measures established for performance of the Interstate System and performance of the NHS (excluding the Interstate System) under 23 U.S.C. 150(c)(3)(ii)(A)(IV)-(V).

Performance gap – The gaps between the current asset condition and state DOT targets for asset condition, and the gaps in system performance effectiveness that are best addressed by improving the physical assets.

Risk – The positive or negative effects of uncertainty or variability upon agency objectives.

Risk management – The processes and framework for managing potential risks, including identifying, analyzing, evaluating, and addressing the risks to assets and system performance.

Work type – The five major work types are initial construction (capacity-adding), maintenance, preservation, rehabilitation, and reconstruction.

13. Appendices

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Appendix A – Key Stakeholders

Federal Government

PennDOT receives substantial funding from the federal government—PennDOT's largest partner—to operate, advance, and manage PennDOT's assets. The primary federal agency responsible for overseeing the appropriation and implementation of this funding for PennDOT is the Federal Highway Administration (FHWA), a division of the United States Department of Transportation (U.S. DOT). The FHWA develops and regulates rulemaking in support of legislation, such as the MAP-21 funding legislation, which requires risk-based TAMPs in support of funding requests. FHWA oversees PennDOT's use of federal funds for preservation and construction of Interstates, U.S. routes, and eligible state routes.

Regional Planning Organizations

Metropolitan and Rural Planning Organizations (MPOs/RPOs) are responsible for long-range planning for the transportation system in their region of the state. MPOs and RPOs are responsible for their region's long-range transportation plan (LRTP), the annual unified planning work program (UPWP), and managing the transportation improvement program (TIP). These planning documents prioritize projects and funding that impact PennDOT's assets.

Municipalities

Municipalities typically own, operate, and maintain roads, bridges, signs, traffic signals, and other assets in their jurisdiction. Any major project or any project with state or federal funding requires PennDOT involvement. Municipalities may also receive grants or set-aside funding for construction or maintenance. Municipalities impact PennDOT's assets through joint maintenance and the interconnection points between municipal roadways and PennDOT-operated roadways and freeways. Municipal stakeholders include but are not limited to:

- Streets Department
- Public Works Department
- City/Township/Borough Engineer
- Parks Department

Pennsylvania Turnpike Commission

The Pennsylvania Turnpike Commission owns NHS assets and works with PennDOT to effectively manage them. PTC was created in 1937 by the General Assembly as an instrumentality of the Commonwealth. The commission currently operates 68 toll interchanges, 17 services plazas, 22 maintenance facilities, two regional offices, and a main headquarters/ administrative building located in Middletown, Pennsylvania.

Public

The most important stakeholders for all transportation assets are the general public and Pennsylvania businesses. These groups depend on the transportation system in their daily lives It is essential to keep the general public in mind as the ultimate beneficiary of the transportation system.

Appendix B –
Pavement and Bridge Asset Owners

This appendix focuses on the breakdown of pavement and bridge asset owners. To date, there 22,673.28 NHS pavement lane-miles in Pennsylvania split among multiple principal pavement owners: PennDOT, PTC, and municipalities. Appendix Table B.1 provides the number and percentage of lane-miles by NHS pavement owner.

Appendix Table B.1: Detailed Breakdown of NHS Pavement Asset Owners

Pavement Owner	Lane-Miles	Percentage of Total Lane-Miles	Pavement Owner	Lane-Miles	Percentage of Total Lane-Miles
PennDOT	20791	88.13%	Swissvale	2.22	0.01%
PA Turnpike	2283	9.68%	Rankin	2.16	0.01%
Pittsburgh	112.046	0.47%	Braddock	2.14	0.01%
Philadelphia	86.16	0.37%	Blakely	1.88	0.01%
Lower Merion Twp	30.92	0.13%	Homestead	1.88	0.01%
Wilkes Barre	23.9	0.10%	Monroeville	1.84	0.01%
Harrisburg	17.18	0.07%	Sunbury City	1.82	0.01%
Lebanon	16.64	0.07%	Warren City	1.82	0.01%
Allentown	16.43	0.07%	Kilbuck	1.64	0.01%
York City	15.61	0.07%	Millcreek	1.56	0.01%
East Norriton	14.24	0.06%	North Braddock	1.44	0.01%
Erie City	14.21	0.06%	Ohio	1.4	0.01%
Plymouth Twp	12.36	0.05%	Edgewood	1.38	0.01%
Whitemarsh	9.84	0.04%	North Wales	1.38	0.01%
Dickson City	7.28	0.03%	South Lebanon	1.22	0.01%
Lower Providence	6.59	0.03%	Chester City	1.12	0.00%
Williamsport	6.51	0.03%	Dravosburg	1.12	0.00%
Norristown	5.46	0.02%	Huntingdon	1.06	0.00%
Upper Gwynedd Twp	5.46	0.02%	Emsworth	1.02	0.00%

Pavement Owner	Lane-Miles	Percentage of Total Lane-Miles	Pavement Owner	Lane-Miles	Percentage of Total Lane-Miles
Upper Dublin Twp	5.16	0.02%	Wilmerding	0.98	0.00%
Mckeesport	4.64	0.02%	West Conshohocken	0.98	0.00%
Bethlehem City	4.48	0.02%	Springfield Twp	0.87	0.00%
Lancaster	4.44	0.02%	Ingram	0.84	0.00%
Ross Twp	4.24	0.02%	Washington	0.83	0.00%
Lower Gwynedd	4.22	0.02%	New Castle	0.74	0.00%
Worcester	4.12	0.02%	Mt Lebanon Twp	0.72	0.00%
Bethlehem	3.98	0.02%	Whitaker	0.68	0.00%
Neville Twp	3.87	0.02%	Yeadon	0.68	0.00%
Scott Twp	3.66	0.02%	Phoenixville	0.66	0.00%
Towamencin	3.3	0.01%	Coraopolis	0.51	0.00%
Scranton	3.2	0.01%	Philipsburg	0.5	0.00%
Altoona City	3.16	0.01%	Collier Twp	0.48	0.00%
Kingston 4	3.02	0.01%	Wall Borough	0.46	0.00%
East Mckeesport	2.85	0.01%	Dingman	0.4	0.00%
Sharon City	2.78	0.01%	East Pittsburgh	0.36	0.00%
Millvale	2.7	0.01%	Northumberland	0.32	0.00%
Plum Borough	2.62	0.01%	Crafton	0.26	0.00%
Easton City	2.49	0.01%	New Kensington	0.1	0.00%
Johnstown	2.47	0.01%	Wilkes Barre Twp	0.06	0.00%
Upper St Clair Twp	2.28	0.01%			

NHS bridges total 5,846 and are divided among 54 owners. Appendix Table B.2 provides the number and percentage of total bridges by NHS bridge owner.

Appendix Table B.2: Detailed Breakdown of NHS Bridge Asset Owners

Bridge Owner	Bridge Count	% of Total	Bridge Owner	Bridge Count	% of Total
PennDOT	5,077	86.85%	City of Erie	1	0.02%
Pennsylvania Turnpike Commission	598	10.23%	City of Johnstown	1	0.02%
Delaware River Joint Toll Bridge Comm.	20	0.34%	City of Reading	1	0.02%
Delaware River Port Authority	20	0.34%	City of Reading, PennDOT, Norfolk Southern	1	0.02%
Allegheny County	18	0.31%	City of Scranton	1	0.02%
Montgomery County	12	0.21%	City of Warren	1	0.02%
City of Pittsburgh	11	0.19%	City of York	1	0.02%
City of Lebanon	7	0.12%	Combination	1	0.02%
City of Philadelphia / PennDOT	7	0.12%	Consolidated Rail	1	0.02%
Norfolk Southern	7	0.12%	CSX / PennDOT	1	0.02%
CSX Railroad	6	0.10%	East Goshen Twp	1	0.02%
Millvale Borough	6	0.10%	Lower Merion	1	0.02%
Amtrak	3	0.05%	Luzerne County	1	0.02%
Conrail	3	0.05%	Northampton County	1	0.02%
Lehigh County	3	0.05%	PA DGS	1	0.02%
City of Philadelphia	3	0.05%	Penn Central	1	0.02%
SEPTA	3	0.05%	PennDOT, City of Johnstown, Norfolk Southern, Cambria City	1	0.02%
City of Allentown	2	0.03%	Philadelphia Water Department	1	0.02%
Bessemer & Lake Erie RR & PennDOT	2	0.03%	Philadelphia/Montgomery Joint County	1	0.02%
Dauphin County	2	0.03%	Private	1	0.02%
City of Harrisburg	2	0.03%	PWSA	1	0.02%
Norristown Borough	2	0.03%	Railroad; Dupont & the Borough of Avoca	1	0.02%
Port Authority of Allegheny County, City of Pittsburgh, Norfolk Southern	2	0.03%	S.Whitehall Twp	1	0.02%
Buffalo, City of Pittsburgh, PennDOT	1	0.02%	South Lebanon Twp	1	0.02%
Burlington County	1	0.02%	Upper Gwynedd Twp	1	0.02%
City of Bethlehem	1	0.02%	US Silica Co.	1	0.02%
City of Chester	1	0.02%	York County	1	0.02%

Appendix Table B.3: NHS Bridge Count by Owner and PennDOT District

District	State Highway Agency (PennDOT)	State Toll Authority (PTC)	City, Municipal Highway Agency, or Borough	County Highway Agency	Local Toll Authority	Railroad	Town or Township Highway Agency	Private (other than Railroad)	Other Local Agencies	Other State Agencies	District Total
1	322	0	2	0	0	0	0	0	0	0	324
2	438	0	0	0	0	2	0	0	0	0	440
3	376	0	0	0	0	0	0	0	0	0	376
4	373	20	1	1	1	1	0	0	0	0	397
5	496	54	4	4	11	2	1	0	0	0	572
6	1,026	133	11	13	30	13	4	1	0	0	1,231
8	553	89	10	3	0	4	1	0	0	1	661
9	308	74	1	0	0	1	0	1	0	0	385
10	245	5	0	0	0	2	0	1	0	0	253
11	638	103	16	18	0	3	0	3	1	0	782
12	302	120	0	0	0	3	0	0	0	0	425

Appendix Table B.4: NHS Bridge Deck Area (sq.ft.) by Owner and PennDOT District

District	State Highway Agency (PennDOT)	State Toll Authority (PTC)	City, Municipal Highway Agency, or Borough	County Highway Agency	Local Toll Authority	Railroad	Town or Township Highway Agency	Private (other than Railroad)	Other Local Agencies	Other State Agencies	District Total
1	3,195,055.40	0.00	27,910.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3,222,965.40
2	4,222,237.39	0.00	0.00	0.00	0.00	11,551.80	0.00	0.00	0.00	0.00	4,233,789.19
3	4,218,976.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4,218,976.57
4	4,162,186.61	380,285.41	1,676.20	6,328.00	36,120.20	11,431.00	0.00	0.00	0.00	0.00	4,598,027.43
5	5,603,121.40	756,157.62	33,762.60	111,197.00	368,623.90	7,020.80	1,800.00	0.00	0.00	0.00	6,881,683.33
6	21,745,586.37	2,151,244.26	146,362.90	92,676.70	4,286,354.15	142,898.21	10,744.00	7,280.00	0.00	0.00	28,583,146.60
8	7,518,639.44	1,308,880.92	44,566.60	14,090.60	0.00	57,208.30	1,170.00	0.00	0.00	110,208.01	9,054,763.88
9	3,159,394.39	571,071.62	12,528.00	0.00	0.00	41,096.00	0.00	7,524.00	0.00	0.00	3,791,614.01
10	3,039,185.21	60,905.90	0.00	0.00	0.00	20,931.00	0.00	3,360.00	0.00	0.00	3,124,382.11
11	11,823,892.06	1,807,987.07	277,858.61	1,003,674.52	0.00	40,890.00	0.00	26,797.90	1,000.00	0.00	14,982,100.16
12	3,424,167.01	2,727,170.88	0.00	0.00	0.00	14,192.00	0.00	0.00	0.00	0.00	6,165,529.89

Appendix Table B.5: Pavement Lane-Miles by BPN by District

District	BPN 1 (NHS Interstate)		BPN 2 (NHS Non-Interstate)		BPN 3 Non-NHS, ADT ≥ 2,000		BPN 4 Non-NHS, ADT ≤ 2,000	
	Lane-Miles	%	Lane-Miles	%	Lane-Miles	%	Lane-Miles	%
1	338.6	13%	973.1	6%	2394.5	7%	9545.5	11%
2	249.8	9%	1144.4	7%	1782.9	5%	9336.2	11%
3	158	6%	1123.7	7%	2407.8	7%	11941.3	13%
4	360.5	14%	696.4	4%	2646.2	8%	9561.7	11%
5	337.6	13%	1502.4	10%	4107.2	12%	5322	6%
6	152.6	6%	3363.6	22%	5517.3	16%	2588.7	3%
8	307.4	12%	1837.6	12%	6625.1	19%	9316.6	11%
9	155.4	6%	1163.9	8%	1869	5%	10691.3	12%
10	157.9	6%	985	6%	1784.1	5%	8504.9	10%
11	213.5	8%	1525.7	10%	2651.8	8%	2967	3%
12	200.3	8%	1190.9	8%	2911.7	8%	8704.7	10%

Source: RMS, June 2019

Appendix Table B.6: Pavement Owners – Lane-Miles by District

PennDOT District	Lane-Miles	Percentage of Total
PennDOT-Owned		
1	1618	8%
2	1634	8%
3	1428	7%
4	1383	7%
5	2150	10%
6	3803	18%
8	2449	12%
9	1459	7%
10	1283	6%
11	1964	9%
12	1548	7%
Pennsylvania Turnpike Commission-Owned		
1	0	0%
2	0	0%
3	0	0%
4	130.4	6%
5	229.1	10%
6	373.6	16%
8	434	19%
9	364.5	16%
10	17.6	1%
11	324.7	14%
12	409.3	18%
City, Municipality, or Borough-Owned		
1	20.4	4%
2	0.5	0%
3	8.7	2%
4	39.7	8%
5	27.4	5%
6	193.5	37%
8	55.1	11%
9	6.7	1%
10	0	0%
11	163.2	32%
12	0.9	0%

Source: RMS, June 2019

Appendix C – Performance Metrics and Prediction Modeling

Pavement Performance Indicators

Appendix Table C.1 summarizes PennDOT's NHS pavement condition by performance indicator. For a one-tenth-mile pavement section to be rated in poor condition overall, two or more of the performance measures must indicate poor condition. Appendix Table C.1 quantifies the conditions as a sum of each tenth-mile section in each condition, but does not account for the number of lanes in each section. Data from 2017 was used to establish baseline and initial targets; 2018 data is provided for comparison.

Appendix Table C.1: PennDOT NHS Pavement Condition by Performance Indicator

2017

Rating	Rutting		Cracking		Faulting		IRI	
	Miles	Percentage	Miles	Percentage	Miles	Percentage	Miles	Percentage
Good	6,857	77.53	8,229	81.81	1,184	97.09	5,754	57.28
Fair	1,895	21.43	1,334	13.26	11	0.90	3,105	30.92
Poor	92	1.04	495	4.92	24	2.01	1,185	11.80

2018

Rating	Rutting		Cracking		Faulting		IRI	
	Miles	Percentage	Miles	Percentage	Miles	Percentage	Miles	Percentage
Good	6,653	75.74	7,868	77.93	1,287	98.08	5,853	58.92
Fair	2,046	23.30	1,583	15.68	20	1.49	2,988	30.08
Poor	85	0.97	646	6.39	6	0.44	1,092	10.99

Pavement Condition Assessment and Projection

Data Compilation

Pavement data is collected for tenth-mile increments and quantified as per the HPMS definitions for IRI, rutting, faulting, and cracking. Based on the MAP-21 definitions for good, fair, and poor for each condition, current percentages of each were determined. The mileage with missing data was also determined, for each condition and overall.

Deterioration

Because no data at tenth-mile increments exists prior to 2017, previously collected segment-level data for the years 2013-2016 was quantified and used to determine deterioration rates for each condition. For each segment, the change of each condition value was determined from 2013 to 2014, from 2014 to 2015, and from 2015 to 2016.

If a value was missing for any year, no change was calculated. If a condition value equaled zero for any year, it was excluded based on the assumption that a significant repair (i.e., a project) had been completed. The change in condition for each year was averaged for each segment; the segment averages were then averaged to determine an overall deterioration rate for each condition.

There are instances where data indicates incremental improvement from one year to the next. This is attributed to minor maintenance and/or inconsistencies in the collection process. These values were included in the analysis. The overall deterioration rate was then increased by 3 percent to reflect the impact of inflation. Since minor maintenance is reflected in the deterioration rate, and PennDOT's ability to continue to perform those activities is affected by inflation, as a worst case, the deterioration would increase proportionately to the decrease in spending power for this work.

Where the segment average resulted in a negative number (i.e., the condition value improved over the three-year period), a value of zero was used for the segment average because deterioration was not reflected in that segment average value.

The resultant deterioration rates are provided in Appendix Table C.2.

Appendix Table C.2: Pavement Condition Deterioration Rates

Condition	Interstate	NHS Non-Interstate
Faulting (inch)	0.00024	0.00153
Concrete Cracking	0.94%	0.89%
Rutting (inch)	0.00651	0.00890
Bituminous Cracking	0.56%	0.90%

Program Impact

The appropriate deterioration rates were applied to each condition, and values for each tenth-mile increment were determined for the years 2021, 2025, and 2029. These values reflect a state of "do nothing."

Based on data from MPMS, all projects programmed on the Interstate and NHS non-Interstate networks for the next four years (2018-2021) were compiled. The mileage of these programmed projects that affected pavements in good, fair, and poor condition was determined, and these proportions were projected over the next four-year period (2022-2025) and the following four-year period (2026-2029). Because the TYP is only fully developed for its first four years, projecting programmed mileage for the first four years is a better representation of the volume of work to be expected, assuming constant funding while reducing affected miles by 3 percent annual inflation.

Given the mileages in good, fair, and poor condition, and the projected programmed miles in each condition, resultant mileages were determined for the years 2021, 2025, and 2029. The mileage with missing data was assumed constant over this duration.

BAMS

The updated parameters for the BAMS (Bridge Care) are shown in Appendix Figure C.1. The chart indicates funding for each year by BPN by deck area. The model run demonstrated in this screenshot was for NHS structures, BPN 1 and 2 only.

Appendix Figure C.1: Bridge Care Run Sheet

BridgeCare

Simulations were run on 5/29/19 in BridgeCare for NBIS length bridges and culverts on the NHS (BPNs 1, 2, H, and T) to produce models with a 12-year duration. The run simulations were optimized for lowest life cycle cost and constrained to budgets provided by the Program Center in 2018. Two separate simulations were run:

1) NHS bridges and culverts, not including Turnpike structures___(BPNs 1, 2, and H)
2) Turnpike bridges and culverts only___(BPNs 1, and T)

The results from the two simulations were combined to produce a model representing the overall NHS, including Turnpike and non-Turnpike NHS bridges and culverts.

Budget			
Year	**State Amount ($)**	**Turnpike Amount ($)**	**TOTAL Amount ($)**
2019	384,000,000	52,038,350	436,038,350
2020	343,000,000	52,990,470	395,990,470
2021	295,000,000	54,335,100	349,335,100
2022	338,000,000	56,269,130	394,269,130
2023	299,000,000	57,811,500	356,811,500
2024	299,000,000	58,881,050	357,881,050
2025	299,000,000	60,507,370	359,507,370
2026	299,000,000	73,837,030	372,837,030
2027	299,000,000	75,801,100	374,801,100
2028	299,000,000	75,801,100	374,801,100
2029	299,000,000	75,801,100	374,801,100
2030	299,000,000	75,801,100	374,801,100

Additional BridgeCare simulation parameters:

- Simulation analyzed using incremental benefit/cost optimization.
- 3% inflation rate
- NHS Indicator = "1"
- NBIS Length = "Y"
- Budget: As Budget Permits
- Weighting: RISK SCORE
- Benefit: CONDITIONINDEX

An additional simulation was run for all non-NHS bridges (BPNs 3 and 4) and NHS bridges (with NBIS Length = "N"). The budget for each year (2019-2030) was $250,000,000.

Appendix D – Financial Planning

Work Types

PennDOT extends its investments across 40 work types. Appendix Table D.1 lists all work types and their associated sub-work type used to simplify categorization within PennDOT. The work types are also matched to the relevant FHWA work type.

Appendix Table D.1: PennDOT Work Types and Assigned Sub-Work Type

Type	Sub-Work Type	FHWA Work Type
Additional Lanes	Pavements	Construction
Bridge Preservation – State-funded	Bridge	Preservation
Bridge Preservation – Federally-funded	Bridge	Preservation
Bridge Replacement	Bridge	Reconstruction
Bridge Restoration	Bridge	Rehabilitation
Congestion Reduction	Other	Construction
Design/Construction	Both	Construction
Disaster	Other	Maintenance
Disaster Permanent Repair	Other	Reconstruction
Transportation Enhancement	Other	Construction
General Maintenance	Maintenance	Maintenance
Highway Reconstruction	Pavements	Reconstruction
Highway Restoration	Pavements	Rehabilitation
Intelligent Transportation System	Ancillary	Construction
Land Acquisition	Other	Construction
New Alignment	Pavements	Construction
New Bridge	Bridge	Construction
Planning	Other	Construction
Planning/Research/Administration	Other	Construction
Preventive Maintenance	Other	Maintenance

Type	Sub-Work Type	FHWA Work Type
Public Transit	Other	Construction
Bridge Removal	Bridge	Construction
Rest Area/Welcome Center	Ancillary	Maintenance
Safety Improvement	Safety	Rehabilitation
Secondary Route	Other	Construction
Study Phase of Project	Other	Construction
Enhanced Maintenance	Maintenance	Maintenance

As shown in Appendix Table D.2, pavement assets receive the greatest amount of funding over the planning horizon. This is in part due to their current value falling significantly short of their replacement value. Bridge assets receive the second-greatest amount of funding, while maintenance, safety, ancillary, and other work types receive the remaining funding.

Appendix Table D.2: Programmed Capital (in millions) by Work Type Category and Federal Fiscal Year

Work Type Category	2017	2018	2019	2020	2021	2022	2023	2024	2025 to 2029	Total
Ancillary	13	7	8	26	14	13	10	12	5	**$123**
Bridge	384	343	295	338	299	298	247	255	207	**$3,284**
Maintenance	382	369	436	348	332	286	251	228	190	**$3,391**
Other	112	57	56	70	53	62	28	42	26	**$583**
Pavements	670	626	554	576	564	558	782	796	821	**$8,411**
Safety	155	134	95	79	105	109	79	96	49	**$1,047**

Pavement Valuation

Age is the most appropriate indicator of remaining useful life of pavement assets, and thus residual value, because sub-base condition—a key driver of overall pavement degradation—is most closely correlated with its age.

Based on historical pavement performance, the useful life of a pavement segment is assumed to be 49 years for this exercise. To simplify the valuation calculation, it is assumed that pavement assets depreciate linearly regardless of surface treatments over the pavement's lifetime; straight-line depreciation was therefore used to estimate PennDOT pavement value over time.

The current value of a pavement asset is calculated by multiplying the age of the pavement by its total replacement cost divided by the 49-year expected life, as shown below:

$$Pavement\ Valuation = \sum_{0}^{x} \frac{Pavement\ Age * Total\ Replacement\ Cost}{Pavement\ Expected\ Life}$$

Based on state averages, the replacement cost for one lane-mile of roadway pavement is $2.1 million. See Appendix Table D.3 for a sample calculation of the current value of a pavement asset.

Based on these calculations, pavement assets depreciate approximately $0.04 billion annually, therefore an investment of that magnitude is required to sustain assets at their current valuation. Without that level of investment in reconstruction, by the year 2041, pavement assets will depreciate to a value of only $2 billion. This analysis supports the estimation by PennDOT pavement engineers, who have said for many years that increased investments in pavement reconstruction will be required to maintain the network, given the age of the system.

Appendix Table D.3: Sample Calculation of Current Value of a Pavement Asset

Variables	
Segment Length	0.675 miles
Year Built	1989
Current Year	2019
Useful Life	49
Segment Type	Road
Number of Lanes	2
Percent of Life Remaining	
1- [(Current Year – Year Built) / Useful Life]	
1-[(2019-1989) / 49] =	39%
Replacement Cost	
Segment Replacement Cost * Segment Length * Number of Lanes	
$2.1 million per linear mile * 0.675 linear miles * 2 lanes =	$2.835 million
Segment Asset Valuation	
Replacement Cost * Percent of Life Remaining	
$2.835 million * 39%	$1.11 million

Bridge Valuation

Based on historical NHS bridge replacement ages, the useful life of an NHS bridge is assumed to be 85 years. To simplify the valuation calculation, it is assumed that bridge assets depreciate linearly over time.

The current value of a bridge asset is calculated by multiplying the age of the bridge by its total replacement cost divided by the 65-year expected life, as shown below:

$$Bridge\ Valuation = \sum_{0}^{x} \frac{Bridge\ Age * Total\ Replacement\ Cost/SF}{Bridge\ Expected\ Life}$$

Based on state averages, the replacement cost for a bridge is $650 per square foot. See Appendix Table D.4 for a sample calculation of the current value of a bridge asset.

Appendix Table D.4: Sample Calculation of Current Value of a Bridge Asset

Variables	
Deck Area	10,944 square feet
Year Built	1988
Current Year	2019
Useful Life	85
Percent of Life Remaining	
1- [(Current Year – Year Built) / Useful Life]	
1-[(2019-1988) / 85] =	63.52%
Replacement Cost	
Deck Area * Replacement Cost	
10,944 square feet * $650/sf =	$7.11 million
Bridge Asset Valuation	
Replacement Cost * Percent of Life Remaining	
$7.11 million * 63.52%	$4.52 million

Appendix E – Part 667 Information

Appendix Table E.1 details the roadway segments located within declared disaster areas. Note the table lists weather events, not infrastructure repairs. While Pennsylvania has had significant damage throughout the state from past named and un-named storms, no individual piece of infrastructure has been substantially repaired or replaced on two or more occasions due to these events.

Appendix Table E.1: Roadways with Declared Emergencies

PennDOT District	County	State Route	Segment	Year	Disaster Declaration Number	Declared Major Disaster
1	Venango	0008	0520	2013	DR-4099	Pennsylvania Hurricane Sandy
				2003	DR-1485	Pennsylvania Severe Storms, Tornadoes, and Flooding
2	Juniata	2017	0010	2013	DR-4099	Pennsylvania Hurricane Sandy
		2022	0060	2004	DR-1557	Pennsylvania Tropical Depression Ivan
3	Bradford	1035	0040	2016	DR-4929	Pennsylvania Severe Storms and Flooding
				2013	DR-4030	Pennsylvania Tropical Storm Lee
				2011	DR-4003	Pennsylvania Severe Storms and Flooding
	Bradford	1026	0080	2007	DR-1684	Pennsylvania Severe Storms and Flooding
				2006	DR-1649	Pennsylvania Severe Storm, Flooding, and Mudslides
				2005	DR-1587	Pennsylvania Severe Storms and Flooding
	Columbia	1022	0160	2013	DR-4030	Pennsylvania Tropical Storm Lee
				2006	DR-1649	Pennsylvania Severe Storm, Flooding, and Mudslides
				2005	DR-1587	Pennsylvania Severe Storms and Flooding
				2004	DR-1557	Pennsylvania Tropical Depression Ivan
	Lycoming	0880	0010	2016	DR-4929	Pennsylvania Severe Storms and Flooding
				2013	DR-4030	Pennsylvania Tropical Storm Lee

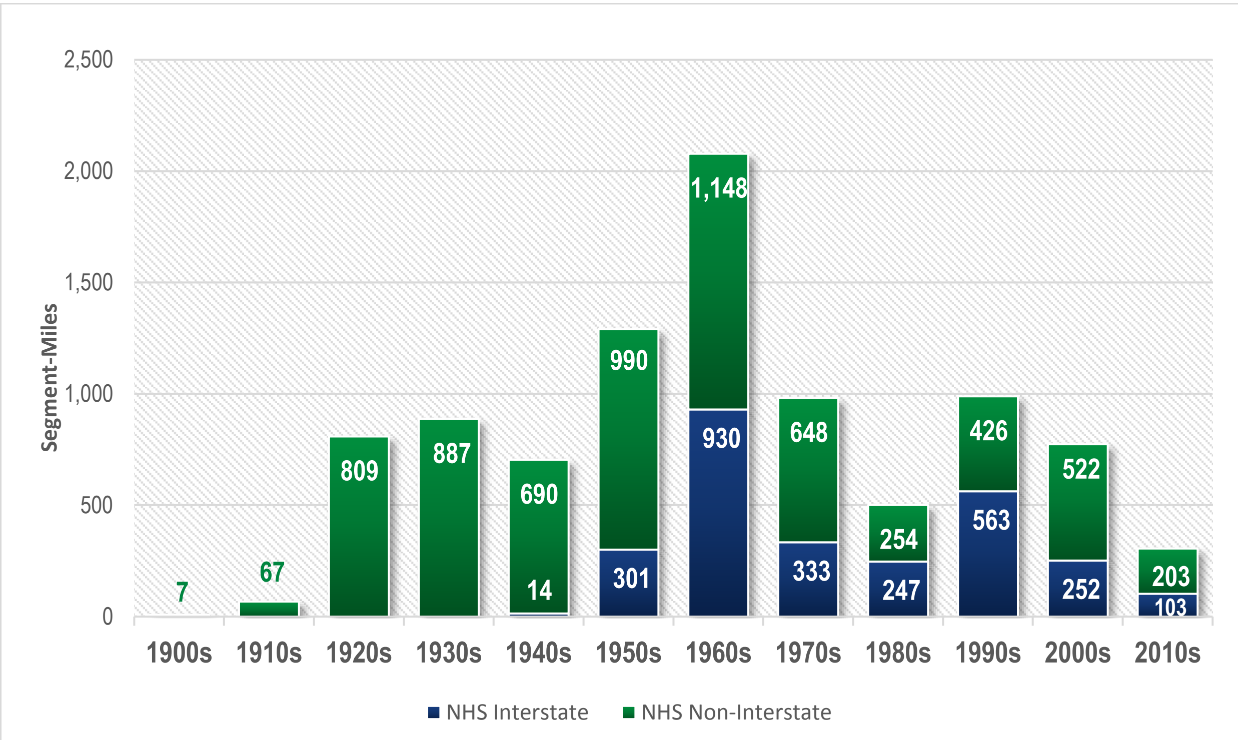
PennDOT District	County	State Route	Segment	Year	Disaster Declaration Number	Declared Major Disaster
				2011	DR-4003	Pennsylvania Severe Storms and Flooding
				2004	DR-1557	Pennsylvania Tropical Depression Ivan
4	Susque-hanna	4018	0010	2013	DR-4030	Pennsylvania Tropical Storm Lee
				2007	DR-1684	Pennsylvania Severe Storms and Flooding
				2006	DR-1649	Pennsylvania Severe Storm, Flooding, and Mudslides
				2005	DR-1587	Pennsylvania Severe Storms and Flooding
				2004	DR-1557	Pennsylvania Tropical Depression Ivan
	Wyoming	3001	0010	2013	DR-4099	Pennsylvania Hurricane Sandy
				2013	DR-4030	Pennsylvania Tropical Storm Lee
				2011	DR-4025	Pennsylvania Hurricane Irene
				2011	DR-4003	Pennsylvania Severe Storms and Flooding
		0187	0050	2007	DR-1684	Pennsylvania Severe Storms and Flooding
				2006	DR-1649	Pennsylvania Severe Storm, Flooding, and Mudslides
				2005	DR-1587	Pennsylvania Severe Storms and Flooding
				2004	DR-1557	Pennsylvania Tropical Depression Ivan
5	Berks	0422	0220	2013	DR-4030	Pennsylvania Tropical Storm Lee
		0625	0050	2006	DR-1649	Pennsylvania Severe Storm, Flooding, and Mudslides
				1999	DR-1294	Pennsylvania Hurricane Floyd
	Schuylkill	3015	0010	2013	DR-4030	Pennsylvania Tropical Storm Lee
				2007	DR-1684	Pennsylvania Severe Storms and Flooding
				2006	DR-1649	Pennsylvania Severe Storm, Flooding, and Mudslides
				2004	DR-1557	Pennsylvania Tropical Depression Ivan
8	Cumberland	2008	0040	2013	DR-4030	Pennsylvania Tropical Storm Lee

PennDOT District	County	State Route	Segment	Year	Disaster Declaration Number	Declared Major Disaster
				2004	DR-1557	Pennsylvania Tropical Depression Ivan
	Dauphin	1013	0070	2013	DR-4099	Pennsylvania Hurricane Sandy
				2013	DR-4030	Pennsylvania Tropical Storm Lee
				2006	DR-1649	Pennsylvania Severe Storm, Flooding, and Mudslides
				2004	DR-1557	Pennsylvania Tropical Depression Ivan
	Lancaster	1045	0080	2013	DR-4030	Pennsylvania Tropical Storm Lee
				2006	DR-1649	Pennsylvania Severe Storm, Flooding, and Mudslides
				1999	DR-1294	Pennsylvania Hurricane Floyd
	York	3017	0050	2013	DR-4030	Pennsylvania Tropical Storm Lee
				2004	DR-1557	Pennsylvania Tropical Depression Ivan
				1999	DR-1294	Pennsylvania Hurricane Floyd
10	Jefferson	0322	0590	2013	DR-4149	Pennsylvania Severe Storms, Tornadoes, and Flooding
				2004	DR-1557	Pennsylvania Tropical Depression Ivan

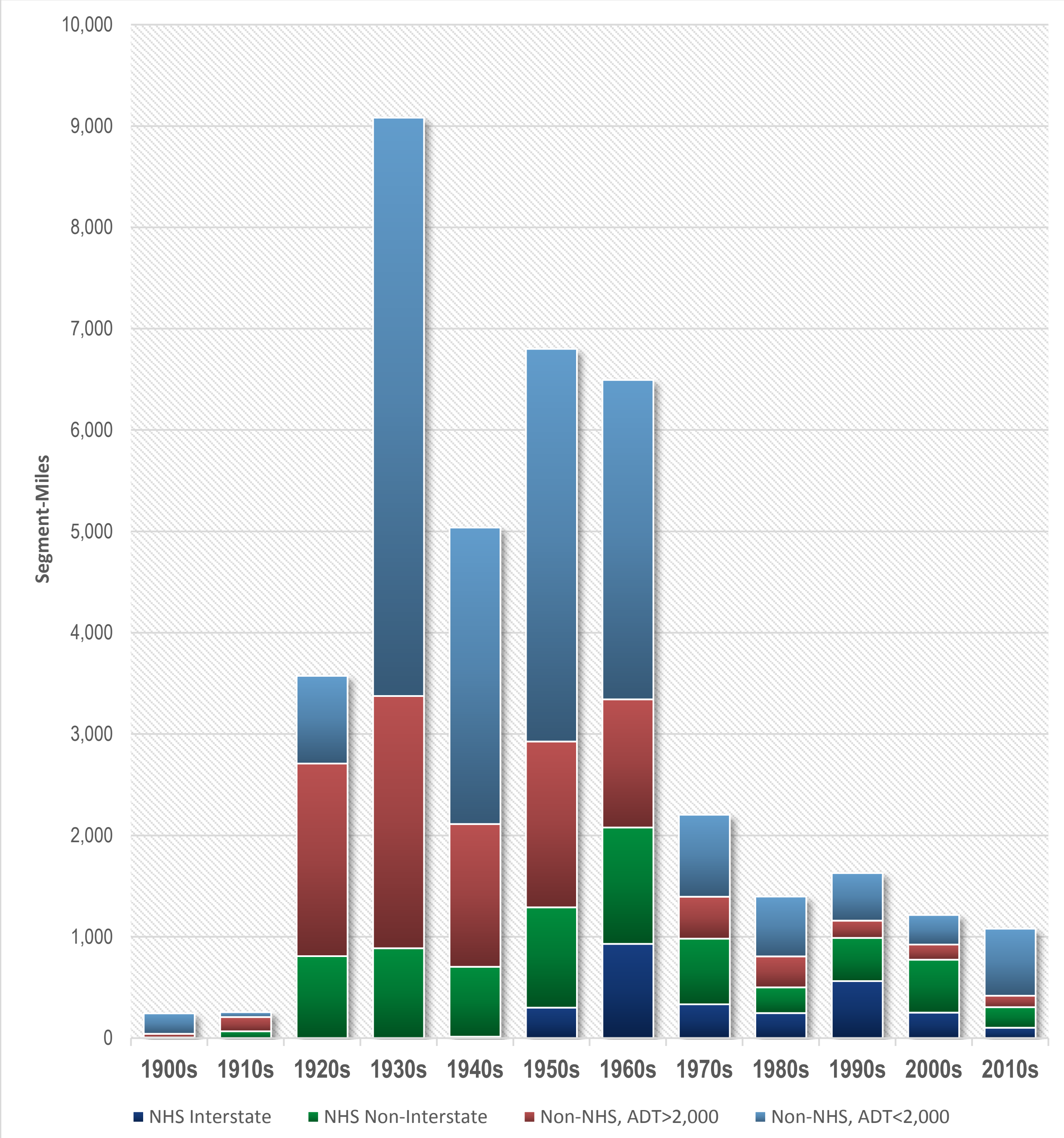
Appendix F – Infrastructure Age

A significant portion of Pennsylvania's infrastructure is more than 50 years old and has exceeded its original design life. This places pressure on limited budgets, as increased investment is required to replace or rehabilitate these aging pavements and bridges. The following figures illustrate the age of Pennsylvania's pavements and bridges.

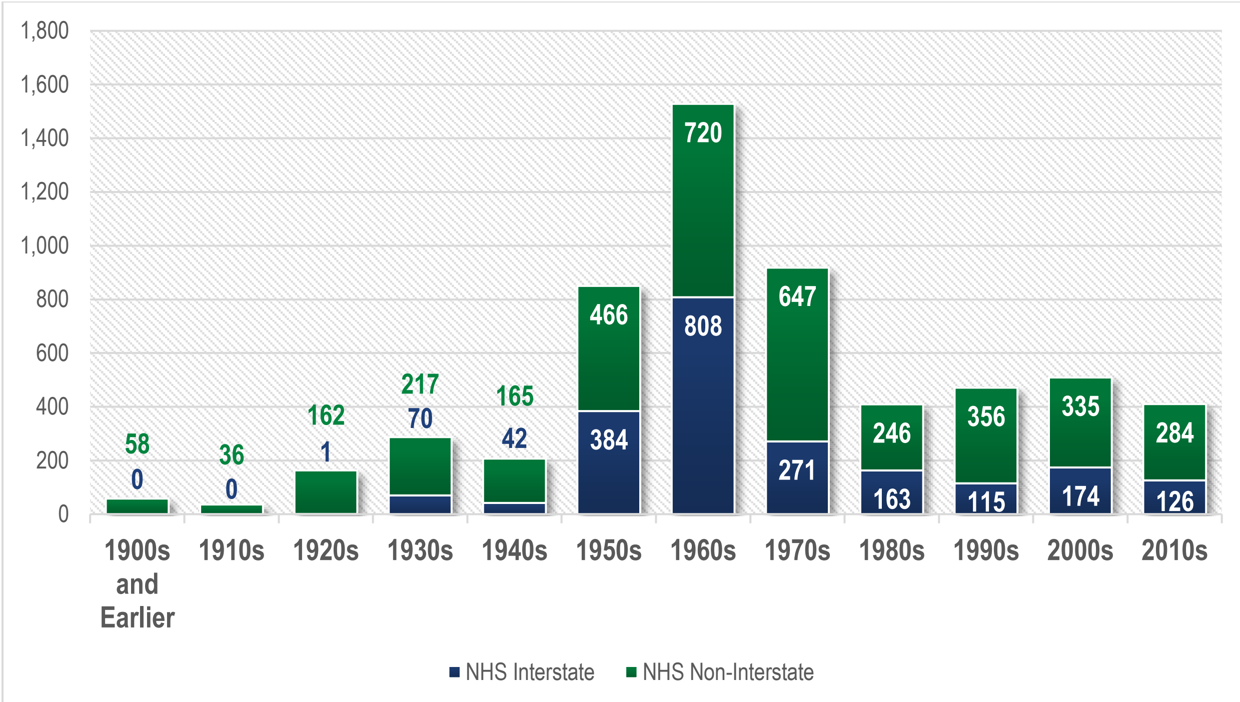
Appendix Figure F.1: Current NHS Pavements by Decade Constructed



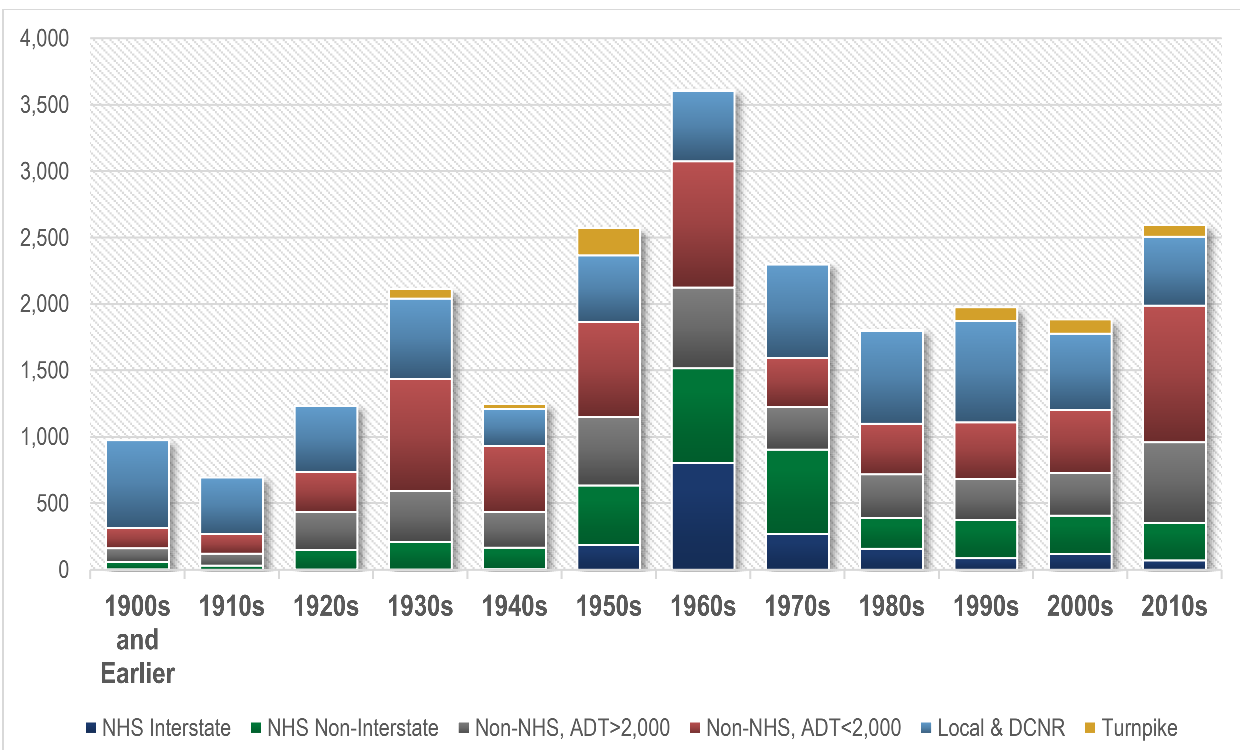
Appendix Figure F.2: Total Pennsylvania Pavements by Business Plan Network and Decade Constructed



Appendix Figure F.3: Current NHS Bridges and Culverts by Decade Constructed



Appendix Figure F.4: Current Pennsylvania Bridges and Culverts (20 feet and greater) by Business Plan Network and Decade Constructed



Appendix G – Pavement and Bridge Condition Forecast Methodology

Pavement Baseline Report and Initial Target Setting Methodology

Data at tenth-mile increments does not exist prior to 2017, therefore previously collected segment-level data for 2013 through 2016 was used to determine deterioration rates for each pavement condition measure. For each segment, the change in each condition value was determined from 2013 to 2014, from 2014 to 2015, and from 2015 to 2016.

If a value was missing for any year, no change was calculated. If a condition value equalled zero for any year, it was excluded based on the assumption that a significant repair (i.e., a project) had been completed. The change in condition for each year was averaged for each segment; the segment averages were then averaged to determine an overall deterioration rate for each condition.

There are instances where there was incremental improvement from one year to the next for the conditions. This is attributed to minor maintenance and/or bias in the collection process. These values were included in the analysis. The overall deterioration rate was then increased by 3 percent to reflect the impact of inflation. Because minor maintenance is reflected in the deterioration rate, and PennDOT's ability to continue to perform those activities is affected by inflation, as a worst case, the deterioration would increase proportionately to the decrease in spending power for this work.

Where the segment average resulted in a negative number (i.e., the condition value improved over the three-year period), a value of zero was used for the segment average because deterioration was not reflected in that segment average value.

The resultant deterioration rates are provided in Appendix Table G.1. These rates were used to establish initial condition targets in the 2018 TAMP baseline assessment report.

Appendix Table G.1: PA Average Annual NHS Pavement Deterioration Rates

Pavement Condition Measure	NHS Interstate Pavements	NHS Non-Interstate Pavements
Faulting (inch)	0.00024	0.00153
Concrete Cracking	0.94%	0.89%
Rutting (inch)	0.00651	0.00890
Bituminous Cracking	0.56%	0.90%

The appropriate deterioration rates were applied to each measure, and values for each tenth-mile increment were projected for the years 2021, 2025, and 2029. These values reflect a state of “do nothing.”

Based on data from MPMS, all projects programmed on the NHS Interstate and NHS non-Interstate networks for the next four years (2018-2021) were compiled. The mileage of these programmed projects that affected pavements in good, fair, and poor condition was determined, and these proportions were projected over the next four-year period (2022-2025) and the following four-year period (2026-2029). Because the TYP is not fully developed beyond the first four years, projecting programmed mileage for the first four years is a better representation of the volume of work to be expected, assuming constant funding while reducing affected miles by 3 percent annual inflation.

Given the current number of miles in good, fair, and poor condition, and the projected programmed miles in each condition, resultant mileages in each condition were determined for the years 2021, 2025, and 2029. The mileage with missing data was assumed to be in constant condition over this duration.

Pavement and Bridge LLCC Methodology

PennDOT forecasts future pavement and bridge conditions and needs using Infrastructure Asset Management (IAM). This system utilizes custom deterministic deterioration modeling in conjunction with historical cost data in a multi-objective decision-making engine that utilizes comprehensive work rules to produce the following outputs:

- 12-24 years of overall future conditions of good, fair, and poor at current investment levels
- 12-24 years of current and future investment needed to maintain a given condition threshold of good, fair, and poor
- Prioritized list of recommended projects by work type based on LLCC for years 1-12

IAM’s capabilities are described in Chapter 11.

Appendix H – Enterprise Risk Register

The Risk Workshop initially conducted on October 31, 2017, and reviewed on April 1, 2019, considered all of the risks detailed in Appendix Table H.1.

Appendix Table H.1: Enterprise Risk Register

Number	Risk	Likelihood	Consequence	Treatment	Owner
1	Funding shortfall	Almost Certain	Severe	1) Innovative financing 2) Innovative contracting 3) Increase funding 4) Improve project selection	1) Agency / Executive Staff 2) P3 Office 3) Agency / Executive staff 4) BOMO AMD
2	Uncertainty of costs due to inflation, market costs, and inaccurate LCCA	Almost Certain	Severe	1) Improved Agency cost estimating 2) Contingency plan for project over-runs 3) Plan and contract development quality 4) Project Scope consistency	1) BOPD 2) Planning and Programming 3) BOPD 4) BOPD
3	Data issues, including but not limited to: 1) Quality vs. data gaps and completeness 2) Data collection for projections (obtaining useful information) 3) Data Analysis - interpretation of existing data sets 4) Data systems,	Almost Certain	Severe	1) Data integrity in all systems 2) Define and enforce standards 3) Awareness and training 4) Field verification and flexibility 5) Quality Assurance	All: Highway Administration and Planning and Programming

Number	Risk	Likelihood	Consequence	Treatment	Owner
	availability and sharing 5) Security (of the data				
4	Loss of institutional management knowledge, including succession planning, knowledge gaps, and skillsets	Almost Certain	Moderate	1) Mentoring, job shadowing and succession planning 2) Creating and providing needed training 3) Creating and documenting a knowledge transfer process	All: Agency
5	Impacts and prediction of changes in land use and demand. Examples include changes in traffic volumes and percentage of heavy loads, legislative changes, industry changes	Almost Certain	Moderate	1) Implementation of advancing technologies 2) Validation & prediction through data collection 3) Adjusting plans based on priorities; ability to modify the TYP	All: Agency
6	Non-state owners of NHS assets	Almost Certain	Moderate	1) Coordinate with non-state owners to collect and obtain data 2) Implement Liquid Fuels funding guidance and/or allocation.	1,2) Planning and Programming
7	Poor quality: 1) Poor maintenance quality 2) Poor material quality 3) Poor construction quality	Probable	High	1) Increased inspection frequency 2) Test and accept new materials	Districts Lab
8	Resource availability: 1) People 2) Funding	Probable	High		

Number	Risk	Likelihood	Consequence	Treatment	Owner
	3) Materials 4) Weather				
9	Changing the way we design and bid projects	Possible	High		
10	Natural disasters - extreme weather events, climate change, and seismic activity	Probable	Moderate	Update DM's	DM owner, Research Div.
11	Political influence outside the department	Probable	Moderate		
12	Changes in administration	Probable	Moderate		
13	Freeze/thaw cycles, changes in climate—changes in deterioration cycle ability to forecast deterioration	Probable	Moderate		
14	Delivery mechanics – Having the correct Scope of Work Planning activities – Intermodal connectivity (opportunity/mitigation strategy)	Probable	Moderate		
15	Local influences to utilize Liquid Fuel funds for 230 miles on NHS	Probable	Low		
16	MPO/RPO stakeholders – uncertainties and decision-making	Probable	Low		
17	SuperPave, Warm Mix, Cold Mix – long term performance is unknown when too	Possible	Moderate		

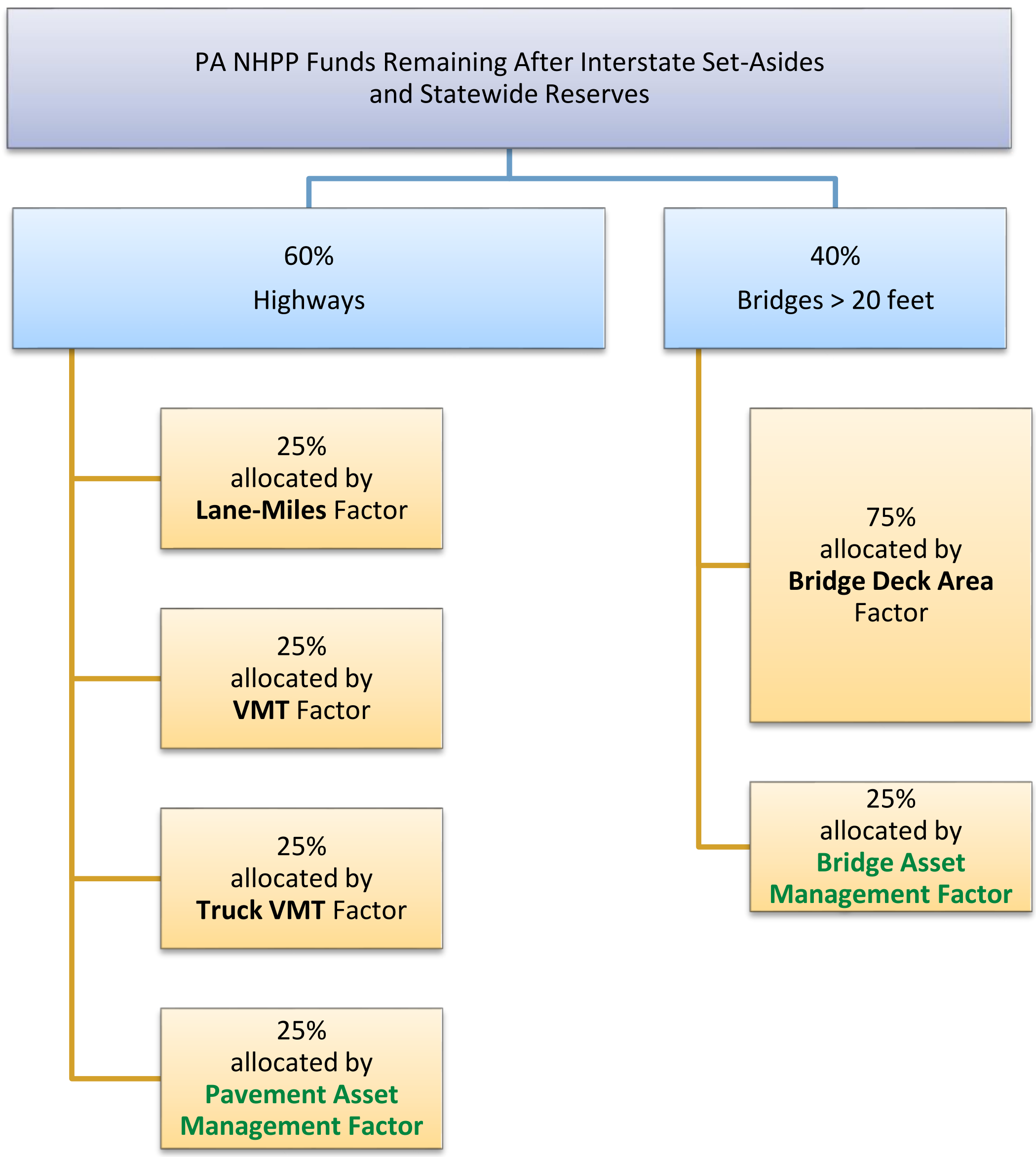
Number	Risk	Likelihood	Consequence	Treatment	Owner
	many changes are implemented.				
18	Cross-allocation of funding	Possible	Moderate		
19	Recognizing not always a “worst-first" scenario by June 2019 but we cannot ignore the backlog we have to address	Possible	Moderate		
20	Accepting a culture change - Change in management to lowest life cycle costs	Rare	Moderate		
21	Resource Availability - Industry capacity	Rare	Moderate		
22	Time for Environmental Compliance - MS4 Compliance	Possible	Low		
23	CFR 667 - extreme weather incident occurring twice at same location (pavement & bridge)	Rare	Low	1) TAMP 2) Allow flexibility in the replacement of the structure (design) if/when a structure is necessary for replacement and federal funding is necessary	FHWA
24	Focus on Life Cycle Costs by June 2021 +	Rare	Low		
25	Correct Validation and use of BAMS & PAMS by June 2019	Rare	Low		
26	Controlling bridges - 10% deck area	Rare	Low		

Number	Risk	Likelihood	Consequence	Treatment	Owner
27	What is critical and what are the priorities - what are the tools in place to identify these?	Rare	Low		
28	View bidding by "projects" vs bidding by "assets." How are boundaries aligned and/or assigned?	Rare	Low		
29	Unrealistic targets	TBD	TBD		
30	Accidents causing infrastructure damage (bridge hits, truck fires etc.)	TBD	TBD		

Appendix I – NHPP Funding Distribution and the Asset Management Factor

The National Highway Performance Program (NHPP) provides funding to states for construction and maintenance of NHS assets. PennDOT distributes most of its share of NHPP funding to MPOs and RPOs, which program and manage projects in their region. Funding historically has been allocated using formulas that factor in a region's relative need, considering its inventory of NHS infrastructure, traffic volume, and asset condition. Beginning in FFY2023, funding will be distributed using an updated formula, depicted in Appendix Figure I.1.

Appendix Figure I.1: NHPP Funding Distribution, 2023–2032



The proportion of total NHPP funding dedicated to pavements vs. bridges is based on the total annual life cycle need of these assets. The pavement need is 60 percent of the total annual life cycle need.

The pavement and bridge asset management factors (AMFs) are new calculations designed to consider treatment needs by dollar value to maintain existing NHS pavements and bridges in a state of good repair, consistent with Pennsylvania's TAMP. The amount of bridges and pavements in poor condition is no longer a factor in the funding allocation. The Pavement or Bridge AMF for each county is the ratio of that county's dollar value of NHS infrastructure needs divided by Pennsylvania's total NHS needs.

PennDOT's Asset Management Division calculates the Pavement AMF and Bridge AMF using the methods outlined below.

Pavement AMF Calculation

Pavement treatment needs and the dollar value of those needs are calculated for each segment of the NHS using the following major steps.

1. Identify asset condition.
   The Asset Management Division accesses the latest pavement condition data for each roadway segment. PennDOT's Automated Pavement Distress Condition Surveying Program, which includes video-logging of all pavements, began in 1997. Pavement condition data for locally owned Federal-Aid roads is also collected. Pavement condition surveys are conducted according to Publication 336: Pavement (Bituminous & Jointed Concrete). More detail on asset condition measures and data collection is provided in Chapter 4.

2. Determine appropriate treatments, consistent with the TAMP.
   The Asset Management Division uses matrices to assign treatments to a segment's pavement based on condition and business plan network. Appendix Table I.1 presents a sample matrix. Appendix Table I.2 provides the corresponding treatment codes.

Appendix Table I.1: Bituminous Pavement Fatigue Cracking (High Severity) Treatment Matrix

Cracking Extent (% of Segment Length)	Treatment Code if Interstate / NHS Expressway	Treatment Code if NHS – Non-Expressway	Treatment Code if Non – NHS ≥ 2000 ADT	Treatment Code if Non – NHS < 2000 ADT
0 – 10%	10	10	10	5
11 – 25%	11	11	11	11
26 – 50%	21	11	11	11
51 – 75%	23	11	11	19
> 75%	23	23	23	23

Appendix Table I.2: Pavement Treatment Codes

Treatment Code	Treatment Description
0	Routine Maintenance
1	Crack Seal
2	Spray Patch
3	Skin Patch
4	Manual Patch
5	Manual Patch, Skin Patch
6	Mechanized Patch
7	Mill, Manual Patch
8	Mill, Mechanized Patch
9	Mill, Mechanized Edge Patch
10	Base Repair, Manual Patch
11	Base Repair, Mechanized Patch
12	Seal Coat
13	Level, Seal Coat
14	Widening, Seal Coat

15	Scratch, Level, Seal Coat
16	Microsurface/Thin Overlay
17	Level, Resurface
18	Mill, Concrete Patch, Level, Resurface
19	Level, Resurface, Base Repair
20	Mill, Level, Resurface
21	Mill, Level, Resurface, Base Repair
22	Construct Paved Shoulder
23	Reconstruction

3. Establish materials lists to perform the treatment.
   Materials and quantities are derived from the treatment code and segment characteristics and dimensions.
4. Calculate the cost of the treatment.
   The total materials required for the needed treatment are translated to a dollar value using price lists that are updated with the latest actual cost data from recent projects.
5. Repeat for each segment; sum dollar needs by route and county.
6. Divide county's dollar needs by state's total dollar needs.
   The resulting ratio, the Pavement AMF, expresses the county's asset management needs as a proportion of the total needs of the state. The PennDOT District or MPO/RPO needs can also be expressed as a portion of the total needs, summing data for their counties.

Bridge AMF Calculation

Treatment needs and the cost of those needs are determined for each bridge on the NHS, following the same general steps used for pavements.

Bridge condition data is derived from inspections conducted every two years or more frequently, depending on bridge condition. PennDOT has conducted bridge inspections to increasingly rigorous federal standards since 1971. PennDOT Publication 100A is the current bridge condition survey field manual.

Appropriate treatments for bridges and culverts are also determined using matrices, such as Appendix Figure I.1.

Appendix Figure I.2: Sample Bridge and Culvert Treatment Matrix

Culvert Preservation	1	10		[BRIDGE_TYPE]='C' AND [BUS_PLAN_NETWORK]='1' AND [CULV_SEEDED]>='6' AND [CULV_SEEDED]<='7'
				[BRIDGE_TYPE]='C' AND [BUS_PLAN_NETWORK]<>'1' AND [CULV_SEEDED]>='5' AND [CULV_SEEDED]<='6'
Culvert Rehabilitation	1	20		[BRIDGE_TYPE]='C' AND [BUS_PLAN_NETWORK]='1' AND [CULV_SEEDED]>='5' AND [CULV_SEEDED]<='6'
				[BRIDGE_TYPE]='C' AND [BUS_PLAN_NETWORK]<>'1' AND [CULV_SEEDED]>='4' AND [CULV_SEEDED]<='5'
Culvert Replacement	1	65		[BRIDGE_TYPE]='C' AND [BUS_PLAN_NETWORK]='1' AND [CULV_SEEDED]<='5'
				[BRIDGE_TYPE]='C' AND [BUS_PLAN_NETWORK]<>'1' AND [CULV_SEEDED]<='4'
Deck Replacement	1	20	Deck replacement with work on beam ends and beam seats	[BRIDGE_TYPE]='B' AND [BUS_PLAN_NETWORK]='1' AND [YEAR_BUILT]<='1983' AND [DECK_SEEDED]<='5'
				[BRIDGE_TYPE]='B' AND [BUS_PLAN_NETWORK]<>'1' AND [YEAR_BUILT]<='1983' AND [DECK_SEEDED]<='4'
				[BRIDGE_TYPE]='B' AND [BUS_PLAN_NETWORK]<>'1' AND [YEAR_BUILT]<='1983' AND [DECK_SEEDED]<'5' AND [DECK_SEEDED]>='4' AND [DECK_DURATION_N]>='20'
Superstructure Replacement	1	30	Superstructure Replacement with work on beam seats	[BRIDGE_TYPE]='B' AND [BUS_PLAN_NETWORK]='1' AND [YEAR_BUILT]<='1983' AND [DECK_AREA]<='30000' AND [SUP_SEEDED]>='3' AND [SUP_SEEDED]<='5'
				[BRIDGE_TYPE]='B' AND [BUS_PLAN_NETWORK]<>'1' AND [YEAR_BUILT]<='1983' AND [DECK_AREA]<='30000' AND [SUP_SEEDED]>='3' AND [SUP_SEEDED]<'4'
				[BRIDGE_TYPE]='B' AND [BUS_PLAN_NETWORK]<>'1' AND [YEAR_BUILT]<='1983' AND [DECK_AREA]<='30000' AND [SUP_SEEDED]>='5' AND [SUP_SEEDED]<'6' AND [SUP_DURATION_N]>='18'
				[BRIDGE_TYPE]='B' AND [BUS_PLAN_NETWORK]<>'1' AND [YEAR_BUILT]<='1983' AND [DECK_AREA]<='30000' AND [SUP_SEEDED]>='4' AND [SUP_SEEDED]<'5' AND [SUP_DURATION_N]>='18'
Bridge Replacement	1	65	Complete bridge replacement	[BRIDGE_TYPE]='B' AND [BUS_PLAN_NETWORK]='1' AND [YEAR_BUILT]<='1983' AND [DECK_AREA]<'30000' AND [SUB_SEEDED]<='5'
				[BRIDGE_TYPE]='B' AND [BUS_PLAN_NETWORK]<>'1' AND [YEAR_BUILT]<='1983' AND [DECK_AREA]<'30000' AND [SUB_SEEDED]>='4' AND [SUB_SEEDED]<'5' AND [SUB_DURATION_N]>='20' AND [SUP_SEEDED]<='6'
				[BRIDGE_TYPE]='B' AND [BUS_PLAN_NETWORK]<>'1' AND [YEAR_BUILT]<='1983' AND [DECK_AREA]<'30000' AND [SUB_SEEDED]<='4'

As with pavements, a Bridge AMF is calculated for each county to express the county's bridge needs as a proportion of the state's total bridge needs.

Appendix J – Pavement and Bridge Risk Score

PennDOT developed new pavement and bridge risk score calculations to assist in prioritizing preservation, rehabilitation, and replacement projects in light of true network-level risk, based on LLCC. These scores do not include condition in the calculation so that risk can be addressed independently, and each asset is ranked on the same scale. It should be noted that risk scores cannot be compared across asset classes at this time.

Pavement Risk Score Calculation

The risk score for each pavement segment is calculated using the formula below. Appendix Table J.1 defines the factors and the parameters that determine factor values.

$$\text{Pavement Risk} = \left(\sqrt{\text{Surface Area} * \text{Annual Average Daily Traffic}}\right) * \text{F}_{\text{aadtt}} * \text{F}_{\text{ffcc}}$$

Appendix Table J.1: Pavement Risk Score Factors

Factor	Definition	Parameter	Factor Value
F_{aadtt}	Annual Average Daily Truck Traffic	Truck traffic is >20% total traffic	2.00
		Truck traffic is ≥ 10% total traffic	1.50
		Truck traffic is <10% total traffic	1.00
F_{ffcc}	Federal Functional Class Code	Rural Principal Arterial–Interstate	2.25
		Rural Principal Arterial-Other	2.20
		Rural Minor Arterial	2.15
		Rural Major Collector	2.10
		Rural Minor Collector	2.05
		Rural Local	2.00
		Urban Principal Arterial–Interstate	1.25
		Urban Principal Arterial-Other Freeways	1.20
		Urban Other Principal Arterial	1.15
		Urban Minor Arterial	1.10
		Urban Collector	1.05
		Urban Local	1.00

Bridge Risk Score Calculation

The risk score for each bridge is calculated using the formula below. Appendix Table J.2 defines the factors and the parameters that determine factor values.

$$\text{Bridge Risk} = \left(\sqrt{\text{Deck Area} * \text{Annual Average Daily Traffic}}\right) * F_s * F_{fc} * F_{det} * F_{aadtt} * F_{flood}$$

Appendix Table J.2: Bridge Risk Score Factors

Factor	Definition	Parameter	Factor Value
F_s	Scour Factor	Scour Rating = A	1.2
		Scour Rating ≠ A	1.0
F_{fc}	Fracture Critical Factor	Fracture Critical Rating < 5	1.4
		Fracture Critical Rating ≥ 5	1.0
F_{det}	Detour Length Factor	Detour Length > 30 miles	2.0
		Detour Length ≥ 10 miles	1.5
		Detour Length < 10 miles	1.0
F_{aadtt}	Annual Average Daily Truck Traffic Factor	Truck traffic > 20% total traffic	2.0
		Truck traffic ≥ 10% total traffic	1.5
		Truck traffic < 10% total traffic	1.0
F_{flood}	Bridge Closed for Flooding Event Factor	Bridge has been closed for flooding	3.0
		Bridge has been overtopped due to flooding	1.5
		Bridge has not been closed or overtopped due to flooding	1.0