Texas Department of Transportation

2022 Transportation Asset Management Plan

June 2022

Texas DOT Transportation Asset Management Plan
Executive Summary

Overview

The Texas Department of Transportation (TxDOT) 2022 Transportation Asset Management Plan (TAMP) presents a 10-year strategy for managing the state's pavements and bridges. TxDOT has constructed, maintains, and inspects the largest network of pavements, bridges, and other assets in the country. TxDOT itself owns, maintains and operates some 201,225 lane miles of roads and 34,865 bridges, which carry 185.8 billion vehicle miles annually.

Transportation Asset Management at TxDOT

In its capacity as steward of the transportation network, TxDOT is responsible for ensuring the safety of the traveling public and the effective long-term operation of infrastructure assets. Effective long-term operation of the infrastructure is regularly achieved through transportation asset management. Transportation asset management (TAM) relies on data-driven decision-making to choose the right improvements at the right time in an asset's lifecycle in order to sustain a desired level of performance in the most cost-effective way.

About the TxDOT TAMP

The TAMP details TxDOT's asset management approach and describes the condition of the transportation system, future investment plans, potential risks to effective operation of the network, the relationship between federal and state condition goals, and TxDOT's success in addressing those goals.

State and Federal Perspectives

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.

While this TAMP meets federal requirements to report on NHS pavements and bridges, this TAMP also includes the entire TxDOT-owned system of pavements and bridges. Texas'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, and more – not only the major routes through the state.

How TxDOT Measures Performance

TxDOT uses state measures of asset condition for state-owned assets and performance measures established by the Federal Highway Administration (FHWA) to calculate asset condition for NHS assets. TxDOT uses both state and federal measures because they serve distinct purposes.

TxDOT Performance Measures

TxDOT's performance measures for state-owned assets are the measures used to manage the system, drive decision-making, and track progress on state goals.

TxDOT tracks 18 performance measures across four categories on its public performance dashboard. The TAMP includes two of the asset performance measures: state pavement condition and state bridge condition.

Why We Measure

TxDOT manages the state-owned system using these measures. Asset condition is a key input to the capital decision-making process.

What We Measure

All state-owned pavements and bridges

How We Measure

PAVEMENT

% lane miles by condition

Very Poor	Poor	Fair	Good	Very Good

Based on Ride Score (roughness) and Distress Score (surface distresses)

BRIDGE

Bridge condition score

50 – 95

Network-level rating from 50 to 95 weighted by deck area

Federal Performance Measures

Federal performance measures for NHS pavements and bridges are required for use by state DOTs to carry out the National Highway Performance Program (NHPP).

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 TAMP.

Why We Measure

Federal measures are used to compare performance across states and to determine federal funding flexibility.

What We Measure

All NHS pavements and bridges (regardless of owner)

How We Measure

PAVEMENT

% lane miles by condition

Poor	Fair	Good

Based on roughness and three distress metrics

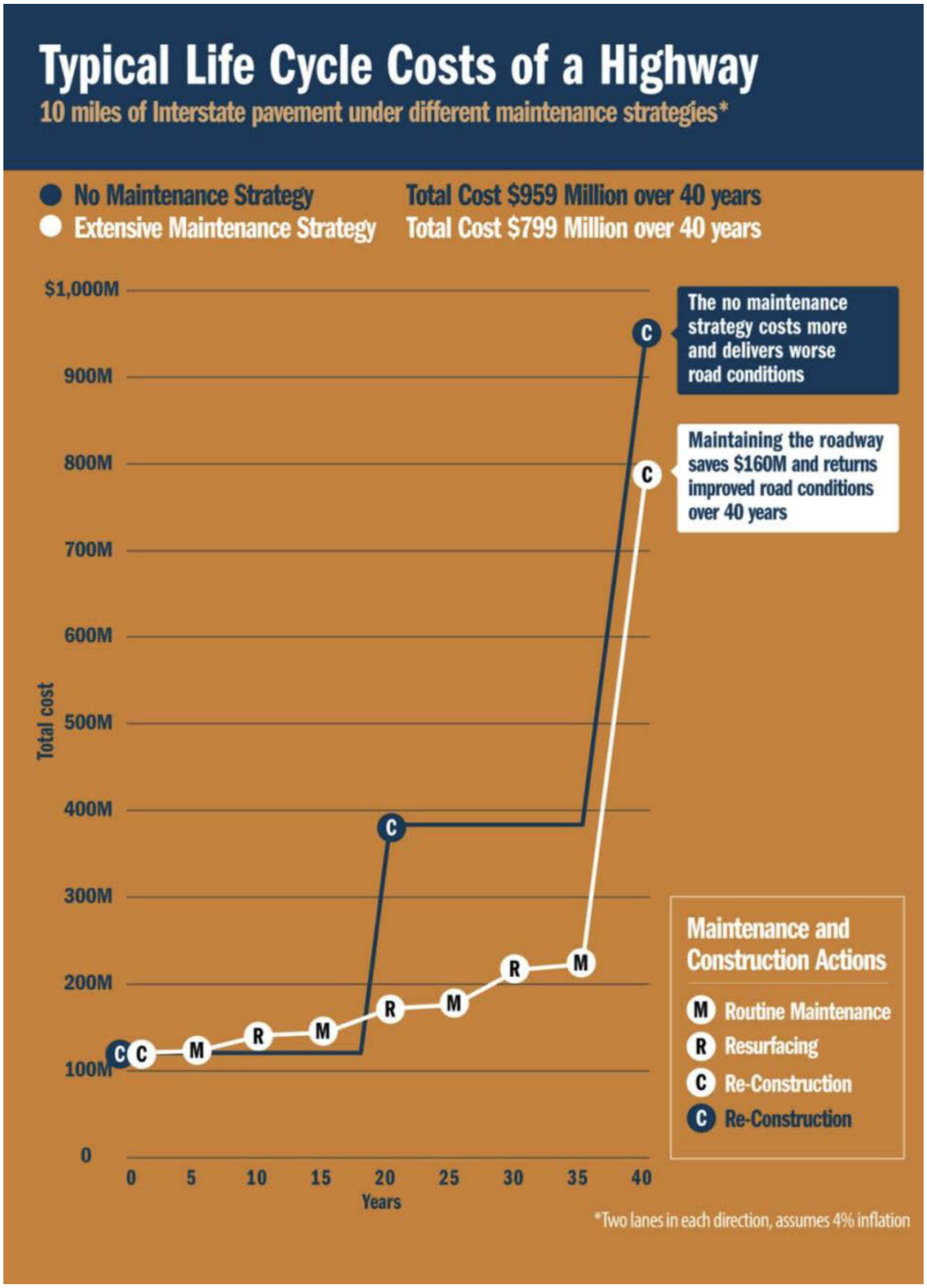
BRIDGE

% deck area by condition

Poor	Fair	Good

Minimum component rating

Life Cycle Planning at TxDOT



Maximizing Asset Life

Maximizing the life of a set of physical assets requires determining what treatments to perform on the assets over time. To make this determination, there must be knowledge of how the assets are likely to perform, how quickly they will deteriorate, and what treatments may potentially be performed on the assets. In evaluating different potential treatments, consideration should be given when different treatments are feasible, what each treatment costs, and how effectively it would maintain or even extend the life of the asset.

The process of analyzing these factors and defining the treatment strategy for a group of assets is called Life Cycle Planning (LCP). The underlying concepts of LCP are similar to Life Cycle Cost Analysis (LCCA). However, LCP is performed at a network level and yields an overall treatment strategy for an asset class or other grouping of assets. By contrast, LCCA is typically a more detailed analysis performed for a specific project or asset to compare different project alternatives.

About the Assets

The most significant assets on Texas's transportation system, in terms of their cost and extent, are pavements and bridges. A pair of two-page fact sheets summarize the inventory, conditions, and future performance of pavement and bridge assets.

Texas DOT Pavement Fact Sheet

Pavement Condition

TxDOT owns, maintains and operates approximately 201,225 lane miles of roads, which carry nearly 186 billion vehicle miles annually. Just over 32 percent of TxDOT lane miles are on the NHS system, while nearly 68 percent are not on the NHS.

On-System Pavement

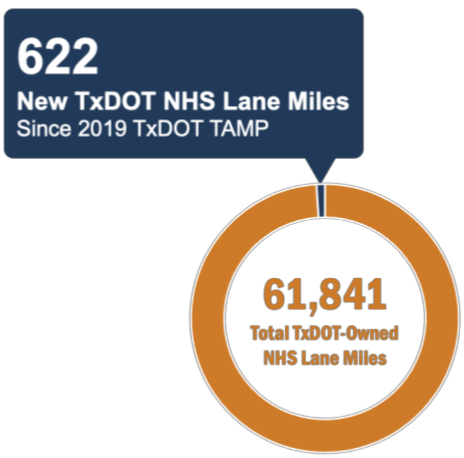
- **More than 89 percent** of On-System pavements have an Overall Condition of Good or Very Good
- **Less than 5 percent** have an Overall Condition of Poor or Very Poor

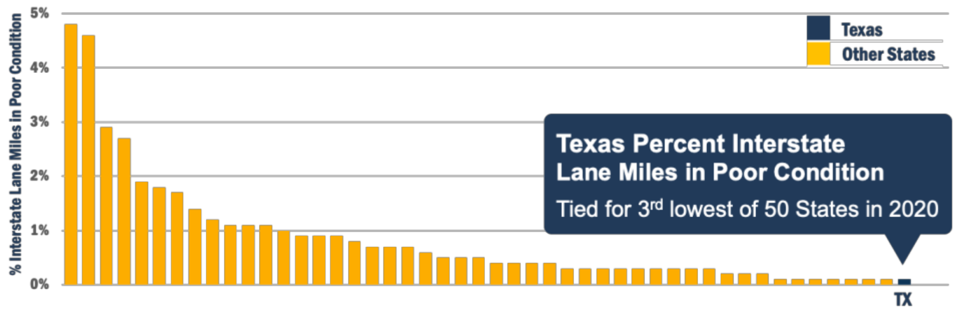
NHS Pavement

- **More than 52 percent** of pavements are in Good condition
- **Less than 1.1 percent** are in Poor condition.

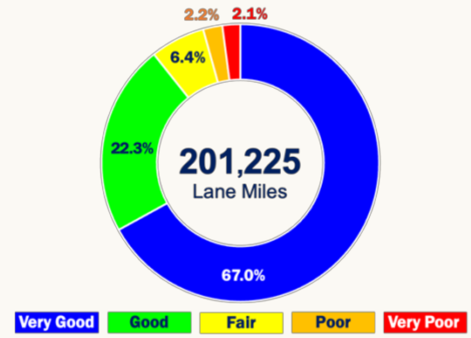
Preserving and Expanding the System

Texas has the second largest state economy in the nation. It is important that the state continue to develop and maintain its system of highways to support the population, vehicle, and freight movement demand on its highways. Highways that are not maintained in a state-of-good-repair (SOGR) will increase transportation costs for people and goods.

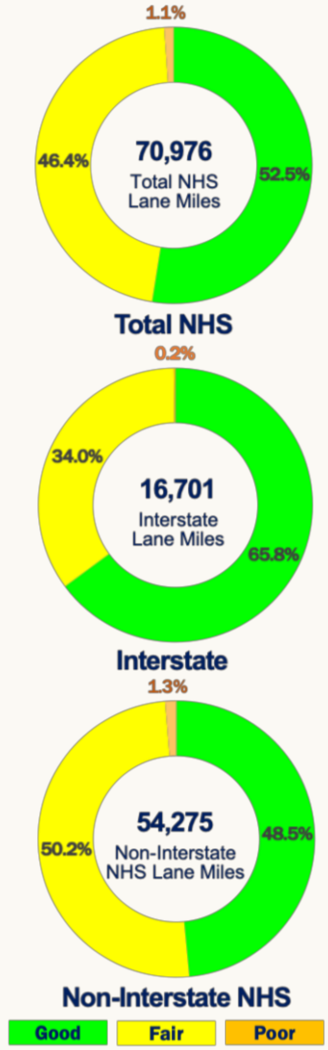




On-System Pavement



NHS Pavement



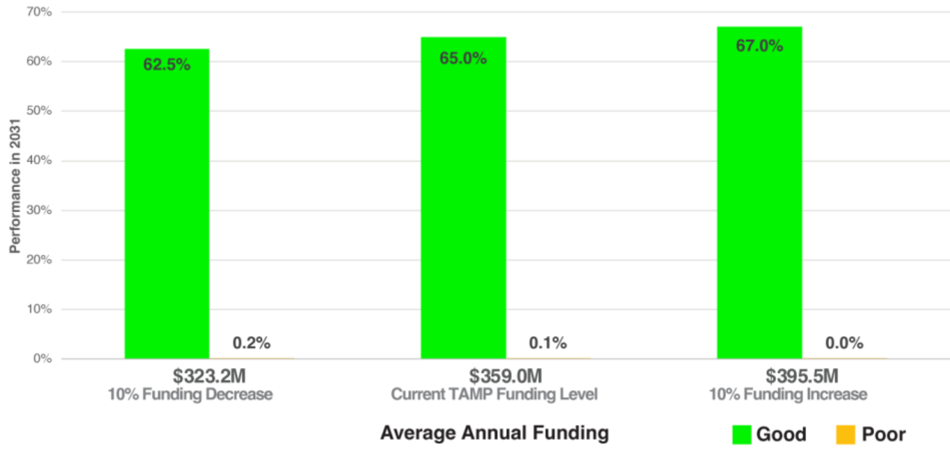
Texas DOT Pavement Fact Sheet

Pavement Performance Projections

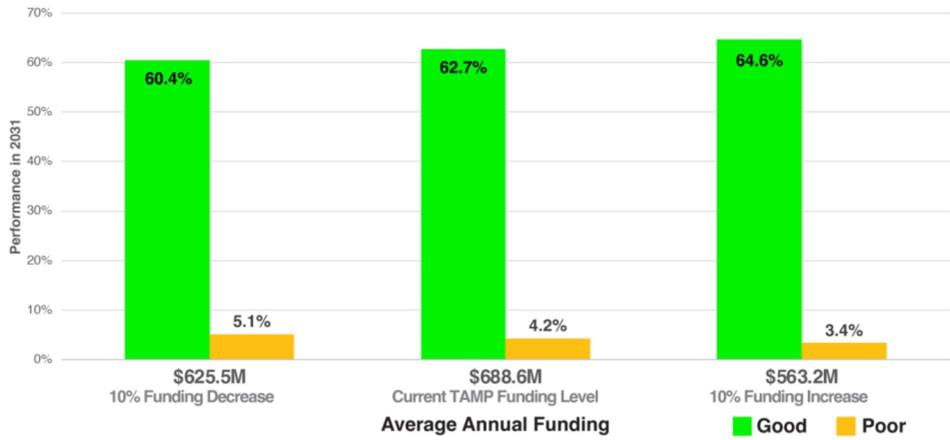
Pavement Performance Targets

Measure	2021 Actual	2022 Target	2022 Adjusted Target	FHWA Minimum Condition Threshold
Interstate				
% Good	64.9%	66.4%	66.5%	
% Poor	0.2%	0.3%	0.2%	5.0%
Non-Interstate NHS				
% Good (IRI only)	52.9%	52.3%	54.1%	
% Poor (IRI only)	14.7%	14.3%	14.2%	

Interstate Pavement – 2031 Performance Projections



Non-Interstate NHS Pavement – 2031 Performance Projections



Investing in Preservation

To sustain pavement performance to 2031 and beyond, TxDOT plans to invest $359 million in Interstate pavements and $625.5 million in non-Interstate NHS pavements, annually. Under this 10-year funding scenario:

- **Interstate pavement condition** is forecasted to improve. Pavements in good condition are predicted to increase from 64.9% to 65.0%, while pavements in poor condition are predicted to drop slightly from approximately 0.2% to 0.1%.
- **Non-Interstate NHS pavement condition** is forecasted to improve over the ten-year period. Pavements in good condition are predicted to increase from 52.9% to 62.7%, while pavements in poor condition are predicted to decline from 14.7% to 4.2%.

About the Measures

This fact sheet presents pavement performance projections according to federal measures of good and poor condition. While TxDOT's own pavement performance measures differ from these federal performance measures, TxDOT has successfully correlated the two sets of measures. This allows the agency to continue to pursue its time-tested approach to asset management, while also meeting federal requirements applied to all DOTs nationwide.

Texas DOT Bridge Fact Sheet

Bridge Condition

There are over 55,000 bridges in Texas listed on the National Bridge Inventory (NBI). Of these, 34,865 are owned and maintained by TxDOT with a total bridge deck area of over 445 million square feet. Nearly 18,000 of the over 55,000 bridges in Texas are on the NHS. TxDOT manages about 90% of the NHS bridges and 85% of the total NHS bridge deck area.

On-System Bridges

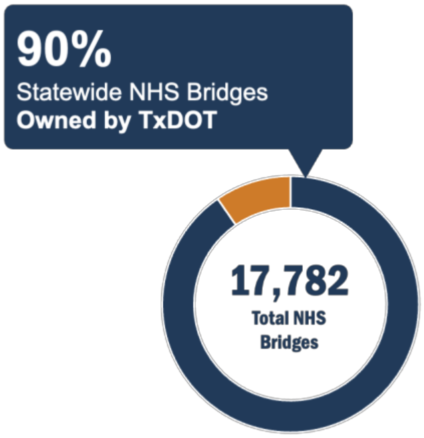
- **More than 48 percent** of on-system bridges are in Good condition
- **1 percent** of on-system bridges are in Poor condition

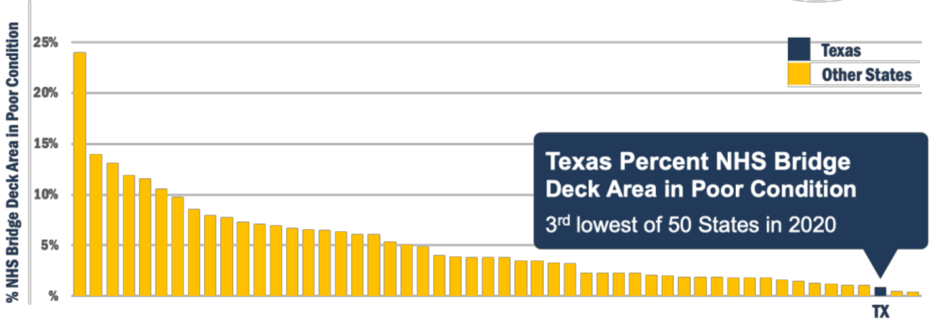
NHS Bridges

- **More than 49 percent** of NHS bridges are in Good condition
- **Less than 1 percent** of NHS bridges are in Poor condition.

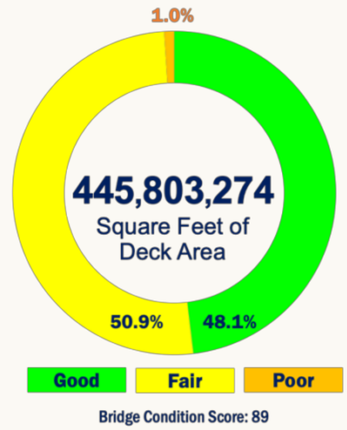
Preserving the System

Texas has the second largest state economy in the nation. It is important that the state continue to develop and maintain its bridge network to support the population, vehicle, and freight movement demand on its highways. Bridges that are not maintained in a state-of-good-repair (SOGR) will increase transportation costs for people and goods.

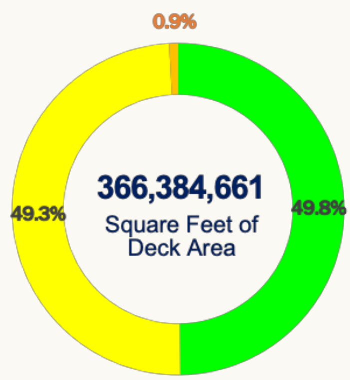




On-System Bridges



NHS Bridges



Federal Requirements

FHWA has defined a minimum condition threshold for NHS bridges in poor condition of 10%, meaning that states must ensure that bridges conditions are below 10% poor. Texas' bridge conditions fall well below this threshold, with only 0.9 percent of NHS deck area classified as poor.

Texas DOT Bridge Fact Sheet

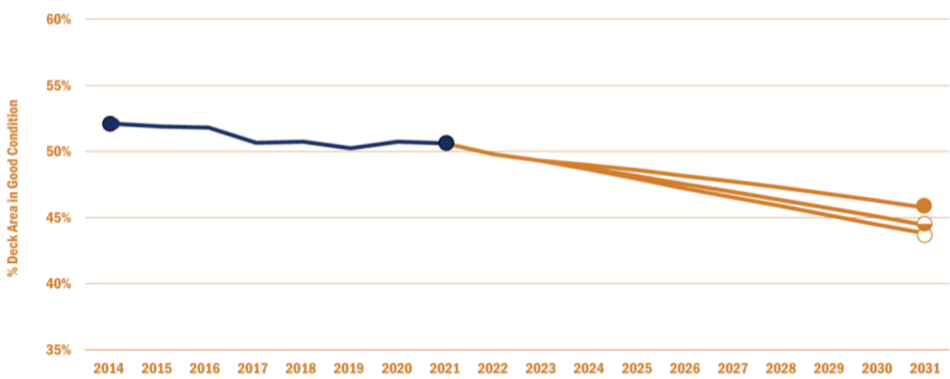
Bridge Performance Projections

Bridge Performance Targets

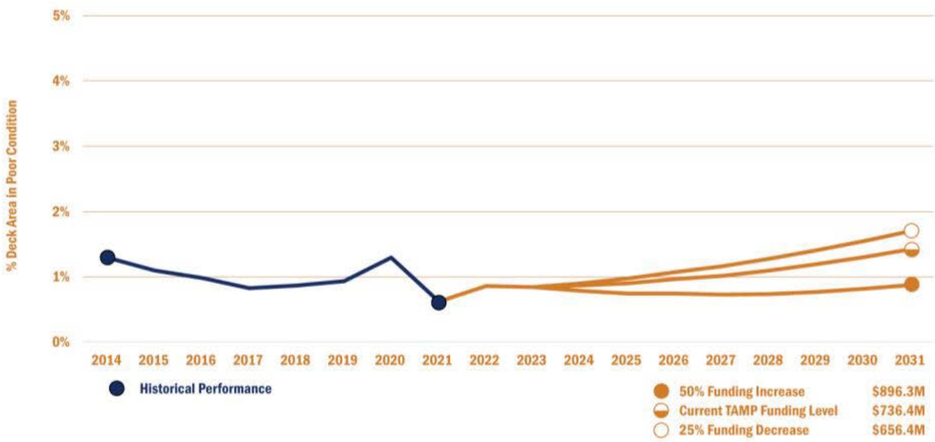
Measure	2021 Actual	2022 Target	2022 Adjusted Target	FHWA Minimum Condition Threshold
NHS Bridge				
% Good	49.8%	50.4%	50.4%	
% Poor	0.9%	0.8%	1.5%	10.0%

NHS Bridge Performance Projections

Good Condition



Poor Condition



Investing in Preservation

To sustain bridge performance to 2031 and beyond, TxDOT plans to invest $736.4 million in bridges, annually. Under this 10-year funding scenario:

- **NHS bridge condition** is forecasted to decline slightly over the ten-year period. Under the baseline funding scenario, the percent of NHS bridge deck area in good condition is predicted to drop from 49.8% to 44.3%, while the percent of bridge deck area in Poor condition is predicted to increase from 0.9% to 1.5%.

About the Measures

This fact sheet presents bridge performance projections according to federal measures of good and poor condition. While TxDOT's own bridge performance measures differ from these federal performance measures, TxDOT's network-level measure of bridge condition is called the Bridge Condition Score and is intended to capture overall network health. Bridge conditions are typically discussed as a function of all primary bridge components.

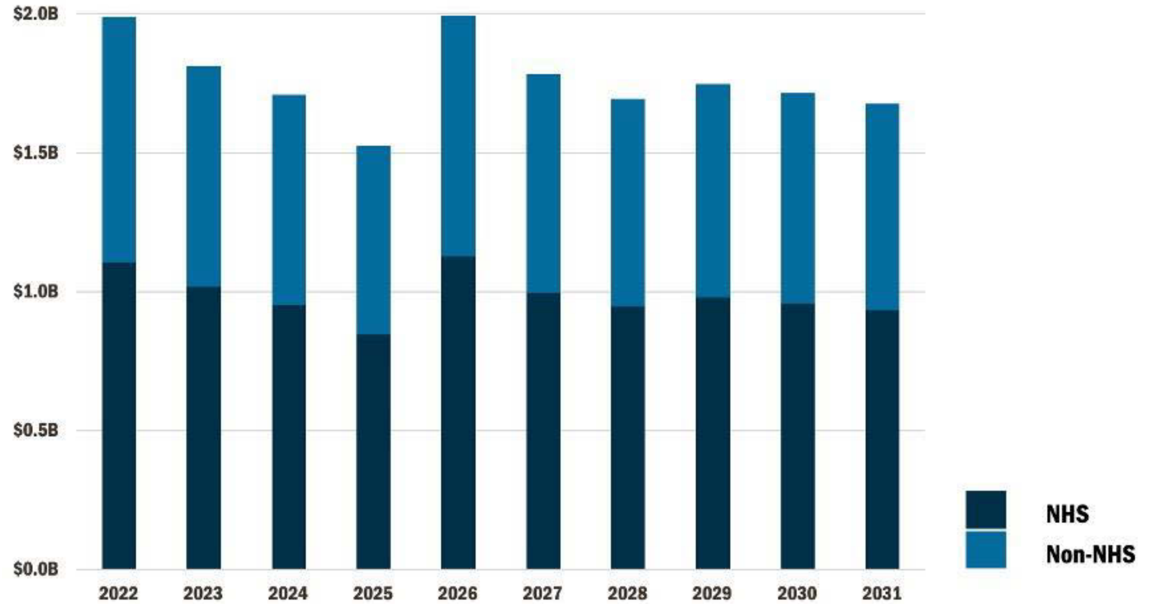
Risk and Resiliency

Risks appear in many forms at TxDOT, from extreme weather, availability of funding, growing use of the system due to rapid population increases, and internal agency processes, to availability of staff. Practicing resiliency at TxDOT means to quickly recover from disruptions through careful preparation, rapid response, and constant adaptation. TxDOT and other local transportation agencies have a long history of risk analysis imbedded in their standard operating processes that consider risks and ensure the safety of the traveling public. The TAMP includes mitigation strategies and actions for each of the identified risks listed below.

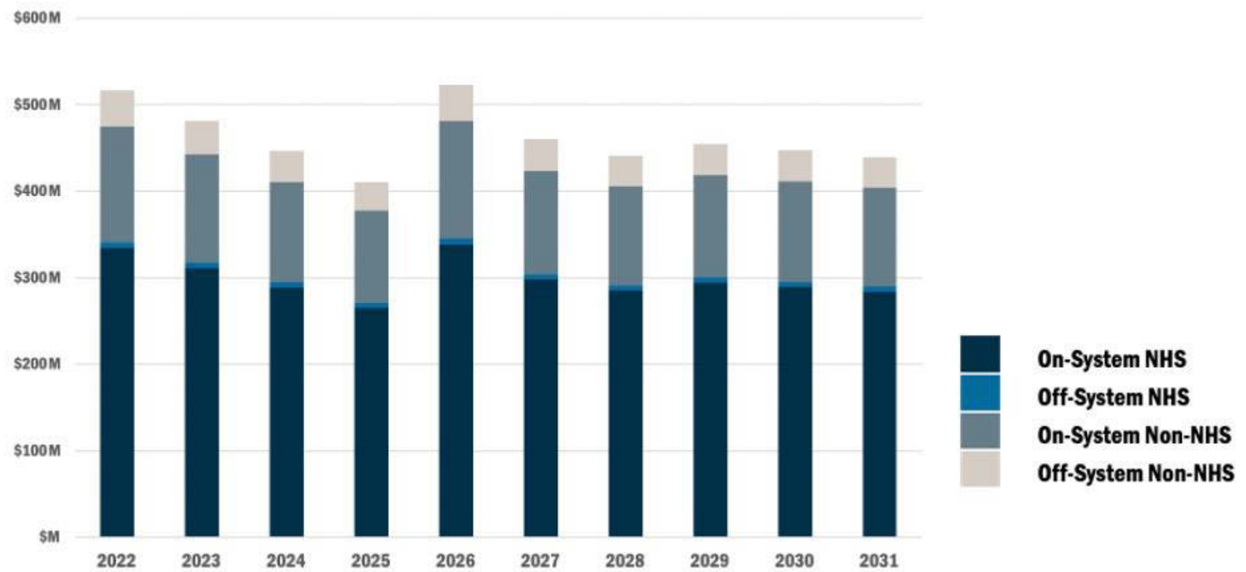
Risk (ID)	Description	Likelihood	Impact	Criticality Score	TxDOT Owner
Natural Disaster (1)	Occurrence of an unanticipated weather event or natural disaster (e.g. hurricane, tornado, snowstorm) resulting in system damage	4.5	4.25	19.1	Maintenance Division and Transportation Planning & Programming
Revenues & Funding (2)	Variability in revenue (sunset dates for Propositions 1 & 7 and FHWA reimbursement) and funding priorities cause variations in realized project delivery, project development, engineering, or construction	4.0	4.0	16.0	Transportation Planning & Programming Division and Finance Division
Heavy Truck Traffic (3)	Accelerated asset deterioration due to unexpected heavy truck traffic from increase in legal loads, energy sector or freight-intensive industry	3.75	4.0	15.0	Maintenance Division and Bridge Division
Material & Labor Costs (4)	Risk related to material and labor costs increasing unexpectedly	4.25	3.25	13.8	Construction Division
Staff Knowledge & Abilities (5)	Ability to maintain or develop staff knowledge and use of technology for asset management	3.75	3.5	13.1	Human Resources Division
Workforce Capacity (6)	Difficulty in project delivery execution with current workforce capacity	3.5	3.5	12.3	TxDOT Executive Leadership
Increasing Population (7)	Continued increases in state population accelerate existing asset deterioration	4.25	2.75	11.7	Maintenance Division
Long-Term Performance Decisions (8)	Slow to make decisions based on long term performance rather than short term gains	3.0	3.75	11.3	Maintenance Division and Bridge Division
Cyberattack (9)	Ransomware or cyberattack resulting in loss of data or network service	3.25	3.25	10.6	Information Technology Division
Public Health Emergency (10)	Occurrence of public health emergency which could affect funding, supply chain, and construction	2.75	3.25	8.9	Human Resources Division, Occupational Safety Division, and Strategic Planning Division

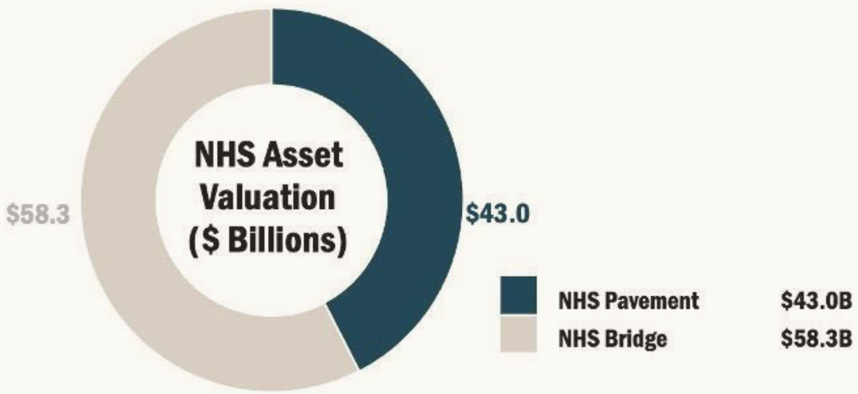
Investing in the Future

Texas's expected NHS pavement asset management expenditures total $9.9B over the period of the TAMP.



Texas's expected NHS bridge asset management expenditures are $4.4B over the period of the TAMP.





The TAMP includes an estimate of asset value for Texas pavement and bridge assets. The estimated current value of NHS system pavement assets is $43.0 billion, and the estimated current value of NHS bridges is $58.3 billion.

Moving Forward with the TxDOT TAMP

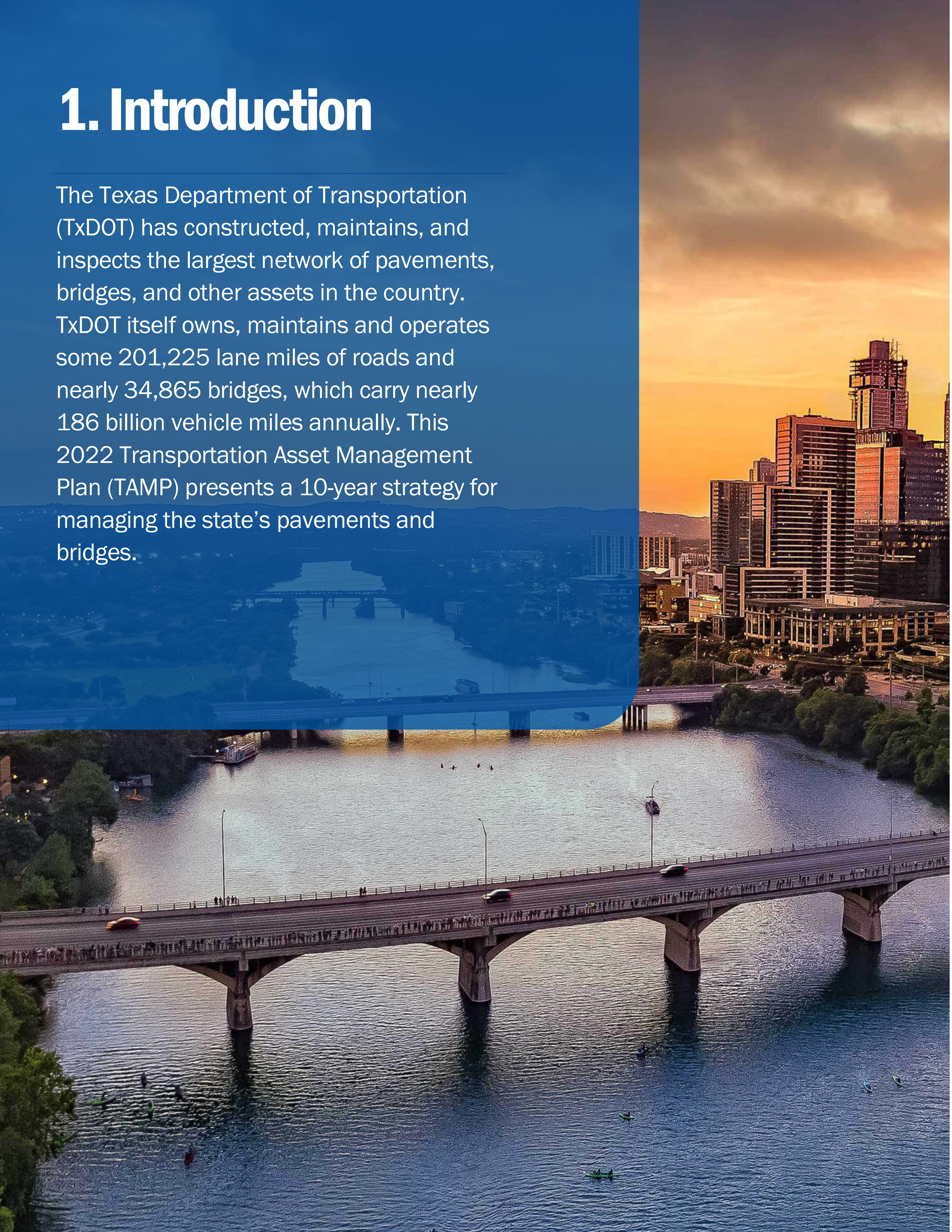
TxDOT has made strong progress in a number of TAMP implementation areas, including implementing its new bridge management system, moving from a worst-first approach to a preservation focus, development of four year pavement and bridge plans, and a number of resiliency efforts.

Opportunities for additional improvement include completing implementation of the BrM bridge management system, improving confidence in forecast of FHWA performance measures for NHS pavement, cross-asset prioritization, and increased coordination between TxDOT and stakeholders (e.g. MPOs, RPOs, local governments) for the TAMP. The series of risk mitigation strategies and actions are also a key part of the TAMP Implementation work.

TABLE OF CONTENTS

1. Introduction

The Texas Department of Transportation (TxDOT) has constructed, maintains, and inspects the largest network of pavements, bridges, and other assets in the country. TxDOT itself owns, maintains and operates some 201,225 lane miles of roads and nearly 34,865 bridges, which carry nearly 186 billion vehicle miles annually. This 2022 Transportation Asset Management Plan (TAMP) presents a 10-year strategy for managing the state's pavements and bridges.



Overview

In its capacity as steward of the transportation network, TxDOT is responsible for, among other things, ensuring both the safety of the traveling public and the effective long-term operation of infrastructure assets. Effective long-term operation of the infrastructure is regularly achieved through Transportation Asset Management. Transportation Asset Management (TAM) relies on data-driven decision-making to choose the right improvements at the right time in an asset's life-cycle in order to sustain a desired level of performance in the most cost-effective way.

The Texas Transportation Commission has established asset management condition goals for TxDOT's roads and bridges of 90 percent good or very good. TxDOT outlines in its agency goals and objectives several priorities that coincide with the goals of transportation asset management. Those goals are:

- Deliver the Right Projects
- Foster Stewardship
- Optimize System Performance
- Preserve our Assets

One key element in TxDOT's asset management efforts is development of the 10-year Unified Transportation Program (UTP). The UTP strikes a strong balance between top-down data-driven investment decision making and bottom-up input from the public, district offices, and local and regional transportation partners. The UTP has proven to be a highly effective tool in the effort to keep roads and bridges in good condition, as demonstrated by the fact that nearly 90 percent of the roads TxDOT is responsible for are in good or very good condition and fewer than five percent of its bridges are in poor condition.

TxDOT's performance measures do not precisely align with the federal performance measures of Good, Fair and Poor, but TxDOT has conducted analysis and developed a matrix to correlate the two sets of measures. This allows the agency to continue to pursue its time-tested approach to asset management, while also meeting federal requirements applied to all DOTs nationwide.

This document, developed to help meet those federal requirements, will help provide an understanding of TxDOT's asset management approach, and describes the condition of the transportation system, future investment plans, potential risks to effective operation of the network, the relationship between the federal and state condition goals, and TxDOT's success in addressing those goals.

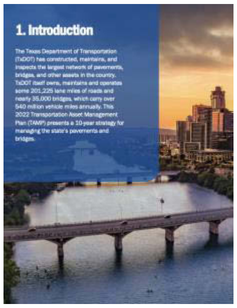
About the TAMP

This 2022 TAMP updates the previous plan released in 2019, as required by federal law. It is intended to meet federal requirements enacted through recent transportation funding bills (MAP-21 and the FAST Act). Federal law requires each state to "develop and implement a Risk Based Asset Management Plan for the National Highway System (NHS) to improve or preserve the condition and performance of the system." Highways on the NHS system are mostly owned, maintained, and operated by TxDOT; however, a portion of the NHS system is under the jurisdiction of cities, counties, and toll authorities.

The Federal Highway Administration (FHWA) has provided states with requirements for TAMP development and implementation. Core components of the plan include Life Cycle Planning, Risk Management, Financial Planning, and Investment Strategies. As part of the national TAMP effort, FHWA has also adopted performance measures for pavements and bridges. Some of these performance measures cannot be directly correlated with TxDOT's historic pavement and bridge performance measures. This document will help explain the relationship between the state and federal measures and demonstrate how they can work together to achieve the goal of infrastructure asset management.

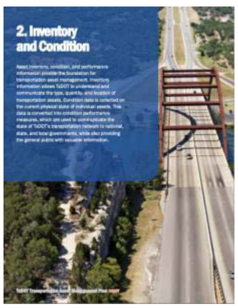
TAMP Organization

The 2022 TxDOT TAMP includes seven chapters.



Introduction

This chapter summarizes the context, scope, and organization of the 2022 TxDOT TAMP. It discusses relevant federal requirements and describes how the TAMP satisfies these requirements.

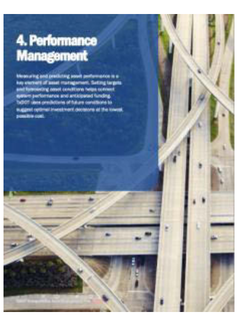


Inventory and Condition

This chapter summarizes the inventory and condition of TxDOT-owned and NHS pavements and bridges. Asset inventory, condition, and performance information provide the foundation for transportation asset management. Inventory information allows TxDOT to understand and communicate the type, quantity, and location of transportation assets. Condition data is collected on the current physical state of individual assets. This data is converted into condition performance measures, which are used to communicate the state of TxDOT's transportation network to national, state, and local governments, while also providing the general public with valuable information.

Life Cycle Planning

This chapter describes the agency's life cycle planning approach for its pavement and bridges. Effective life cycle planning (LCP) is an essential process of TAM. The goal of LCP is to determine what treatments to perform on an asset over its life from initial construction through its replacement or retirement in order to maintain the asset in the most efficient and cost-effective manner, while providing the desired level of service. As evidenced by the condition of the asset inventory described in the previous chapters, TxDOT has been very successful in developing life cycle plans for its assets and putting these plans into action.



Performance Management

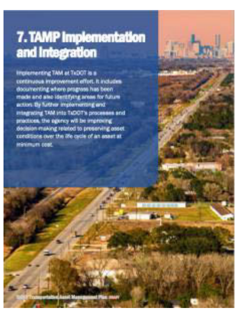
This chapter summarizes TxDOT's measures of asset condition for pavements and bridges, lists performance targets, provides predictions of future performance, and addresses performance gaps. Measuring and predicting asset performance is a key element of asset management. Setting targets and forecasting asset conditions helps connect system performance and anticipated funding. TxDOT uses predictions of future conditions to suggest optimal investment decisions at the lowest possible cost.

Risk Management

This chapter summarizes the TxDOT approach for asset risk management. Risk management at TxDOT means identifying, studying, and managing the risks that could impact the performance of the state's bridge and pavement assets. The application of risk management informs decisions throughout the agency on topics from the safety of the public and staff employees to system performance and project delivery. Practicing resiliency is a key element of the way that TxDOT does business, building the capability to quickly recover from disruptions through careful preparation, rapid response, and constant adaptation. Risk management is adopted and applied across all agency levels for an institutional response to prevent the worst risks from materializing. Year after year, TxDOT learns from the risks that occur and adapts our procedures to prevent and minimize the effects. Through a structured risk management process and continual learning, TxDOT is in a much better position to handle the risks faced and future challenges with the resources at hand.

Financial Plan and Investment Strategies

This chapter summarizes the cost of future programmed work to implement the investment strategies outlined in this asset management plan and expected levels of funding over a 10-year period. The financial plan communicates the revenues available for asset management and how TxDOT expects to allocate them to assets and work types. The investment strategies bring together the asset performance projections and targets, life cycle planning, and risk mitigation strategies and actions with the available financial resources to make progress towards achieving state and federal performance goals.

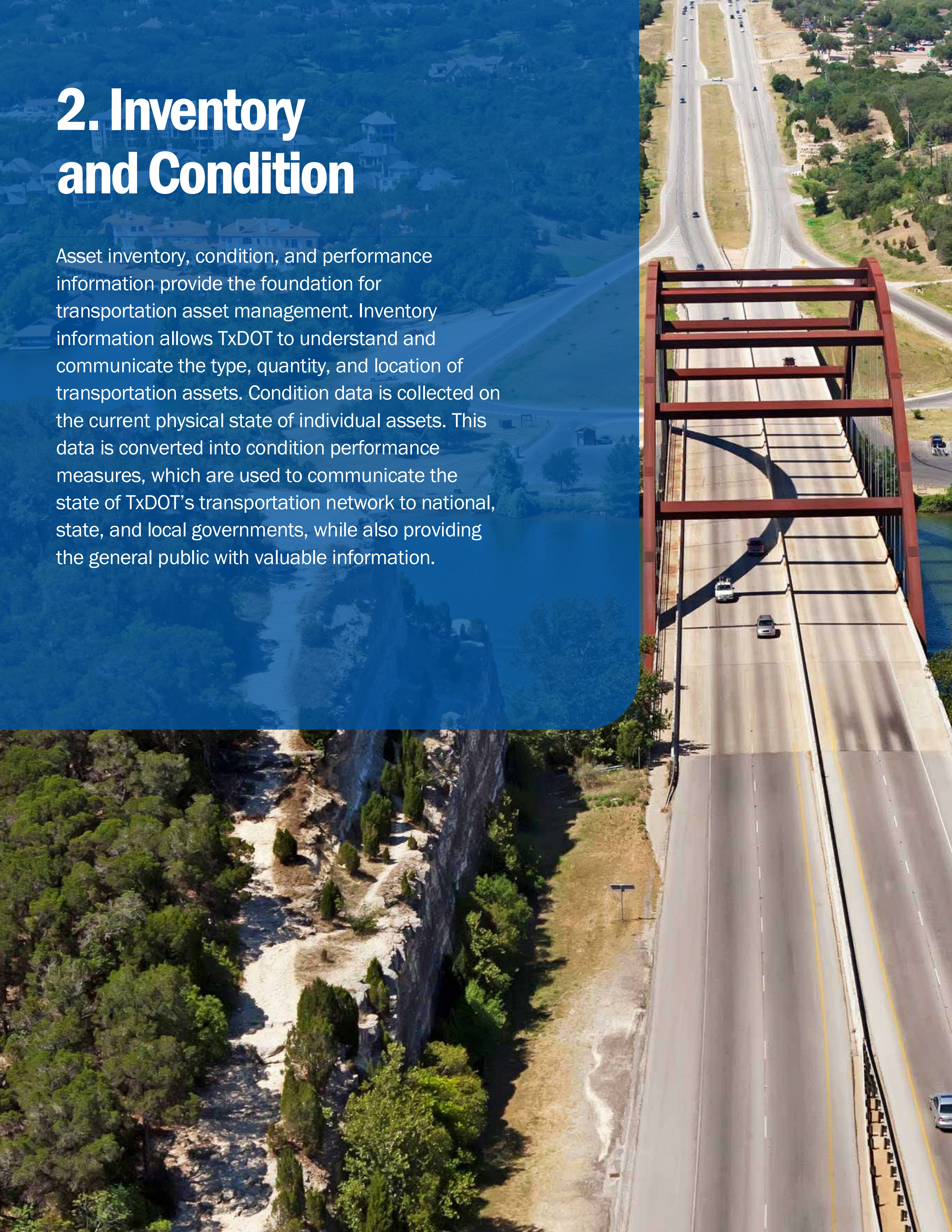


Implementation Plan

This chapter presents TxDOT's plan for continuing to implement TAM and the TAMP over the next four years. Implementing TAM at TxDOT is a continuous improvement effort. It includes documenting where progress has been made and also identifying areas for future action. By further implementing and integrating TAM into TxDOT's processes and practices, the agency will be improving decision-making related to preserving asset conditions over the life cycle of an asset at minimum cost.

2. Inventory and Condition

Asset inventory, condition, and performance information provide the foundation for transportation asset management. Inventory information allows TxDOT to understand and communicate the type, quantity, and location of transportation assets. Condition data is collected on the current physical state of individual assets. This data is converted into condition performance measures, which are used to communicate the state of TxDOT's transportation network to national, state, and local governments, while also providing the general public with valuable information.



System Summary

The Texas highway transportation system includes assets owned and operated by several federal agencies, state agencies, tribal governments, cities, counties, toll authorities, and public/private partnerships. Highways on the NHS system are mostly owned, maintained, and operated by TxDOT; however, a portion of the NHS system is under the jurisdiction of cities, counties, and toll authorities.

This TAMP presents the data for both NHS and the state-owned pavements and bridges, and also identifies and clarifies differences between FHWA and TxDOT criteria. FHWA requirements for network segmentation, asset condition evaluation, and performance measurements differ in some ways from Texas' existing processes. While the focus of the TAMP is the NHS and federal performance measures, TxDOT also manages the entire TxDOT-owned system using state performance measures. Changes to the NHS inventory since the previous TAMP may be the result of multiple factors, including system expansion and an NHS review conducted with TxDOT Districts and MPOs which added some assets to the NHS system. TxDOT-owned assets are summarized in Figure 2-1 using state performance measures. NHS assets are summarized in Figure 2-2 using FHWA performance measures.

TxDOT-Owned Assets – Inventory and Condition: State Performance Measures

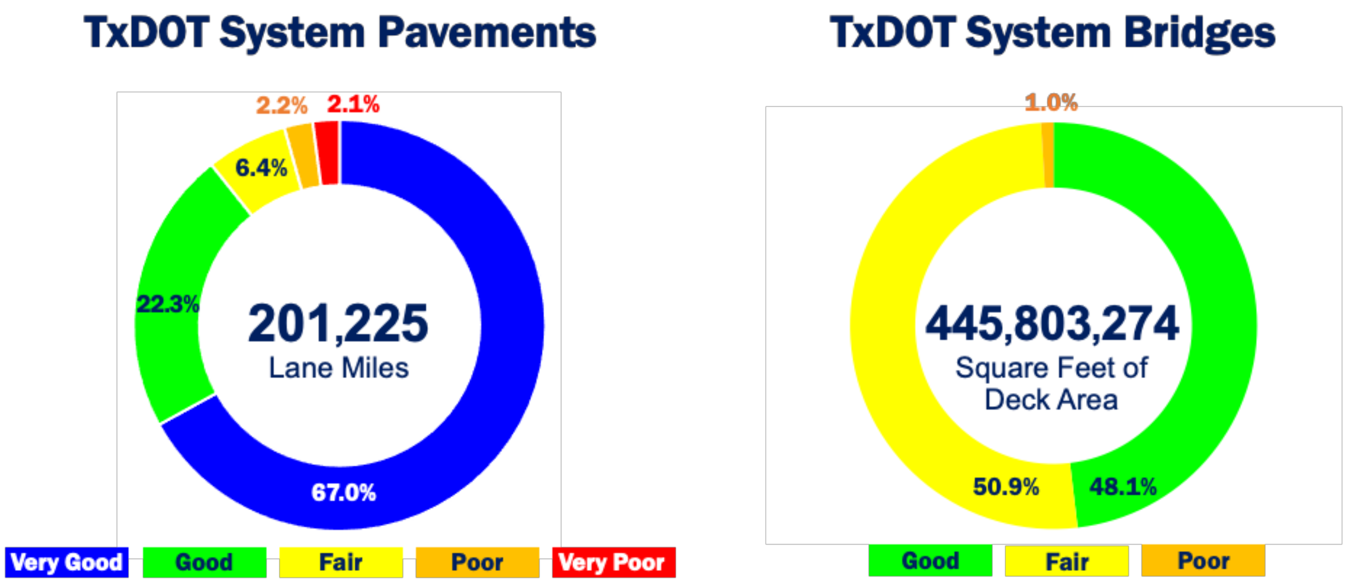


Figure 2-1. Summary of TxDOT System Pavement and Bridge Condition

National Highway System Assets – Inventory and Condition: Federal Performance Measures

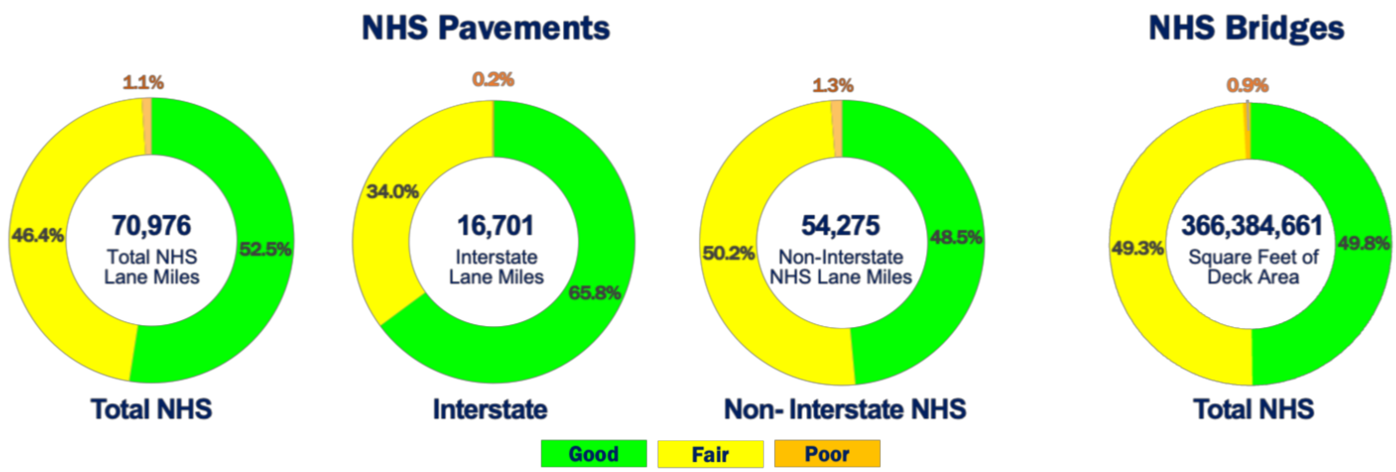


Figure 2-2. NHS Pavement and Bridge Condition

How TxDOT Measures Performance

TxDOT uses different measures of asset condition for TxDOT-owned and NHS assets. State-owned and maintained assets, referred to as on-system in this TAMP, are measured using state performance measures, while NHS assets are measured using performance measures established by FHWA. Certain assets are measured using both state and federal performance measures. For example, on-system pavement on the NHS would use TxDOT measures and FHWA measures.

TxDOT Performance Measures

TxDOT's performance measures for state-owned assets are the measures used to manage the system, drive decision-making, and track progress on state goals.

TxDOT tracks 18 performance measures across four categories on its public performance dashboard. The TAMP includes two of the asset performance measures: state pavement condition and state bridge condition.

Why We Measure

TxDOT manages the state-owned system using these measures. Asset condition is a key input to the capital decision-making process.

What We Measure

All state-owned pavements and bridges

How We Measure

PAVEMENT

% lane miles by condition

Very Poor	Poor	Fair	Good	Very Good

Based on Ride Score (roughness) and Distress Score (surface distresses)

BRIDGE

Bridge condition score

50 — 95

Network-level rating from 50 to 95 weighted by deck area

Federal Performance Measures

Federal performance measures for NHS pavements and bridges are required for use by state DOTs to carry out the National Highway Performance Program (NHPP).

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 TAMP.

Why We Measure

Federal measures are used to compare performance across states and to determine federal funding flexibility.

What We Measure

All NHS pavements and bridges (regardless of owner)

How We Measure

PAVEMENT

% lane miles by condition

Poor	Fair	Good

Based on roughness and three distress metrics

BRIDGE

% deck area by condition

Poor	Fair	Good

Minimum component rating

Pavement

Inventory and Condition

TxDOT-Owned Pavement

TxDOT owns, maintains, and operates approximately 201,225 lane miles of roads, which carry nearly 186 billion vehicle miles annually. Table 2-1 and Figure 2-3 show TxDOT-owned pavement inventory information. Just over 30 percent of TxDOT lane miles are on the NHS system, while nearly 70 percent are not on the NHS. Texas is one of a few states that has a relatively large portion of state-owned pavements that are not on the NHS, indicating the magnitude of the state-owned system and the challenge of managing a wide variety of pavement assets. Condition data exclude miles missing or invalid data.

Table 2-1. TxDOT Pavement Inventory and Condition

TxDOT System	Inventory	Very Good	Good	Fair	Poor	Very Poor
Total	**201,225** Lane miles	**67.0%**	**22.3%**	**6.4%**	**2.2%**	**2.1%**
TxDOT NHS	**61,841** Lane miles	**69.5%**	**19.7%**	**6.0%**	**2.4%**	**2.4%**
Interstate	**16,701** Lane miles	**76.8%**	**16.1%**	**4.4%**	**1.7%**	**1.0%**
Non-Interstate NHS	**45,140** Lane miles	**66.8%**	**21.0%**	**6.6%**	**2.7%**	**2.9%**

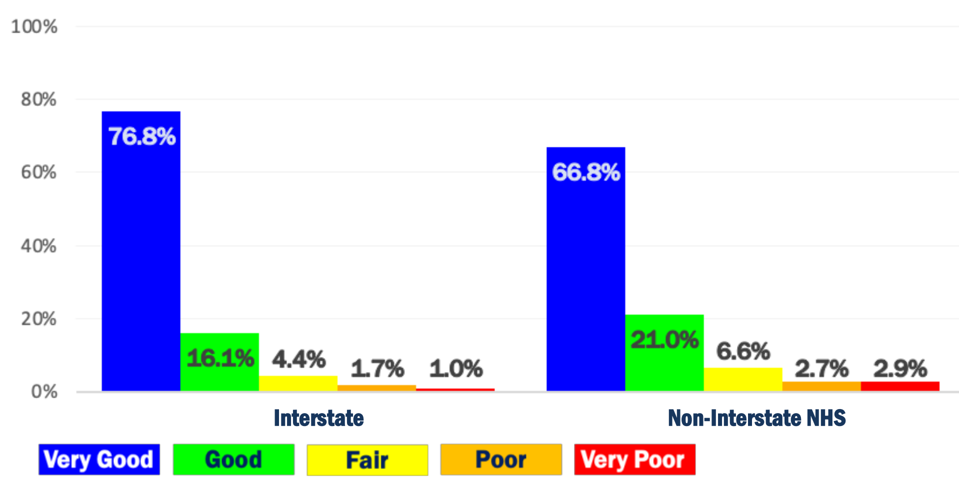


Figure 2-3. Condition of TxDOT-Owned Pavement, Separated by System Status

National Highway System Pavement

Table 2-2 and Figure 2-4 show pavement lane miles for the NHS in Texas. TxDOT-owned NHS mileage totals 61,841 lane-miles (Interstate and Non-Interstate). Off-system pavement mileage for the NHS in Texas is 9,135, which means about 12.9 percent of the NHS is owned, maintained, and operated by non-TxDOT entities including cities, counties, and toll authorities. Figure 2-5 shows the lane miles of pavements owned and operated by non-TxDOT or off-system entities. Note that Interstate frontage roads are not included in the NHS.

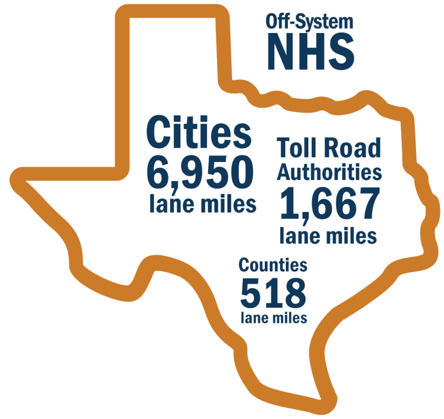


Table 2-2. NHS Inventory and Condition

Owner	NHS	Inventory	Good	Fair	Poor
All	**NHS**	**70,976** Lane miles	**52.5%**	**46.4%**	**1.1%**
TxDOT	Interstate	16,701 Lane miles	65.8%	34.0%	0.2%
All	**Non-Interstate NHS**	**54,275** Lane miles	**48.5%**	**50.2%**	**1.3%**
TxDOT	Non-Interstate NHS	45,140 Lane miles	54.4%	45.2%	0.4%
Other	Non-Interstate NHS	9,135 Lane miles	19.1%	74.9%	6.0%

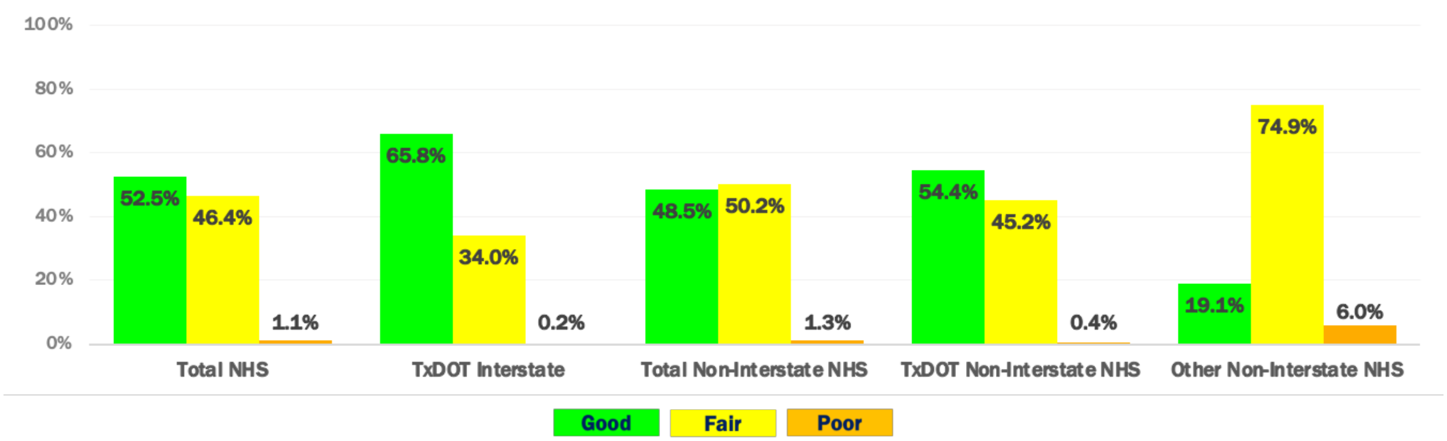


Figure 2-4. Condition of NHS Pavement, Separated by System and Ownership

FHWA has defined a minimum condition threshold for Interstate pavements in poor condition of 5%, meaning that states must ensure that Interstate conditions are below 5% poor. If FHWA determines a state DOT to be out of compliance, the state must obligate and set aside funding for eligible projects on the Interstate. This funding requirement will remain in effect each year until the state is in compliance. Texas' Interstate conditions fall well below this threshold, with only 0.2 percent of Interstate lane miles classified as poor.

Pavement Performance Measures

TxDOT and FHWA both use numerous performance measures for assessing pavement asset condition in Texas. Texas uses a condition score rating to manage the on-system assets and make investment decisions. In addition, the NHS is assessed using a separate performance measure defined by FHWA, which allows for comparisons between states.

Measuring Performance on the TxDOT System

TxDOT collects pavement data on the entire state-maintained network annually through an automated/semi-automated survey, using three-dimension laser technology and high-resolution cameras to provide 1/32 inch (1mm) transversal accuracy. TxDOT changed its reporting interval in 2017 from 0.5-mile to 0.1-mile to meet the federal HPMS data reporting requirements. More granular pavement data makes tracking FHWA performance measures for the NHS possible. More importantly, five years of pavement data have been accumulated, which establishes the baseline needed for pavement performance target setting.

The off-system NHS and Highway Performance Monitoring System (HMPS) samples are also collected with the on-system network under the same contract. The off-system NHS data is shared with MPOs for planning and program purposes.

TxDOT measures pavement conditions for on-system roads using an overall Condition Score, which is developed based on the two other measures calculated by TxDOT: Distress Score (surface condition) and Ride Score (pavement roughness). The Condition Score, ranging from 1-100, is a combination of the Distress Score and Ride Score and represents the overall condition of the pavement. TxDOT reports the condition of its pavements on an annual basis using these scores.

Table 2-3 provides a conversion from the Distress Score, Ride Score, and Condition Score to a descriptive class used by TxDOT to communicate the condition of pavements from a surface condition standpoint. This TAMP uses Condition Score as the primary measure of pavement condition.

Table 2-3. TxDOT Pavement Performance Thresholds

Metric	Very Good	Good	Fair	Poor	Very Poor
Condition Score	**90-100**	**70-89**	**50-69**	**35-49**	**1-34**
Distress Score	90-100	80-89	70-79	60-69	1-59
Ride Score	4.0-5.0	3.0-3.9	2.0-2.9	1.0-1.9	0.1-0.9

Measuring Performance on the NHS

NHS pavement conditions are further evaluated using performance measures defined by FHWA. The measures are calculated based on metrics for ride quality (measured using IRI) and pavement surface distress. The metrics and performance thresholds vary depending on whether the pavement is asphalt concrete pavement (ACP), jointed concrete pavement (JCP), or continuously reinforced concrete pavement (CRCP).

Table 2-4 shows criteria for pavements designated as being in Good, Fair, or Poor condition. A pavement section (0.1-mile in length) is classified as Good condition if all the metrics shown in Table 2-4 are good. The rating of a section will be Poor if two or more metrics are evaluated as poor. All other pavement sections are rated Fair.

Table 2-4. Federal Requirements for Pavement Condition Thresholds

Metric	Good	Fair	Poor
IRI (inches/mile) (all types)	<95	95-170	>170
Cracking (%)			
Asphalt Concrete Pavement	<5	5-20	>20
Jointed Concrete Pavement	<5	5-15	>15
Continuously Reinforced Concrete Pavement	<5	5-10	>10
Faulting (inches) (JCP only)	<0.10	0.10-0.15	>0.15
Rutting (inches) (ACP only)	<0.20	0.20-0.40	>0.40

Bridges

Inventory and Condition

TxDOT-Owned Bridges

There are over 55,000 bridges in Texas listed on the National Bridge Inventory (NBI), with 34,865 owned and maintained by TxDOT. The NBI is a federal database that includes all structures longer than 20 feet and open to public vehicular traffic. TxDOT oversees the inspection of all Texas NBI bridges in accordance with National Bridge Inspection Standards (NBIS) and has been collecting bridge inventory data for decades. Bridge inventory and condition data can be represented by number of bridges and by bridge deck area. Table 2-5 and Figure 2-6 shows the breakdown of state-owned bridge inventory. TAMP inventory and condition data is based on TxDOT's 2021 NBI submittal.

Table 2-5. TxDOT Inventory and Condition

TxDOT System	Bridge Count	Deck Area	Good	Fair	Poor
Total	34,865 Bridges	445,803,274 Square feet	48.1%	50.9%	1.0%
NHS	16,072 Bridges	311,179,899 Square feet	46.7%	52.5%	0.8%
Non-NHS	18,793 Bridges	134,623,375 Square feet	51.4%	47.3%	1.3%

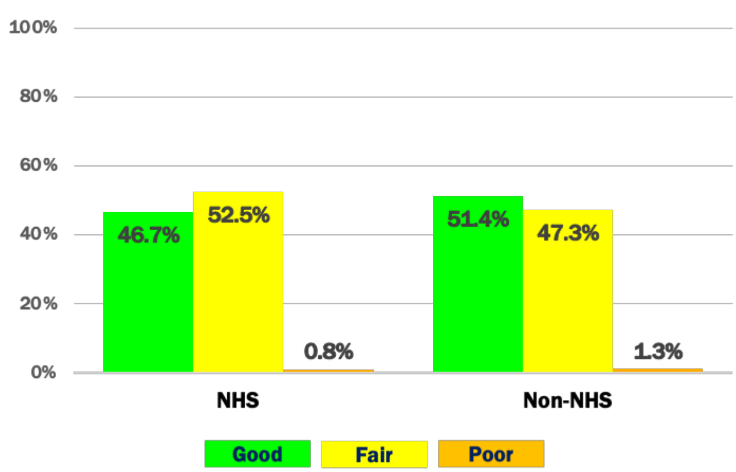


Figure 2-6. Condition of TxDOT-Owned Bridges, Separated by System Status

National Highway System Bridges

Nearly 18,000 of the over 55,000 bridges in Texas are on the NHS. TxDOT manages about 90% of the NHS bridges and 85% of the total NHS bridge deck area. Table 2-6 and Figure 2-7 show the breakdown of NHS bridge inventory. TAMP inventory and condition data is based on TxDOT's 2021 NBI submittal.

Table 2-6. NHS Inventory and Condition

Owner	Bridge Count	Deck Area	Good	Fair	Poor
Total	17,782 Bridges	366,384,661 Square feet	49.8%	49.3%	0.9%
TxDOT	16,072 Bridges	311,179,899 Square feet	46.7%	52.5%	0.8%
Other	1,710 Bridges	55,204,762 Square feet	67.4%	31.6%	1.0%

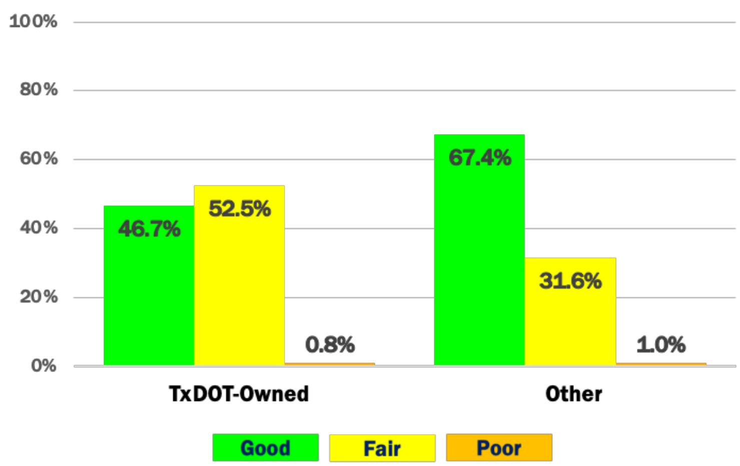


Figure 2-7. Condition of NHS Bridges Owned by TxDOT and Other Agencies

FHWA has defined a minimum condition threshold for NHS bridges in poor condition of 10%, meaning that states must ensure that bridge conditions are below 10% poor. If FHWA determines a state DOT to be out of compliance, the state must obligate and set aside funding for eligible projects on bridges on the NHS. This funding requirement will remain in effect each year until the state is in compliance. Texas' bridge conditions fall well below this threshold, with only 0.9 percent of NHS deck area classified as poor.

Bridge Performance Measures

TxDOT and FHWA both use numerous performance measures for assessing the health of Texas' bridge network. Network-level performance evaluations in Texas are executed by TxDOT's Bridge Division and are used to communicate with several key stakeholders including FHWA, state policymakers, the Texas Transportation Commission, TxDOT's Administration, TxDOT Districts, and the public.

Measuring Performance on the Texas Bridge Inventory

TxDOT's network-level measure of bridge condition is called the Bridge Condition Score and is intended to capture overall network health. Bridge conditions are typically discussed as a function of all primary bridge components. Bridges are composed of the following primary components, as listed in the NBI: deck, superstructure, substructure, and culvert. For bridge-class culverts, only the culvert condition rating is considered.

Each bridge is given a score between 50 and 95 based on its lowest rated NBI component. A composite Bridge Condition Score for the network is calculated as the average of each individual bridge's numeric score, weighted by deck area. Table 2-7 defines how a bridge's minimum component rating dictates the corresponding numeric score and letter score.

Table 2-7. TxDOT Bridge Condition Score Groups

Numeric Score (Letter Grade)	95 (A)	85 (B)	75 (C)	65 (D)	50 (F)
Minimum Component Rating	7 or greater	6	5	3 or 4	2 or less

TxDOT also uses measures defined by FHWA using NBI bridge component condition data to rate TxDOT bridge conditions as Good, Fair or Poor, as described below.

Measuring Performance on the NHS

FHWA has defined performance measures to be evaluated for each state's NHS bridge inventory:

- Percent of NHS bridge deck area in good condition
- Percent of NHS bridge deck area in poor condition

FHWA's two federal performance measures are a function of NBI ratings for primary bridge components: deck, superstructure, substructure, or culvert. Based on the minimum NBI component condition for each of these four items, a bridge is assigned an overall condition rating of good, fair, or poor.

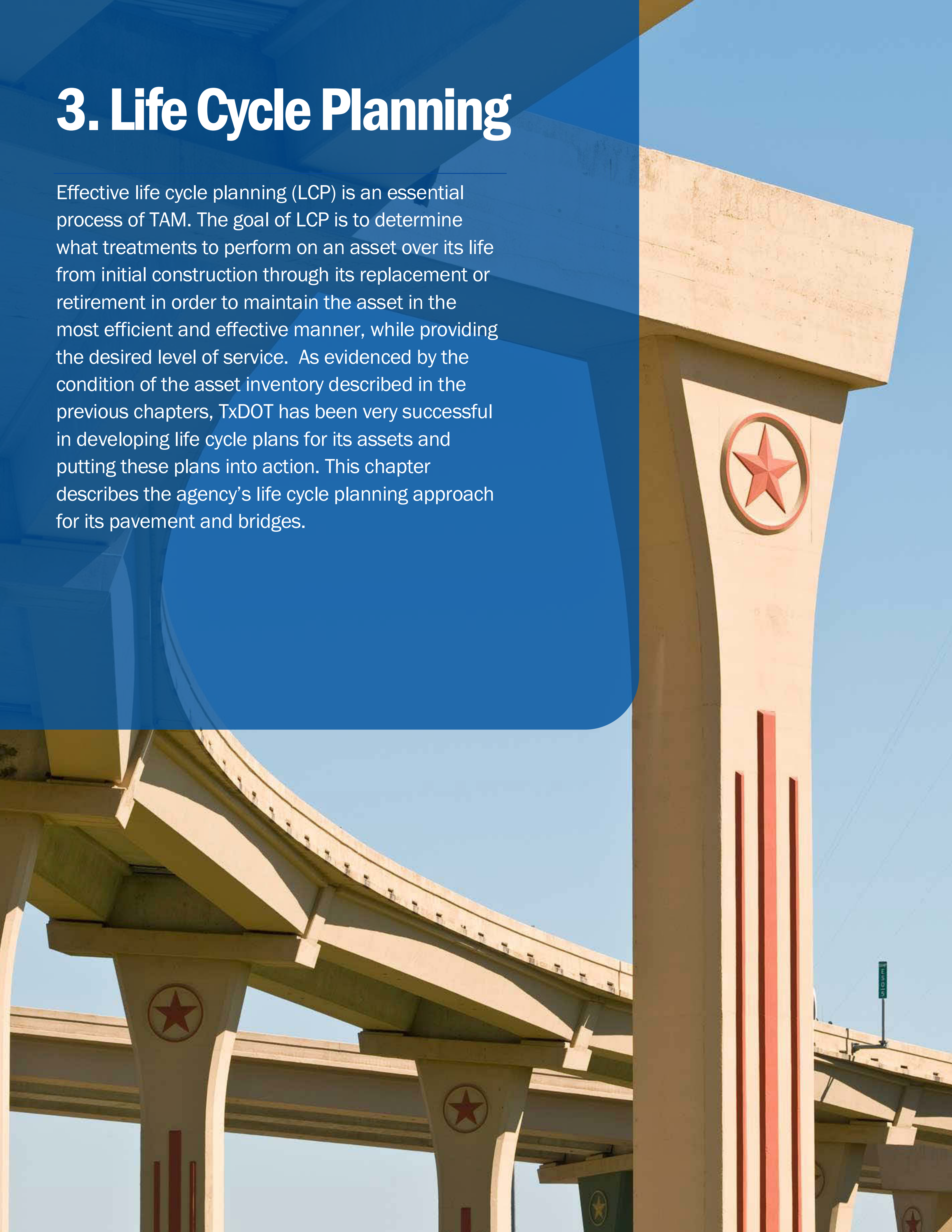
Table 2-8 shows how a bridge is classified as good, fair, or poor based on the criteria. At the network level, conditions are summarized by calculating the percent of bridge deck area in good, fair, and poor condition.

Table 2-8. FHWA Bridge Condition Ratings

Metric	Good	Fair	Poor
Minimum Component Rating	7 or greater	5 or 6	4 or less

3. Life Cycle Planning

Effective life cycle planning (LCP) is an essential process of TAM. The goal of LCP is to determine what treatments to perform on an asset over its life from initial construction through its replacement or retirement in order to maintain the asset in the most efficient and effective manner, while providing the desired level of service. As evidenced by the condition of the asset inventory described in the previous chapters, TxDOT has been very successful in developing life cycle plans for its assets and putting these plans into action. This chapter describes the agency's life cycle planning approach for its pavement and bridges.



Overview

Importance of LCP

Maximizing the life of a set of physical assets requires determining what treatments to perform on the assets over time. To make this determination, there must be knowledge of how the assets are likely to perform, how quickly they will deteriorate, and what treatments may potentially be performed on the assets. In evaluating different potential treatments, consideration should be given when different treatments are feasible, what each treatment costs, and how effectively it would maintain or even extend the life of the asset.

The process of analyzing these factors and defining the treatment strategy for a group of assets is called Life Cycle Planning (LCP). The underlying concepts of LCP are similar to Life Cycle Cost Analysis (LCCA). However, LCP is performed at a network level and yields an overall treatment strategy for an asset class or other grouping of assets. By contrast, LCCA is typically a more detailed analysis performed for a specific project or asset to compare different project alternatives.

LCP typically emphasizes performing preventive and routine maintenance, as doing so tends to keep assets in good condition as long as possible, and extends asset life in a cost-effective manner. Figure 3-1 shows an example of a typical life-cycle cost scenario for a highway without a preventive and routine maintenance strategy versus a scenario with a preventive and

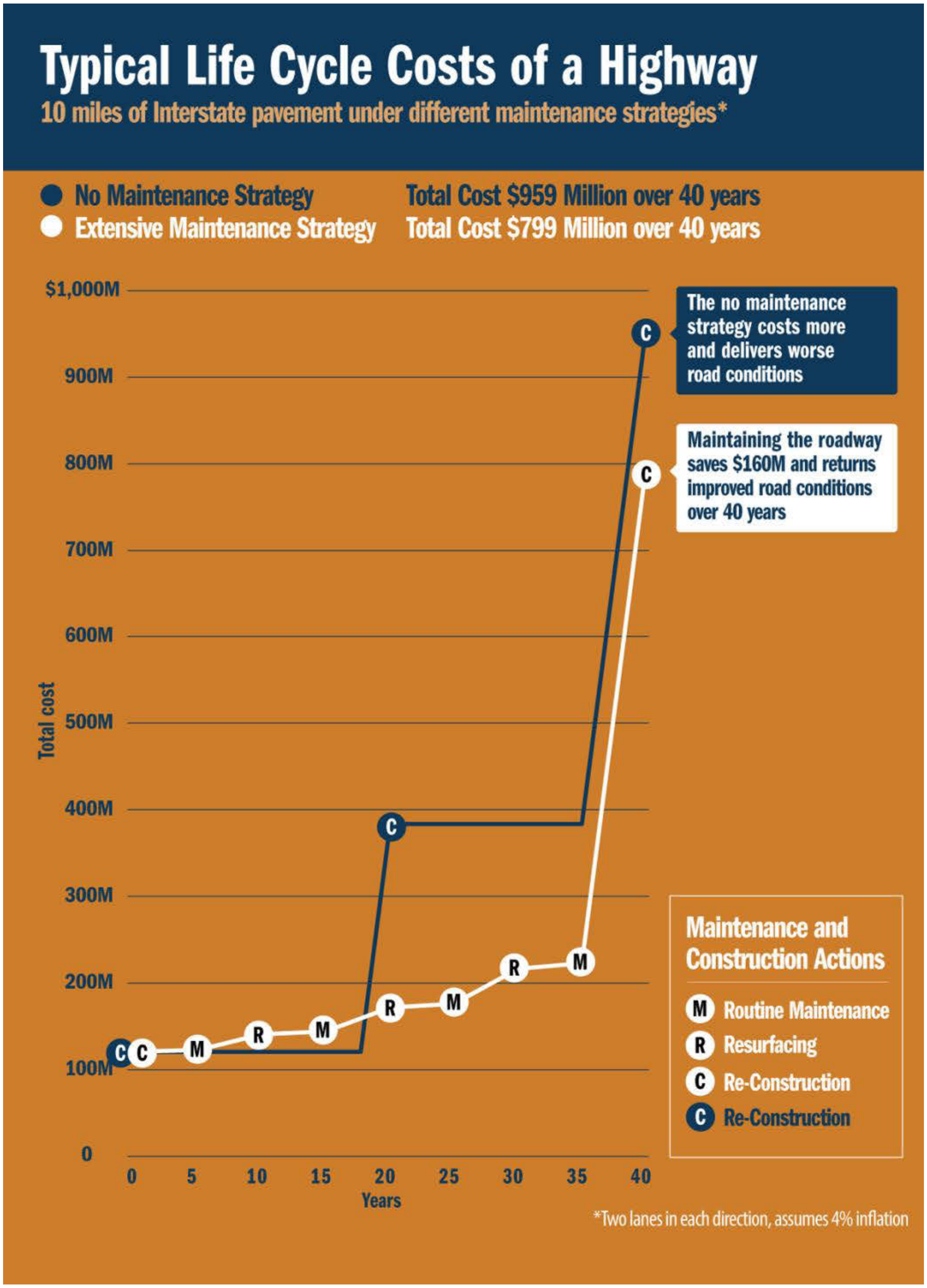


Figure 3-1. Typical Life Cycle Costs of a Highway

routine maintenance strategy similar to that typically used by TxDOT. As shown in the figure, the initial costs of the preventive and routine maintenance strategy are more than offset by the cost savings realized over time. In this example the sum of costs in current dollars over a 40-year period is $799 million for the preventive and routine maintenance strategy, and $959 million where maintenance treatments are deferred.

Federal Requirements

In 23 CFR 515.1, FHWA defines LCP as "a process to estimate the cost of managing an asset class, or asset sub-group over its whole life with consideration for minimizing cost while preserving or improving the condition." In 23 CFR 515.7(b) FHWA requires that States implement a process for conducting LCP as part of the development of their TAMP. The life cycle planning process should include:

- State DOT targets for asset condition for each asset class or asset sub-group;
- Identification of deterioration models for each asset class or asset sub-group;
- Potential work types across the whole life of each asset class or asset sub-group with their relative unit cost; and
- A strategy for managing each asset class or asset sub-group by minimizing its life-cycle costs, while achieving the State DOT targets for asset condition for NHS pavements and bridges.

FHWA notes that the LCP process should include consideration of various factors that could impact asset whole life costs. This includes future changes in demand; information on current and future environmental conditions including extreme weather events, climate change, and seismic activity; and other factors that could impact whole life costs of assets.

To support LCP and other TAMP-related processes FHWA requires the implementation of pavement and bridge management systems in 23 CFR 515.17. A management system may be a single system or set of multiple systems and processes. Required functionality for pavement and bridge management systems is summarized in the callout box below.

Required Management System Functionality

- **Collecting, processing, storing, and updating inventory and condition data**
- **Forecasting deterioration**
- **Determining the benefit-cost over the life cycle of assets to evaluate alternative actions (including no action decisions), for managing asset condition**
- **Identifying short- and long-term budget needs for managing asset condition that maximize overall program benefits within the financial constraints**
- **Recommending programs and implementation schedules to manage asset condition within policy and budget constraints**

Pavement Life Cycle Planning

Data

The core data required for pavement LCP are described in Chapter 2 and include the following pavement metrics collected by pavement section on the TxDOT network:

- Pavement roughness
- Cracking
- Rutting (Asphalt Concrete Pavement only)
- Faulting (Jointed Concrete Pavement only)

Modeling Approach

TxDOT's Pavement Management System is a Software-as-a-Service (SaaS) system called Pavement Analyst (PA), a comprehensive engineering and economic system that simulates the performance of each TxDOT highway section over time. In PA the TxDOT network is represented as a set of homogenous management sections of varying length. Conditions, deterioration and treatments are modeled for these management sections.

The deterioration of each highway section is modeled using a set of linear ride and sigmoidal distress deterioration models that predict change in condition over time. The following factors were considered in developing TxDOT's pavement deterioration models:

- Climate and subgrade zone - four climatic and subgrade zones.
- Pavement families based on pavement type and thickness.
- Treatment types or alternatives - preventive maintenance and light, medium, and heavy rehabilitation.
- Traffic loading levels - based on a truck traffic indicator or ESALs (low, medium, and high level).

TxDOT Pavement Deterioration Models

TxDOT considered the following factors in developing pavement deterioration models:

- **Climate and subgrade zone - four climatic and subgrade zones.**
- **Pavement type and thickness - asphalt and Portland cement concrete pavements of different types and thicknesses.**
- **Treatment types or alternatives - preventive maintenance and light, medium, and heavy rehabilitation.**
- **Traffic loading levels - based on a truck traffic indicator (low, medium, and high level).**

As a pavement gets older, the amount of distress and roughness will increase and a pavement's overall performance will drop. The PA performance prediction equations make it possible to estimate an effective pavement age based on the amount of observed distress and measured roughness. They also make it possible to estimate expected distress ratings and ride quality based on pavement age. The basic shape of the PMIS performance factor equation is S-shaped ("sigmoidal"). There is little change in performance at both ends of the curve, but substantial changes in the middle.

PA uses a set of decision trees to determine which treatments are feasible for a given pavement section based on its distresses, ride score, distress score, condition score, traffic, and other factors. The system uses the decision trees to define the feasible treatments for a section over a 10-year period, potentially including different treatments for preventive maintenance (PM), light rehabilitation (LR), medium rehabilitation (MR), and heavy rehabilitation (HR).

Once feasible treatments have been established, PA optimizes treatment selection considering the costs and benefits of each feasible treatment. The objective of the optimization is to maximize benefits subject to a budget constraint and/or other constraints; or to minimize budget subject to conditions. An increase in condition is used as a proxy for benefits. The outputs of a PA analysis include predicted conditions over time, an allocation of the available budget between different treatments and network classifications, treated lane miles, and recommendations on specific treatments to perform.

Treatments

Table 3-1 summarizes the unit cost to treat one lane mile by pavement type and treatment type. These treatment costs are updated as often as necessary to ensure accurate forecasting using PA.

Table 3-1. Pavement Treatment Unit Costs.

Pavement Type	Treatment Type	Treatment Unit Cost per Lane Mile ($)
CRCP	**PM**	**$ 88,485**
	LR	$ 307,824
	MR	**$399,621**
	HR	**$ 992,071**
JCP	**PM**	**$ 88,485**
	LR	**$ 307,824**
	MR	**$ 399,621**
	HR	**$ 992,071**
ACP	**PM**	**$ 67,549**
	LR	$ 283,756
	MR	$ 400,260
	HR	$ 579,727

Table 3-2 summarizes how TxDOT maps the pavement treatments list above to the treatment categories described in 23 CFR 515.

Table 3-2. Federal and TxDOT Work Types Crosswalk

23 CFR 515 Work Types	TxDOT Work Types
Initial construction	New construction
Maintenance	Routine maintenance
Preservation	Preventive maintenance
Rehabilitation	Light Rehabilitation, Medium Rehabilitation, Heavy Rehabilitation (excluding reconstruction)
Reconstruction	Heavy Rehabilitation (reconstruction)

Strategy

TxDOT staff run PA both to support high-level analyses of pavement condition, and to help support project decisions for pavements made at the district level. TxDOT runs PA annually to help support development of the ten-year Unified Transportation Program (UTP). A portion of the UTP is dedicated for pavement preventive maintenance and rehabilitation. In addition, there is a maintenance budget allocated for pavements. These funds may vary considering the uncertainty/risk in the financial forecast. To develop the TAMP, TxDOT performs updated analyses in PA using the most recent approved UTP budget. TxDOT also evaluates the impact of varying the funding both above and below the funding level in the UTP. This helps show the sensitivity of the results, and provides an opportunity to mitigate risks resulting from changes in the budget or changes in inflation, or other factors.

In further support of pavement LCP at the district level, TxDOT has developed four-year pavement management plans for each district. Rider 55 of TxDOT's appropriations bill requires the department to provide the Legislative Budget Board and the Governor with a detailed plan for the use of funds prior to each fiscal year. The plan should include, but is not limited to, a district-by-district analysis of pavement score targets and how proposed maintenance spending will impact pavement scores in each District. To fulfill this requirement, TxDOT and its Districts develop the 4-year pavement management plans (PMP) and update the plans every year. These plans are formed using results from PA, as well as visual inspections of the network. These are project-specific and financially constrained plans which map out the pavement work needed, along with expected changes in pavement condition. Figure 3-2 summarizes the process for developing these plans.

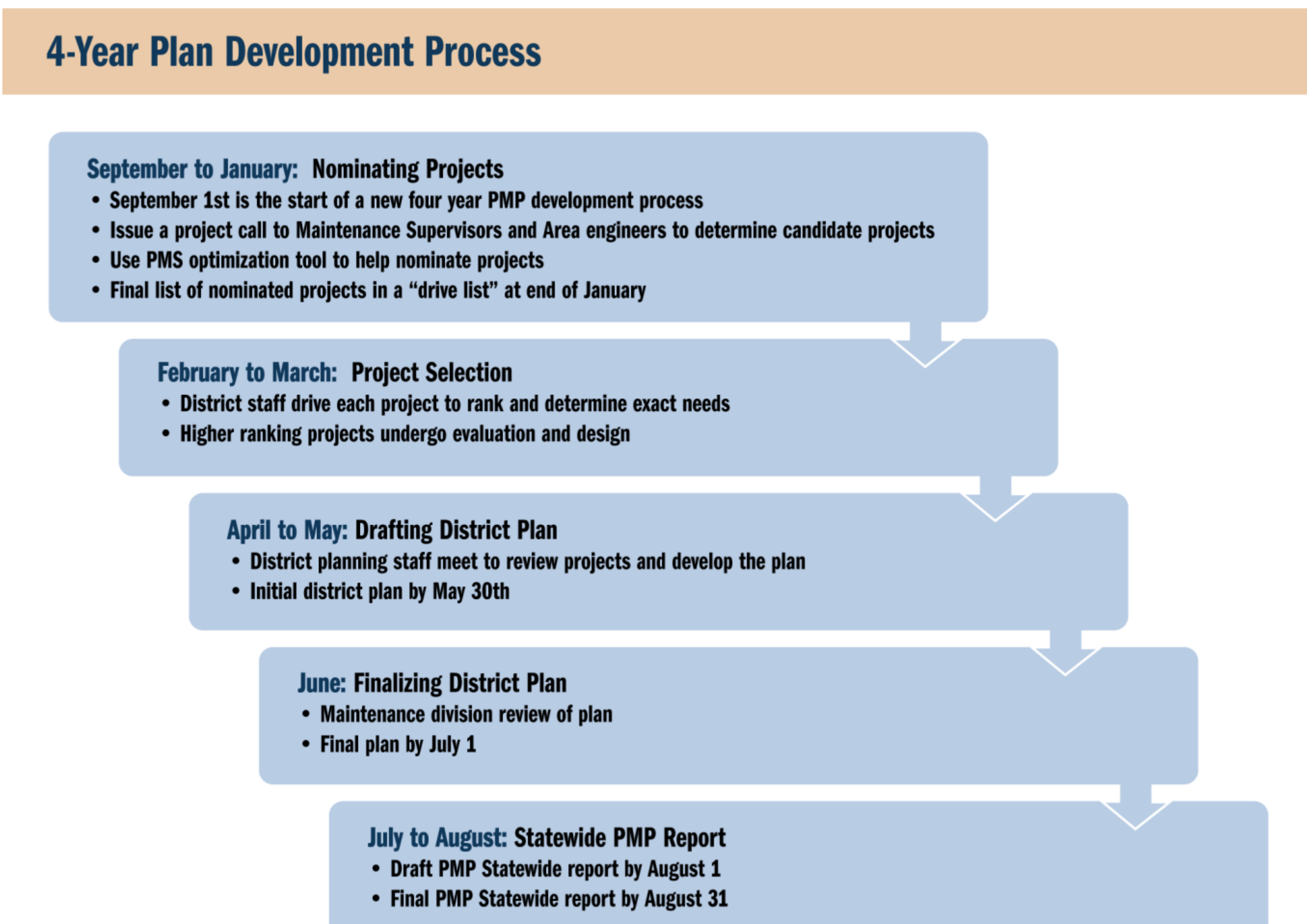


Figure 3-2. 4-Year Plan Development Process

The 4-year PMP provides TxDOT with a mechanism to predict pavement conditions based on a specified funding level and project-specific plan. The resulting report consists of the summary of the number of lane miles that each District plans to treat as Preventive Maintenance; Light, Medium, or Heavy Rehabilitation; and the impact that those treatments are predicted to have on the pavement conditions.

Each District has its own unique challenges and slightly different approaches in developing the PMP. TxDOT created a PMP Guidance Document to share best practices and a recommended approach to assist Districts in assembling the 4-year PMP.

Following submittal of each District PMP, TxDOT Maintenance Division runs PA based on the submitted plans to predict the pavement performance for the next 4-years and publishes an annual, statewide 4-year plan report. The PMP process has had the immediate benefit of giving districts a tool to plan out pavement preservation and maintenance work rather than being reactive to it.

This effort is reflected in overall statewide pavement condition score. The statewide percentage of lane miles in "Good" or better condition has steadily increased since FY 2001 when the Texas Transportation Commission established the statewide pavement condition goal. FY 2021's 89.31 percent of Pavements in Good or Better condition is the highest percentage in the last twenty-five years.

Bridge Life Cycle Planning

Data

Data used for bridge LCP include the deck, superstructure and substructure ratings for each highway bridge, as well as the culvert rating for each bridge-class culvert. TxDOT also collects more detailed condition data for bridge structural elements. TxDOT collects this data through its routine bridge inspection program.

Modeling Approach

TxDOT uses multiple systems to meet FHWA's requirements for bridge management systems. TxDOT uses the Bridge Inspection Database as its repository of bridge inventory and inspection data. TxDOT staff routinely utilize the data in the system to review bridge needs and help establish plans for individual bridges.

In addition, TxDOT has established the Bridge Network Model (BNM) to support development of its bridge life cycle plans and perform the analyses needed to support development of the TAMP. The BNM is Markovian model based on the Bridge Condition Forecasting System (BCFS) developed by Michigan DOT. In BNM bridges are represented as being in one of five condition levels (A, B, C, D or F) based on the minimum of their component conditions. The system predicts deterioration probabilistically based on the one-year transition from each condition level to every other condition level. The system models bridge replacement, rehabilitation, improvement and maintenance/preservation. It predicts treatment costs and conditions for the following groups of bridges:

- On-System (TxDOT-owned)
- NHS On-System
- NHS (including on and off-system bridges)
- Statewide (including all bridges in the network)

TxDOT Bridge Network Model (BNM)

While the system is designed as a network-level model and does not generate recommendations for specific bridges, BNM has several features essential for supporting bridge LCP not commonly supported by other bridge management models:

Uses a probabilistic rather than deterministic deterioration modeling approach, resulting in better prediction of actual conditions

Accounts for new bridge construction and bridge improvement, which are a significant factor in Texas

Directly predicts the Federal bridge measures

While the system is designed as a network-level model and does not generate recommendations for specific bridges, it has several features essential for supporting bridge LCP not commonly supported by other bridge management models. Specifically, BNM:

- Uses a probabilistic rather than deterministic deterioration modeling approach, resulting in better prediction of actual conditions.
- Accounts for new bridge construction and bridge improvement, which are a significant factor in Texas.
- Directly predicts the Federal bridge measures.

TxDOT's Bridge Preservation Guide details TxDOT's life cycle strategies for the bridge inventory, and is used to help determine what specific treatments to perform on a given bridge. Further, TxDOT is continuing to implement AASHTOWare BrM as an enterprise tool for further improved bridge-level life-cycle planning. BrM has additional modeling capabilities for predicting performance, needs and work for individual bridge structural elements.

In TxDOT's configuration of BrM, bridge deterioration is modeled primarily through deterministic changes to component condition ratings: Deck, Superstructure, Substructure, and Culverts. These models have been developed through multiple research efforts in partnership with The University of Texas at San Antonio and Texas A&M. Specifically, the results of project 6979-1 "Developing Deterioration Rates of Texas Bridges Using NBI Data" have been converted into a deterministic set of models for BrM's condition rating profiles. These profiles distinguish between statistically distinct groups of bridges and predict the most-likely rating of each bridge component based on the bridge's condition history. Table 3-3 is an example of this modeling approach for on-system bridges built within the past 22 years.

Table 3-3. On-System Span Type, Age 0-22 Years

Component Rating	Time in Rating (years)		
	Deck	Superstructure	Substructure
9	**1**	**1**	**1**
8	2	4	2
7	22	13	15
6	24	18	21
5	55	43	26
4	9	10	10
3	4	5	4
2	2	3	2
1	1	1	1

Treatments

For the purpose of network-level modeling TxDOT models four treatment categories:

- Replacement at a unit cost of $100 per square foot of deck area
- Functional improvement at a unit cost of $100 per square foot
- Rehabilitation at a cost of $90 per square foot
- Preservation at a cost of $30 per square foot

These costs are exclusively for the bridge work and do not include related costs such as traffic control. Bridge replacement restores a bridge to new condition. TxDOT has established treatment effectiveness matrices to estimate the impact of improvement and rehabilitation based on the existing condition of the bridge. Preservation is assumed to reduce deterioration by 30 to 50% depending upon the existing condition of the bridge.

While preservation is characterized at a high level in BNM, TxDOT considers this treatment category in much greater detail when making project decisions. The Bridge Preservation Guide is incorporated by reference. This guide details specific preservation treatments for the following types of elements:

- Bridge decks
- Bridge joints
- Conventionally reinforced concrete superstructures
- Prestressed concrete superstructures
- Steel superstructures
- Concrete substructure
- Steel piling and concrete encasements
- Bridge railing
- Concrete culverts

The guide also details use of fiber reinforced polymers, cathodic protection and riprap repair.

Table 3-4 below provides an example of specific treatments detailed in the guide. The table lists potential preservation treatments for bridge decks, detailing which treatments may be considered based on the deck condition rating, surface area deficiency and degree of deck cracking. Deck preservation actions as well as more substantial rehabilitation, replacement, and widening activities are modeled within BrM using cost-benefit analysis.

Table 3-4. Preservation Treatments for Decks

Deck Rating in Safety Inspection	Surface Area Deficiency				Deck Cracking		Preservation Action (Repair/Retrofitting Option)	Anticipated Service Life of Action (years)
	Type A	Type B	Type C	Type D	Type E	Type F		
>5	<10%						Contact BRG	
>5		<5%		<2%			Isolated partial-depth deck repair; concrete patch	10-15
>5		<5%		<2%			Silane treatment to bridge deck	5-10
>5					Spacing >4 ft; crack width >0.01 in.		Seal individual cracks with epoxy Apply silane treatment to bridge deck	5-10
>5					Spacing >4 ft; crack width <0.01 in.		Apply silane treatment to bridge deck	5-10
5	10-25%						Contact BRG	
5		5-25%					Partial-depth deck repair; then multi-layer polymer overlay or polyester polymer concrete overlay	10-20
5		5-25%					For pre-cast panel with cast-in-place partial depth deck topping, partial-depth deck repair	10-20
5			<2%				Isolated full-depth deck repair	10-20
5				<10%			Chloride content <1.5 lb per cy (for uncoated reinforcing steel or 4 lbs per cy for epoxy coated reinforcing) – Perform isolated concrete repair. Cathodic anodes are optional.	5-15
5				<10% (or more)			Chloride content <1.5 lb per cy (for uncoated reinforcing steel or 4 lbs per cy for epoxy coated reinforcing) – Perform deck replacement.	30-40
5					Crack spacing <4 ft.; width >0.01 in.		Multi-layer polymer overlay	10-20
5					Crack spacing <4 ft.; width >0.01 in.		Polyester polymer concrete overlay	20
5						Spacing > 4 ft.; width <0.01 in.	Contact BRG; Load rate deck; Retrofit with concrete inlay or overlay if necessary	
4	>25%						Contact BRG;	
4		>25%					Deck Replacement	30-40
4			>10%				Deck Replacement	30-40
4				>10%			Deck Replacement	30-40
4					Spacing <2 ft.; width >0.01 in.	Width >0.01 in.	Contact BRG;	
3							Inform BRG and District	

Strategy

TxDOT staff run BNM to help make predictions of future bridge condition, support development of the UTP, and help prepare the TAMP. In the system, the overall budget is specified by year. Typically, scenarios are run to show the impacts of deterioration with no funding, planned funding, and funding 10% above and below the planned funding (similar to that analyzed for pavement). The result of a BNM analysis is a prediction of the distribution of bridge conditions by year for four systems (statewide, NHS, on system and NHS on system) for each scenario analyzed.

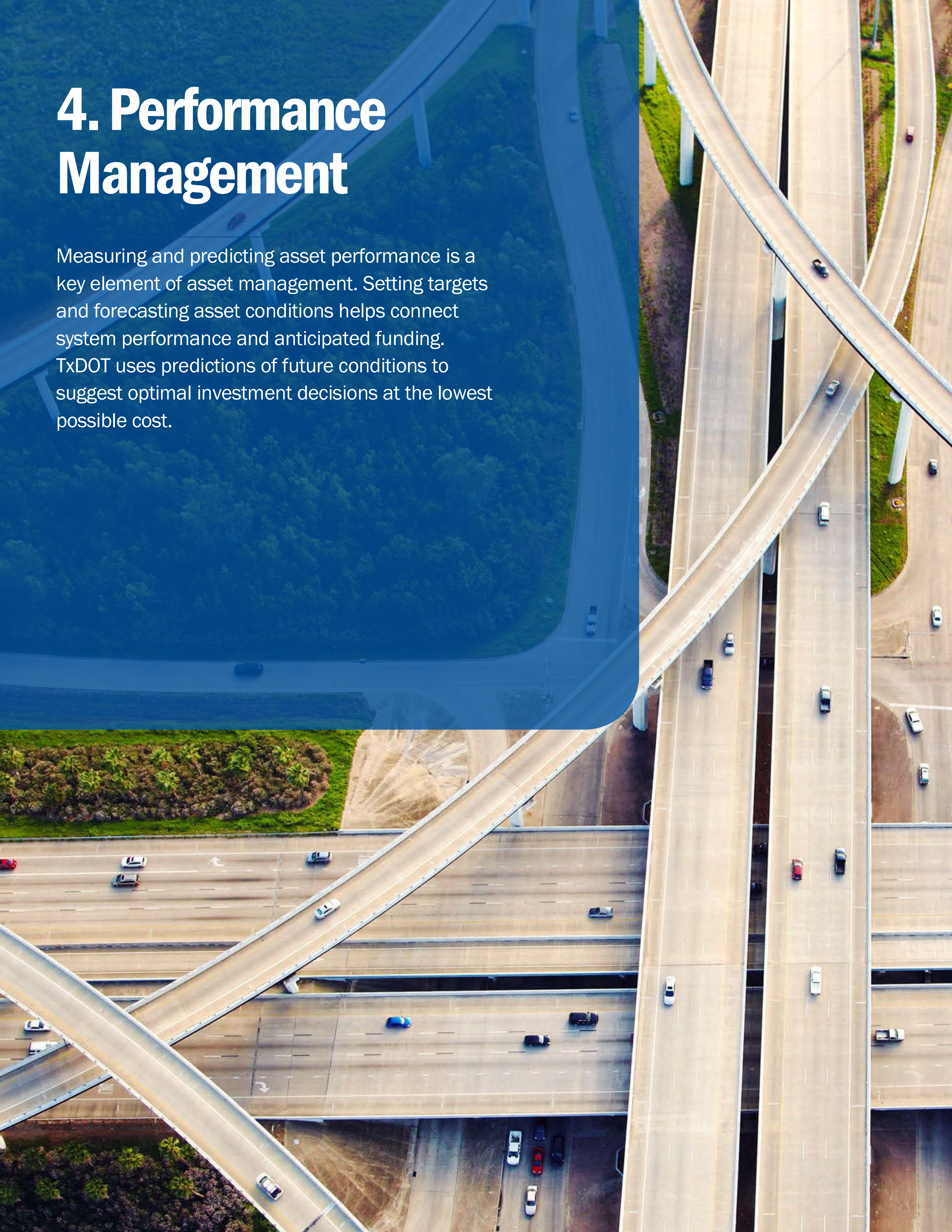
For each analysis in BNM one must specify the budget for preservation and the percent of the budget used for each combination of treatment and condition. When running the system, TxDOT staff update the system parameters, including typical budget distribution, treatment cost, inflation rate, extent of new construction, and other parameters based on analysis of historic data. Also, staff export data from the inspection system to summarize initial conditions. The results of the BNM analyses help inform decisions about overall budgets for bridge-related work and targets for bridge condition established in the UTP given TxDOT's life cycle strategies for its bridges.

Separately from this process of running BNM, the division office and district staff make treatment decisions on individual bridges consistent with TxDOT's life cycle strategies. Staff use the TxDOT Bridge Preservation Guide to support this process. The Guide was developed in 2021 in recognition of the fact that determining specific preservation plans for bridges frequently requires additional information not available from routine inspection reports. To establish these plans, it is generally necessary to prepare additional detailed field condition survey reports that include proposed repair and rehabilitation quantities and estimated costs. Within TxDOT, these plans are reviewed by the Bridge Division before treatments are performed. Plans are further evaluated based on engineering judgement and consideration of future changes in demand, extreme weather, and climate change.

The Guide details the additional data needed to develop a bridge preservation plan that enables TxDOT staff and consultants to create project plans in support of TxDOT's life cycle strategies. For each of the different types of elements listed above, the Guide describes typical distresses, candidate treatments, and factors to consider in treatment selection. Also, the Guide describes the process for preparing plans and presents working drawings for 24 common treatments. The Guide encourages early detection of condition issues so that a preservation treatment can be applied to a bridge well before it reaches a poor condition. This LCP approach keeps bridges in good and fair condition significantly longer than a strategy of deferring maintenance and preservation work, which generally results in worse conditions and higher costs over time.

4. Performance Management

Measuring and predicting asset performance is a key element of asset management. Setting targets and forecasting asset conditions helps connect system performance and anticipated funding. TxDOT uses predictions of future conditions to suggest optimal investment decisions at the lowest possible cost.



Pavement Performance Projections and Targets

TxDOT Maintenance Division is responsible for measuring pavement condition, reporting performance trends, and projecting pavement conditions using its enterprise Pavement Management System. Pavement management systems in TxDOT have evolved from a basic Pavement Evaluation System in the 1970s to a fully comprehensive Pavement Management System in the early 1990s. Most recently TxDOT implemented a modern pavement management system, referred to as Pavement Analyst (PA). In 2016, methods to measure the condition of assets and their performance changed and will continue to change in the future due to advancements in technology and development of new knowledge. However, historical data are valuable to obtain performance trends and develop predictive capabilities. The modeling approach and parameters are discussed in greater detail in Chapter 3, Life Cycle Planning.

The prediction analysis process includes the following five steps:

Step 1: Define Asset Analysis Scope

The scope covers the highway network to be considered in the analysis. The data set for the assets under consideration are located and imported into the program. For the TAMP, the analysis was performed on all on-system pavements, including NHS and non-NHS pavements.

Step 2: Develop Funding Level Scenario

TxDOT develops funding scenarios based on the funding levels established in the annual Unified Transportation Program (UTP) document. The UTP outlines 10 years of authorized funding, including a portion dedicated for pavement preventive maintenance and rehabilitation. In addition, there is a separate maintenance budget allocated for pavements. These funds may vary considering the uncertainty/risk in the financial forecast. The TAMP uses various 10-year UTP and maintenance funds in the LCP analysis as described in greater detail in Chapter 6, Financial Plan and Investment Strategies. The funding scenarios for pavement are listed below:

- Current planned investment levels
- Reduced funding investment levels (e.g., 10 percent lower than planned)
- Increased funding investment levels (e.g., 10 percent higher than planned)
- In addition, a scenario showing a “Worst First” approach with current funding was prepared for statewide pavements

Step 3: Prepare Scenario Inputs

For each scenario, a series of factors is needed as input, including network scope, start condition, analysis length, decision trees, financial parameters, etc. The TAMP analysis uses 2021 pavement inventory and condition data as the start and predicts performance over ten years (ending year 2031). Other inputs are discussed in more detail in Chapter 3 Life Cycle Planning.

Step 4: Run Prediction and Optimization Analysis

Once the inputs are prepared, each scenario is run in the PA program to obtain the optimal solutions that meet the objective under the constraints. The optimal solutions include the right treatment at the right location and right time. As a result, PA will provide the selected treatment and predicted condition for each section in the network in each year. It will also provide the summary statistics in condition, treated lane-miles, total treatment cost, etc. for the entire network.

Step 5: Assess Results

Based on the results in Step 4, the next step is to make an assessment from an engineering and economic perspective. This step typically involves answering the following questions:

- What is the impact of different funding levels on the network level performance?
- What is the gap between the projected condition of the system and the established criteria for defining the desired State of Good repair (SOGR) for any given funding level?
- How does the financial plan address the gap?

These items are addressed in the gap assessment in this chapter and in Chapter 6, Financial Plan and Investment Strategies. Modeling results are provided in the following sections.

On-System Pavement

Predicted performance for on-system pavements using TxDOT's condition score is shown in Figure 4-1.

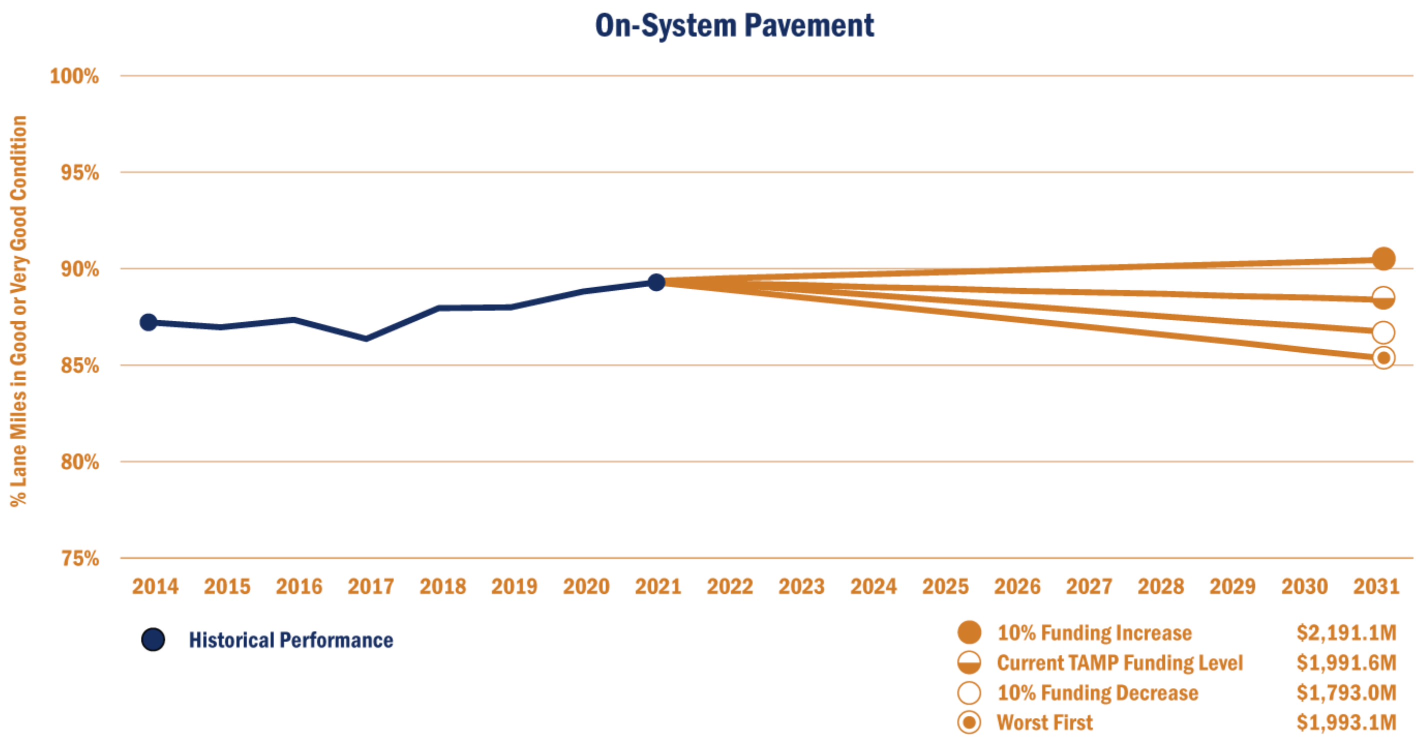


Figure 4-1. On-System Pavement Projections

On-system pavement condition is forecasted to remain steady over the ten-year period of the TAMP, given the current annual funding level for pavement of $1.99 billion.

An 10% increase in funding is predicted to yield an increase in the percent of pavement in good or better condition from 89.3% to 90.4%, while a 10% decrease in funding will lead to a decline in condition to 86.1%. Notably, using the current funding scenario but employing a "worst first" management approach yields an even greater decline in condition to 85.3%.

TxDOT-Owned NHS Pavement

TxDOT manages its pavements and predicts future conditions using its Condition Score described previously. While TxDOT is in the process of developing the capability to directly model future pavement conditions on the NHS using the FHWA performance measure, TxDOT is still building confidence in the approach and the results.

As an interim solution, TxDOT performed a statistical analysis to correlate the FHWA measure and the TxDOT condition score. TxDOT section-level pavement data on the NHS were matched to underlying 0.1 mile sections. For each TxDOT section, FHWA Good, Fair, and Poor was calculated based on the total length of underlying 0.1 mile sections in each condition state. Each TxDOT section became a data point providing both Condition Score and FHWA Good/Fair/Poor. Using the compiled condition data, TxDOT performed a least squares regression to fit models for percent of pavement in good and poor condition (FHWA measure) as a function of Condition Score. The result of this process was a model that allows TxDOT to estimate FHWA Good/Fair/Poor using TxDOT condition score and to translate predicted performance using the TxDOT measure to the federal measure. The forecasted conditions for NHS pavements shown in Figures 4-2 and 4-3 are a product of this correlation process.

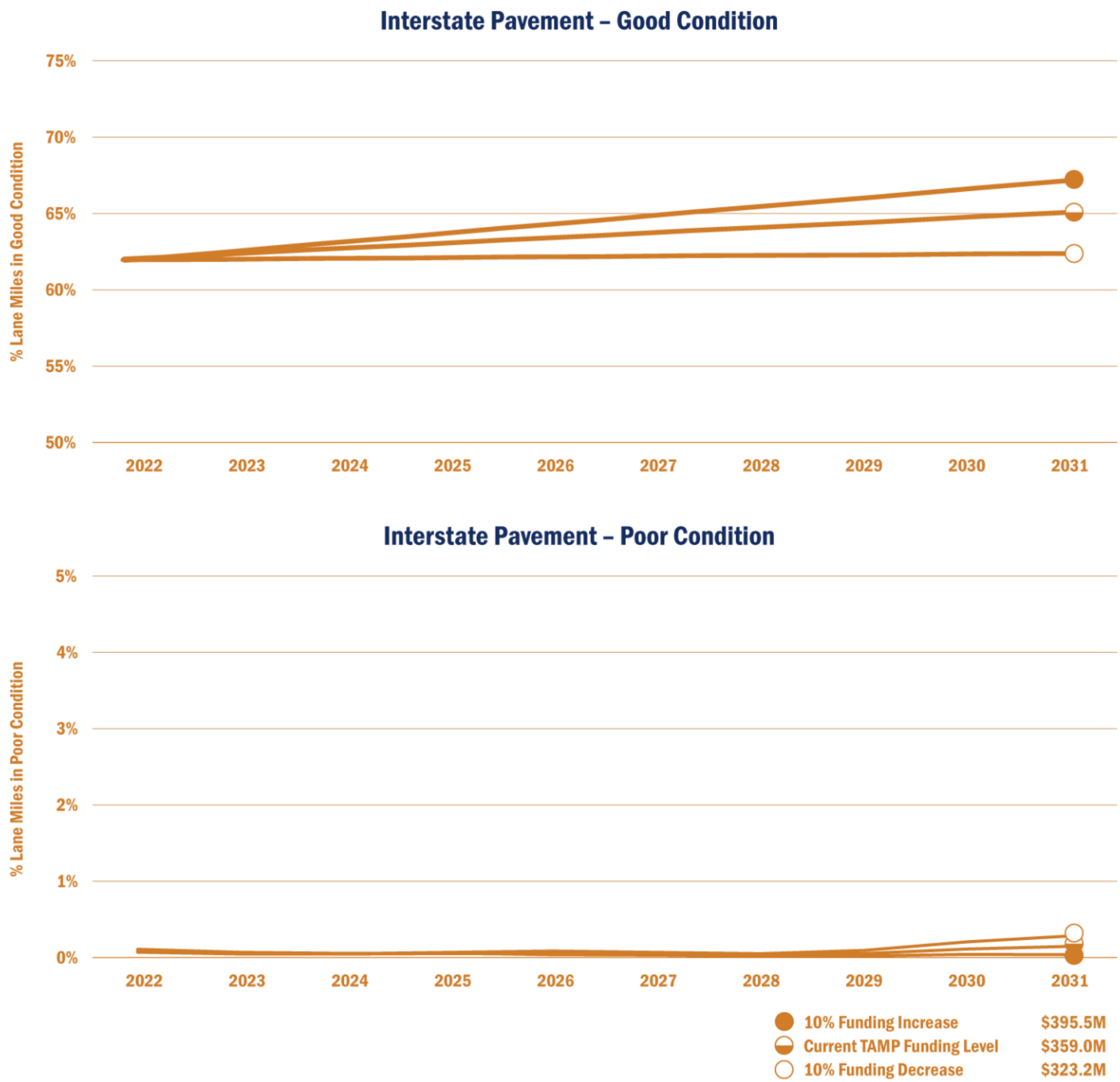
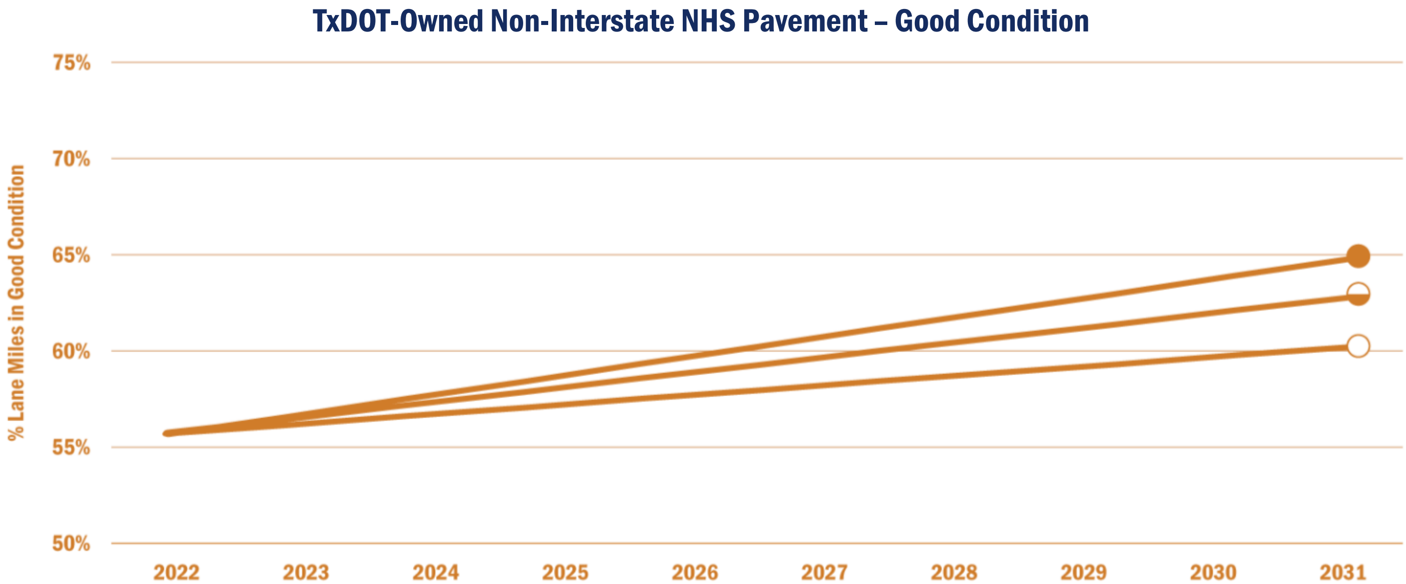


Figure 4-2. Interstate Pavement

Interstate pavement condition is forecasted to remain steady over the ten-year period in the expected funding scenario given the estimated current annual funding level for pavement of $359 million. Pavements in good condition are predicted to increase slightly from 61.9% to 65.0%, while pavements in poor condition are predicted to stay at 0.1%. A 10% increase in funding is predicted to yield a percent of pavement in good condition of 67.0%, and a decrease in poor condition to 0.0%, while a 10% decrease in funding is forecasted to result in 62.5% good condition and 0.2% poor.

Note that predicted percent of pavement in good condition for 2022 is lower than actual conditions in 2021. This is a result of the fact that 47% of TxDOT's pavements currently have a condition score of 100

(Very Good), the highest possible rating using the state performance measure. These pavements are predicted to deteriorate slightly in the first year according to the model, resulting in an initial decline in pavements in good condition. As these predictions are estimates, they do not show the actual condition values in 2021.



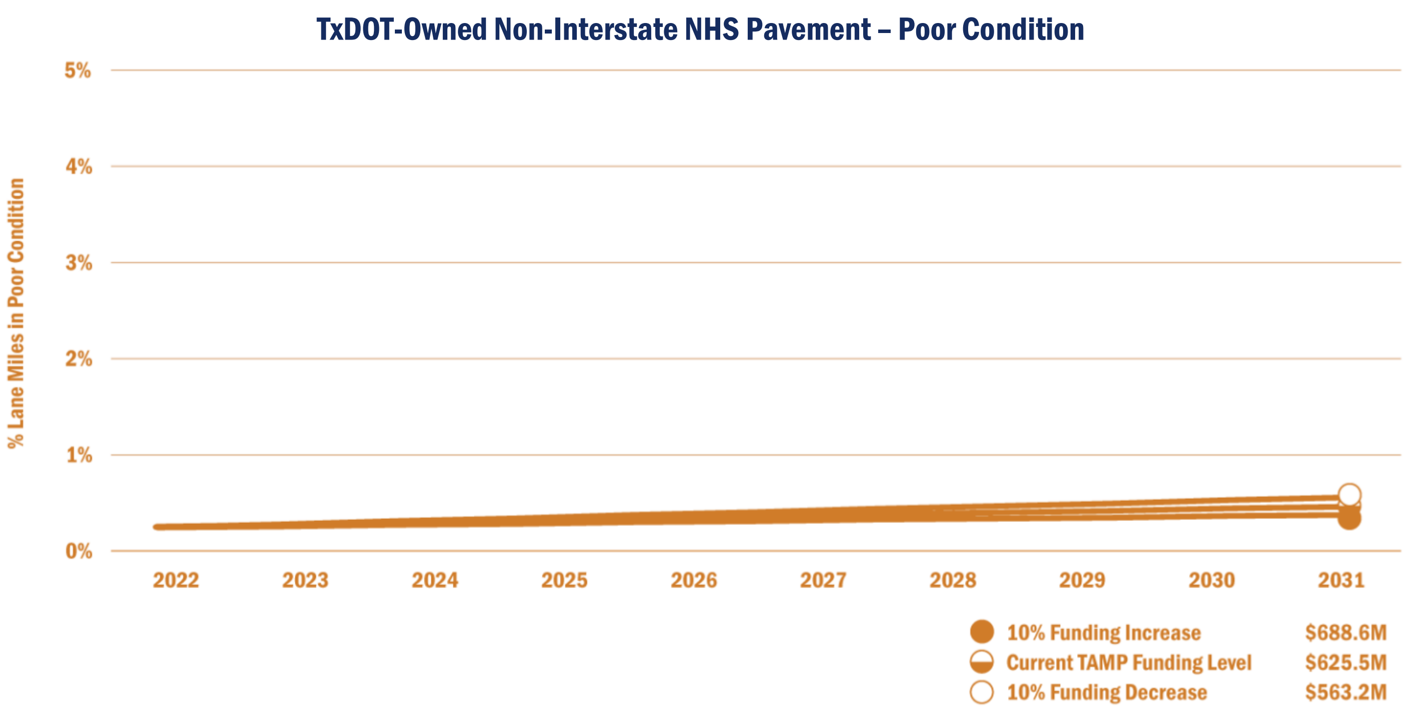


Figure 4-3. TxDOT-Owned Non-Interstate NHS Pavement

TxDOT-owned Non-Interstate NHS pavement condition is forecasted to improve slightly over the ten-year period in the expected funding scenario given the estimated current annual funding level for pavement of $625 million. Pavements in good condition are predicted to increase slightly from 55.8% to 61.9%, while pavements in poor condition are predicted to rise slightly from 0.2% to 0.4%. A 10% increase in funding is predicted to yield an increase in the percent of pavement in good condition to 63.6% and poor condition will stay at 0.3%. A 10% decrease in funding is forecasted to result in 59.9% good condition and an increase to 0.5% poor condition.

The minor decline in Non-Interstate NHS condition is the result of funding priority being given to Interstate pavements. In the modeling scenarios, the first priority is to maintain Interstate conditions. Once a level of funding sufficient to maintain Interstate has been established, then money is allocated to Non-Interstate pavements, both NHS and non-NHS.

Bridge Performance Projections and Targets

TxDOT Bridge Division is responsible for projecting bridge conditions using its Bridge Network Model (BNM), described in greater detail in Chapter 3 Life Cycle Planning.

The prediction analysis process includes the following five steps:

Step 1: Define Asset Analysis Scope

The scope covers the highway network to be considered in the analysis. TxDOT typically includes all bridges statewide in the analysis, but the result of the analysis is a prediction of the distribution of bridge conditions by year for four systems (statewide, NHS, on-system and NHS on-system) for each scenario analyzed. The TAMP includes results for TxDOT-owned bridges and all NHS bridges.

Step 2: Develop Funding Level Scenario

TxDOT develops funding scenarios based on the funding levels established in the annual Unified Transportation Program (UTP) document. The TAMP uses various 10-year UTP funds in the LCP analysis as described in greater detail in Chapter 6, Financial Plan and Investment Strategies. These funds may vary considering the uncertainty/risk in the financial forecast. The funding scenarios for bridge are listed below:

- Baseline or current planned investment levels
- Reduced funding investment levels (25 percent lower than planned)
- Increased funding investment levels (50 percent higher than planned)

The 'Baseline' funding scenario includes current funding levels and planned funding levels as outlined in the 2022 Unified Transportation Program (UTP) over the next ten years. This scenario does not include additional funds from the Infrastructure Investment and Jobs Act (IIJA)/ Bipartisan Infrastructure Legislation (BIL). The '+50%' funding scenario assumes a 50% increase to Category 6 (bridge) funds through the UTP. This scenario accounts for possible increases in bridge funding through the IIJA/BIL, offset by potential reallocation of state funds towards other UTP categories. The '-25%' funding scenario assumes a 25% decrease to Category 6 (bridge) funds through the UTP. While less likely, this scenario accounts for unexpected changes to bridge funds as a result of decreased revenue or significant realignment of TxDOT goals and UTP category allocations.

Step 3: Prepare Scenario Inputs

For each scenario, a series of factors is needed as input, including network scope, start condition, analysis length, financial parameters, etc. The TAMP analysis uses 2021 bridge inventory and condition data as the start and predicts performance over ten years (ending year 2031). Other inputs are discussed in more detail in Chapter 3 Life Cycle Planning.

Step 4: Run Prediction Analysis

Once the inputs are prepared, each scenario is run in the BNM to predict treatment costs and conditions at the network level.

Step 5: Assess Results

Based on the results in Step 4, the next step is to make an assessment from an engineering and economic perspective. This step typically involves answering the following questions:

- What is the impact of different funding levels on the network level performance?
- What is the gap between the projected condition of the system and the established criteria for defining the SOGR for any given funding level?
- How does the financial plan address the gap?

These items are addressed in the gap assessment in this chapter and in Chapter 6, Financial Plan and Investment Strategies. Modeling results are provided in the following sections.

On-System Bridges

Predicted performance for on-system bridges using TxDOT's bridge condition score is shown in Figure 4-4.

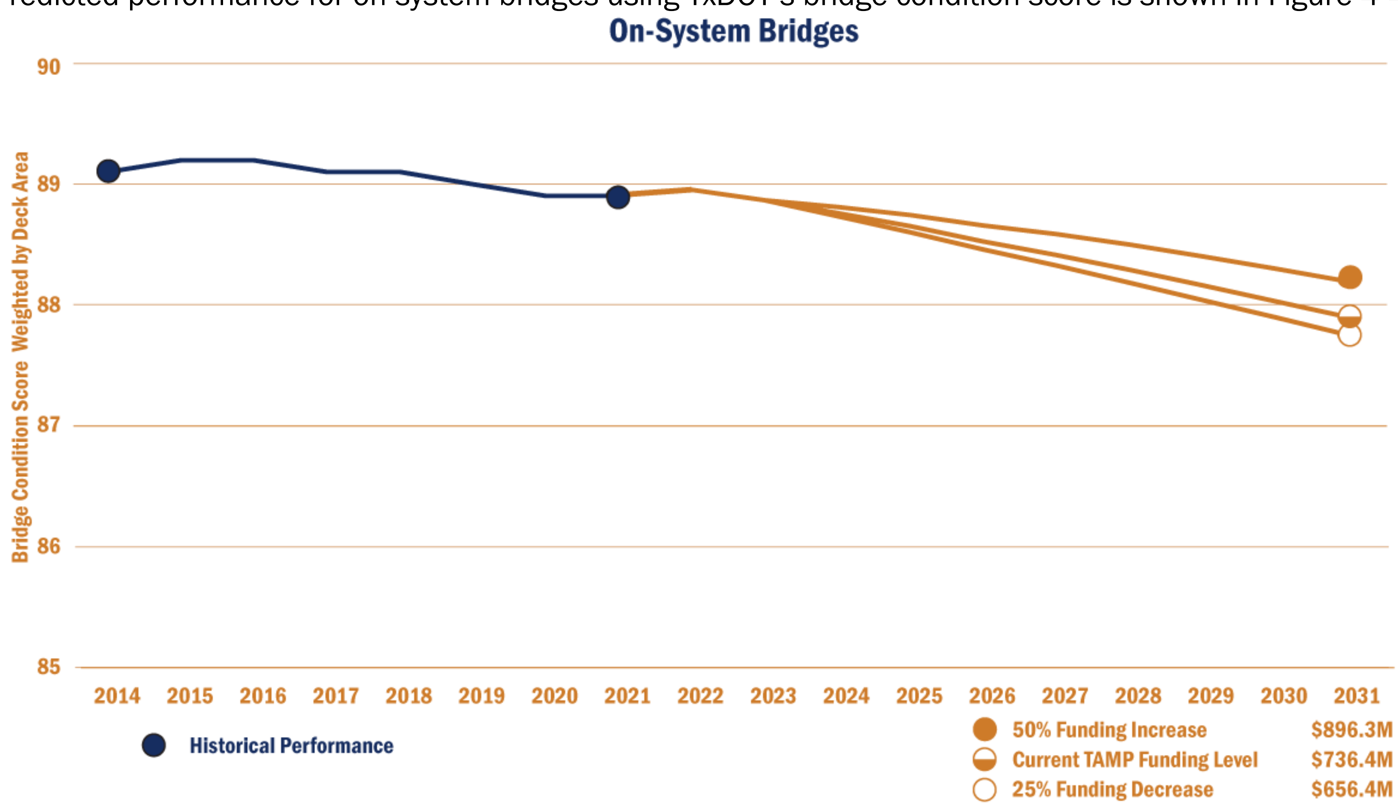


Figure 4-4. On-System Bridges

On-system bridge condition is forecasted to decline over the 10-year period from a condition score of 88.9 to 87.9. In the -25% funding scenario, condition is predicted to decline further to 87.7, while in the +50% funding scenario condition is predicted to decline less at 88.2. The expected declines in condition reflect the fact that TxDOT has by far the largest bridge inventory of any state and one of the lowest rates of bridges in poor condition. As TxDOT's bridges age, it will become increasingly difficult to maintain older bridges in good condition with current funding. However, even with the small expected decline, TxDOT bridge condition scores will still be close to the Texas Transportation Commission goal of 90.

NHS Bridges

Predicted conditions on NHS bridges using the FHWA performance measure for bridge conditions are shown in Figures 4-5 and 4-6.

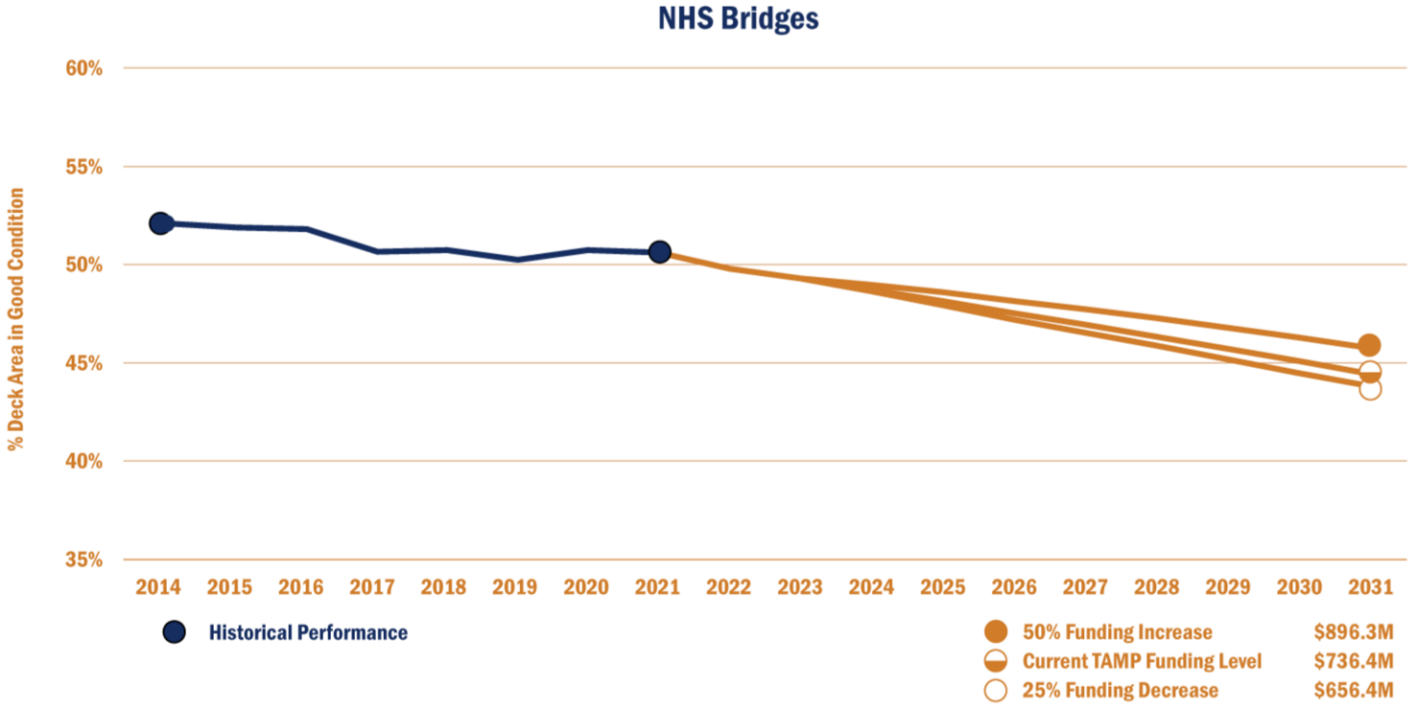


Figure 4-5. Bridge – NHS % Good

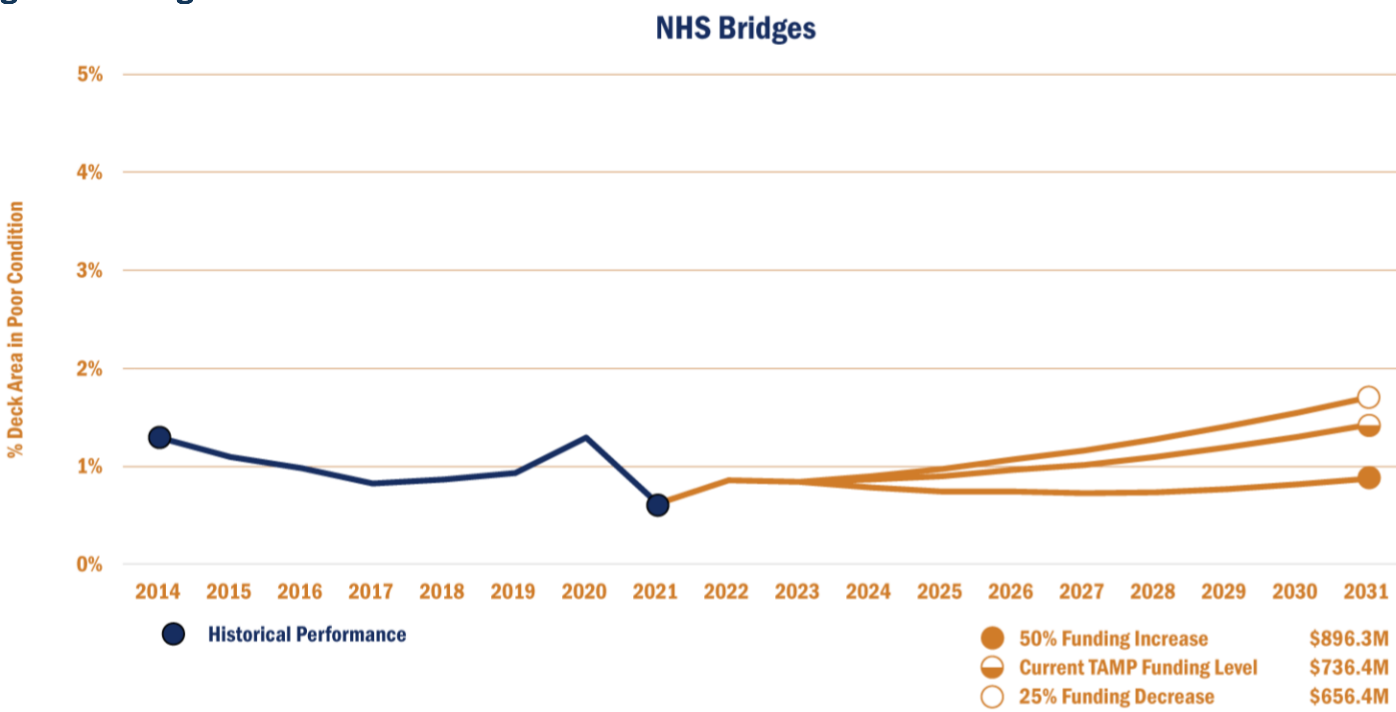


Figure 4-6. Bridge – NHS % Poor

Under the current funding scenario the percent of NHS bridge deck area in good condition is predicted to drop from 50.6% to 44.3%, while the percent of bridge deck area in Poor condition is predicted to increase from 0.6% to 1.5%. In the -25% funding scenario, percent good is predicted to decline to 43.7% and percent poor is predicted to increase to 1.7%,while in the +50% funding scenario, percent good is predicted to decline to 45.6% and percent poor is predicted to remain at 0.9%.

Performance Dashboard

TxDOT maintains a dashboard that highlights performance measures related to the seven goals adopted in the TxDOT 2021-2025 Strategic Plan. The goal "Preserve Our Assets" is directly related to the TAMP and TxDOT reports measures of bridge and pavement condition to the dashboard.

For pavement, TxDOT tracks the percentage of lane miles in good or better condition (measured using the condition score). The measure is calculated for five different categories of roads as shown in Figure 4-7. The percentage of statewide lane miles in good or better condition increased in 2021 thanks to improved pavement management, maintenance, and rehabilitation techniques.

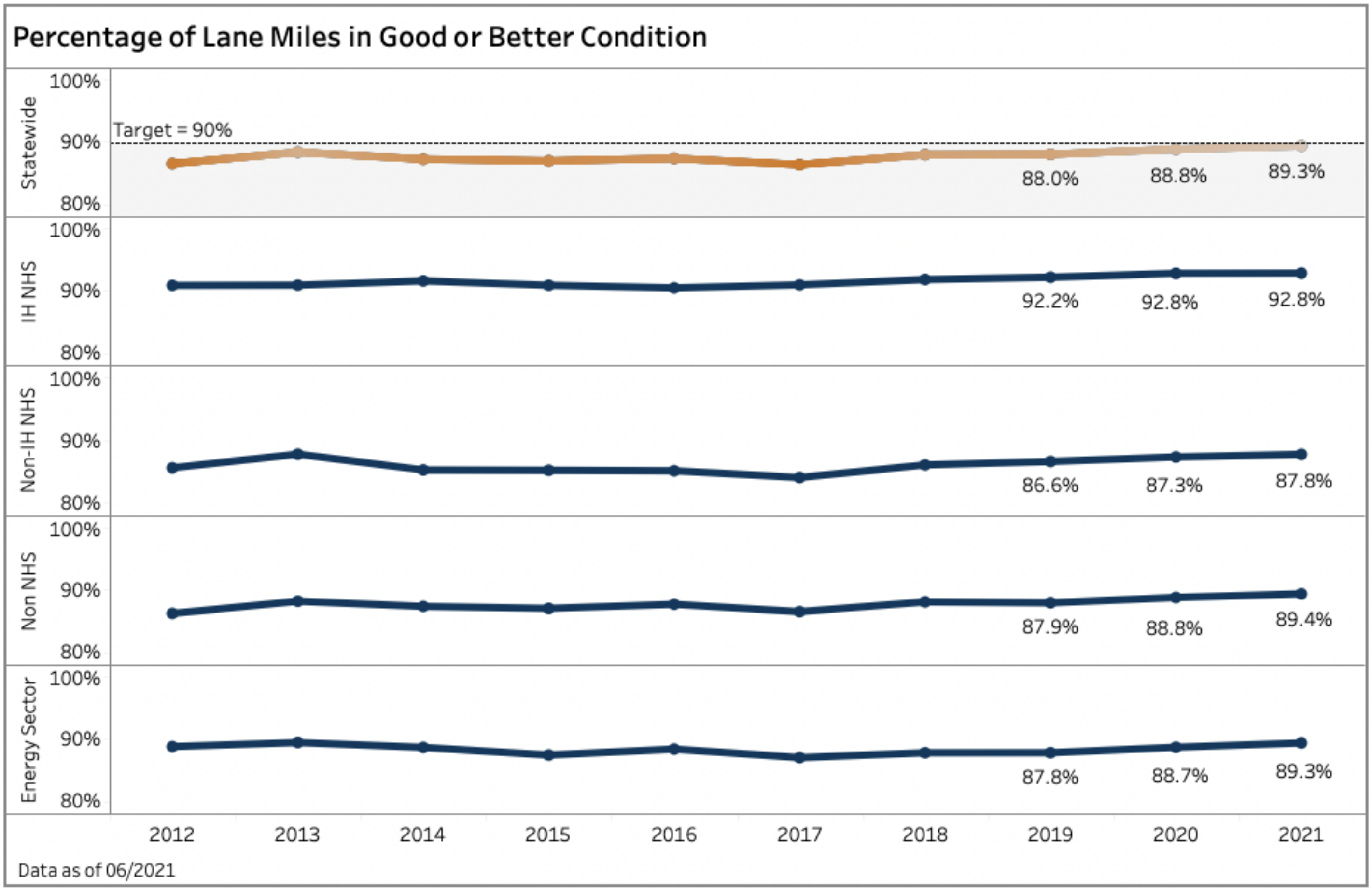


Figure 4-7. Pavement Condition Dashboard Screenshot

For bridges, TxDOT tracks the bridge condition score for the four different categories as shown in Figure 4-8. The statewide bridge condition score has remained stable over the last several years thanks in part to our bridge management programs and maintenance activities. However, some leading indicators suggest the measure is likely to see a slight decline in the next few years.

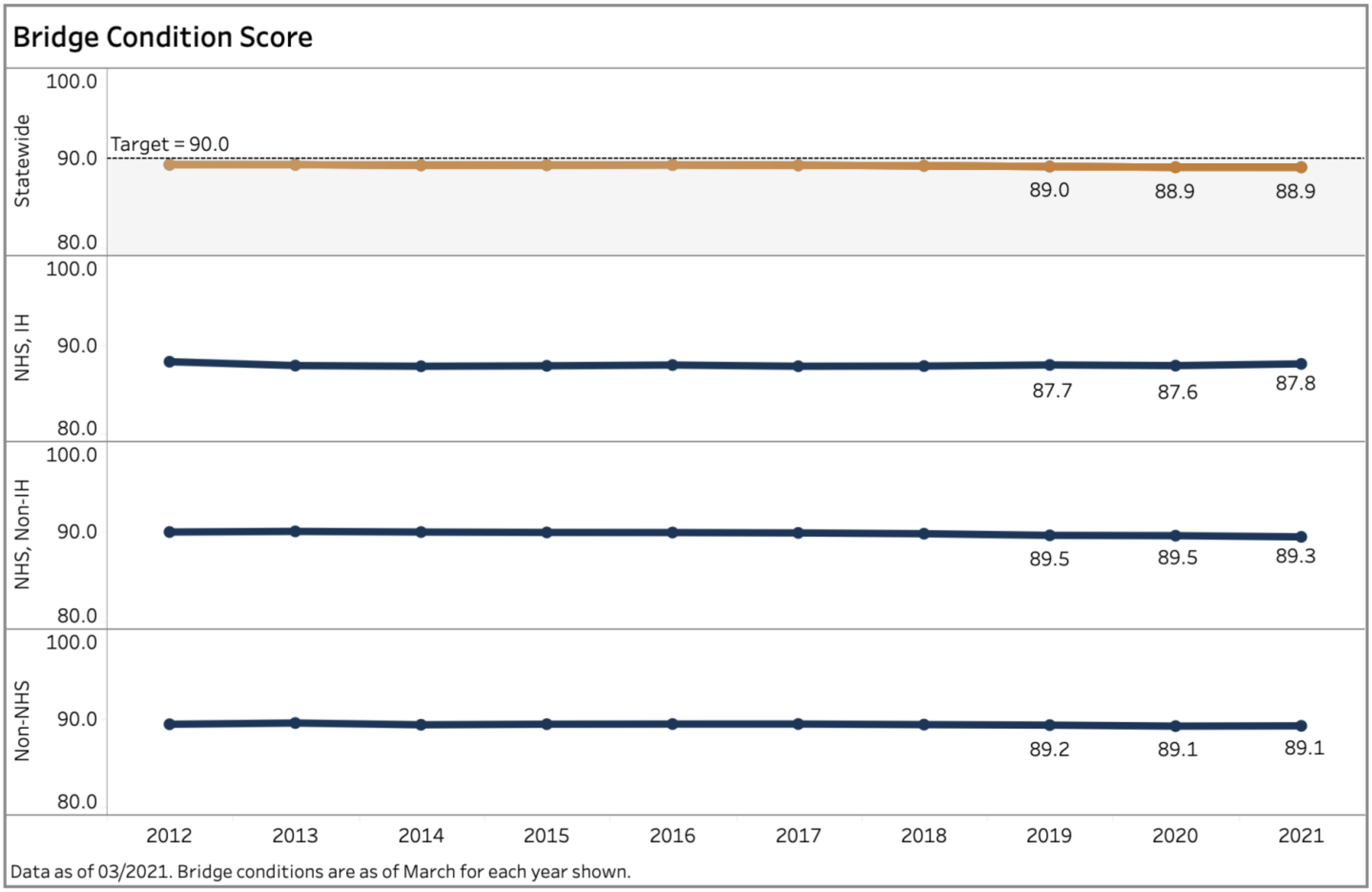


Figure 4-8. Bridge Condition Dashboard Screenshot

Gap Summary/Discussion

TxDOT maintains its pavement and bridges to make progress towards national performance goals and to meet federal minimum condition thresholds for Interstate pavements and NHS bridges. The Texas Transportation Commission has set ambitious asset condition goals and the department strives towards these aspirational goals. TxDOT's continual focus on pavement and bridges ensures the delivery of the best asset conditions possible given the available resources. Resource allocation decisions are made throughout the year as actions are taken and results are reviewed. The predicted gap is the difference between the current condition score and the predicted performance. Table 4-1 shows that a minor gap that is predicted and pavement and bridge conditions in Texas are expected to remain in relatively good condition.

Table 4-1. Gap Assessment using TxDOT Measures

Measure	2021 Actual	2031 Predicted Performance	Predicted Gap
% On-System Pavement Good/ Very Good	89.3%	88.4%	0.9%
On-System Bridge Condition Score	88.9	87.9	1.0

In addition, TxDOT sets 2 and 4 year performance targets using FHWA performance measures for the NHS. Targets are set on a four year cycle, meaning that the 2024 and 2026 targets have yet to be finalized at the time of publication of this TAMP. The most recent available target is the 2022 target, which TxDOT adjusted for both pavement and bridge. TxDOT's 2022 pavement targets were adjusted using only semi-auto/automated HPMS pavement data from the last three years. The 3-year moving average approach was used to set the 2022 targets for both Interstate and non-Interstate NHS systems. A summary of TxDOT targets for NHS assets using FHWA performance measures is shown in Table 4-2.

Texas not only has the largest network of pavements and bridges of any state in the country, but the assets are in relatively good condition. As a result, the desired State of Good Repair (SOGR) at TxDOT is to maintain NHS asset conditions and levels of service at a sustainable steady-state which meets or exceeds state performance measure targets for pavements and bridges. The percent of Interstate pavements in poor condition is predicted to fall below the federal minimum condition threshold. Likewise, NHS bridges in poor condition are predicted to be far below the federal minimum condition threshold of 10%.

Table 4-2. TxDOT Targets for NHS Assets using FHWA Measures

Measure	2021 Actual	2022 Target	2022 Adjusted Target	FHWA Minimum Condition Threshold
Interstate				
% Good	64.9%	66.4%	66.5%	
% Poor	0.2%	0.3%	0.2%	5.0%
Non-Interstate NHS				
% Good	52.9%	52.3%	54.1%	
% Poor	14.7%	14.3%	14.2%	
NHS Bridge				
% Good	49.8%	50.4%	50.4%	
% Poor	0.9%	0.8%	1.5%	10.0%

Strategies to Address Gaps

TxDOT will continue to improve pavement management, maintenance, and rehabilitation techniques. These management efforts can allow TxDOT to treat additional lane miles, keep the pavement network in overall good condition despite increased traffic loading, and reduce the long-term cost of maintaining pavements. Specific details about these efforts are provided below:

TxDOT will continue to produce a Four-Year Pavement Management Plan each year that includes all aspects of pavement-related work. These are project-specific and financially-constrained plans which map out the pavement work needed, along with expected changes in pavement condition. This will have the immediate benefit of giving districts a tool to plan out their pavement preservation and maintenance work rather than being reactive to it.

TxDOT will continue the series of Peer Reviews of each district's pavement and bridge maintenance programs. The Peer Reviews work for districts to share "best practices" in order to make the best use of resources to improve the effectiveness of maintenance activities on pavement and bridge assets.

TxDOT will continue the implementation of annual four-year bridge plans, enabling districts to better manage the on-system bridge inventory. These plans and review processes will continue to strengthen the lines of communication between districts and TxDOT leadership, and more proactively coordinate bridge programming.

TxDOT will continue to improve and implement AASHTOWare Bridge Management (BrM) for project identification and program optimization. Improved configuration of BrM and wider adoption will empower bridge managers to more effectively predict the need for preventive maintenance and light rehabilitation projects in addition to the heavy rehabilitation and replacement of bridge structures.

5. Risk Management

Risk management at TxDOT means identifying, studying, and managing the risks that could impact the performance of the state's bridge and pavement assets. The application of risk management informs decisions throughout the agency on topics from the safety of the public and staff employees to system performance and project delivery. Risk management is adopted and applied across all agency levels for an institutional response to prevent the worst risks from materializing.

Year after year, TxDOT learns from the risks that occur and adapts our procedures to prevent and minimize the effects. Through a structured risk management process and continual learning, TxDOT is in a much better position to handle the risks faced and future challenges with the resources at hand.

Existing Risk Management Practices

Risks appear in many forms at TxDOT, from extreme weather, availability of funding, growing use of the system due to rapid population increases, and internal agency processes, to availability of staff. Many of these risks are dealt with through agency policies or ongoing programs featuring analysis, implementation, and observation. However, the risk of extreme weather and the need to build resiliency requires more intentional discussion and action. Over the course of the last four years, Texas agencies (including TxDOT as well as many regional MPOs) have pursued resiliency plans, pilots, and research endeavors all to understand and adapt to the growing threat of extreme weather. TxDOT and other local transportation agencies have a long history of risk analysis imbedded in their standard operating processes that consider risks and ensure the safety of the traveling public.

Resiliency

Practicing resiliency at TxDOT means to quickly recover from disruptions through careful preparation, rapid response, and constant adaptation. Resilience has always been an important piece of transportation planning, asset management, and project selection at TxDOT. Flood mapping, coastal surge data, and other relevant data are being gathered and applied to asset management, and engineers design facilities to sustain the effects of heat, flood, precipitation, wind, and tides. More recently, TxDOT has adjusted their process for bridge maintenance to address and reduce bridge scour in flood-prone areas: strengthening channels and embankments as well as raising bridges where necessary to prevent future damage from extreme storms. Resiliency efforts for riverine and coastal areas are also included in planning and programming processes at TxDOT. Excluding extreme weather, most environmental stressors are accounted for in TxDOT's construction, reconstruction, rehabilitation, and maintenance programs. However, the increased risk of extreme weather in the state has bolstered the need for focused attention on the challenges of building resiliency.

During the period of 2017 – 2021, Texas experienced the category 4 Hurricane Harvey, three additional lower category hurricanes, three tropical storms, Winter Storm Uri, and numerous localized droughts, tornados, wildfires, and flood events. Texas has 367 miles of coastline along the Gulf of Mexico (NOAA Shoreline Website, A Guide to National Shoreline Data and Terms, National Oceanic and Atmospheric Administration. Last Updated May 9, 2016. https://shoreline.noaa.gov/.) and it contains 11 major rivers with extensive tributaries that drain into the Gulf of Mexico, so flood risk will always be one of the primary challenges facing transportation infrastructure. Table 5-1 shows the climate variables featured in Texas, their impacts, and the current levels of change. While seismic activity is not a prominent risk in Texas, TxDOT does use a rapid warning system (ShakeCast) and monitors related research projects.

Table 5-1. Texas Climate Variables and Impacts

Climate Variable	Impact	Change
Temperature	Heat waves, wildfire, and freeze-thaw cycles	1.5°F increase since start of 20th century. Predict increase of 20-30 days above 95°F by 2055. 40% more days above 100°F in 2036 compared to current average from 2000-2021. Source: https://climatexas.tamu.edu/files/ClimateReport-1900 to2036-2021Update
Drought	Decreased precipitation, wildfire	Inconclusive evidence for statewide projections, but evidence suggests increasing severity. Source: https://climatexas.tamu.edu/files/ClimateReport-1900to2036-2021Update
Sea Level Rise	Increased water elevation	7.1mm/yr at Rockport & 6.6 mm/yr at Galveston Source:https://www.vims.edu/newsandevents/topstories/2021/slrc_2020.php)
Precipitation	Flooding, drought	No significant change in overall precipitation levels, but predict an increase in extreme precipitation. Source: https://climatexas.tamu.edu/files/ClimateReport-1900to2036-2021Update

The significant risks presented by temperature, drought, sea level rise, and especially flooding, are studied, discussed, and managed in a number of projects, events, and reports completed by TxDOT in recent years.

Statewide Resiliency Plan

TPP's Statewide Planning Branch will be developing a Statewide Resiliency Plan beginning in 2022 on a 16 month timeline. TxDOT plans to leverage foundational work already going on within the Department at the Division and District level, as well as with external partners. TxDOT has established a Steering Committee made of Divisions and Districts to guide development of this plan to ensure it meets the needs of the Department as they relate to resiliency planning. Some of the intentions for this plan include, but are not limited to:

- defining what resiliency means to/for TxDOT
- setting goals and vision with respect to resiliency
- providing a foundation, framework, and tools for Divisions and Districts to incorporate resiliency into their processes
- including an inventory of critical assets and an assessment of their role/vulnerability
- including an inventory of major disruptors, natural and man-made, that affect the transportation system
- developing an implementation plan that includes strategies (policies, projects, etc.) and planning tools for improving the resiliency of the transportation system, enhancing resiliency planning, and incorporating resiliency into project development/selection; plan to include a Resiliency Improvement Plan, which aligns with new federal funding for resiliency from the Bipartisan Infrastructure Law (BIL)

Source:
https://library.ctr.utexas.edu/Presto/content/Detail.aspx?ctID=M2UxNzg5YmEtYzMyZS00ZjBlLWIyODctYzljMzQ3ZmVmOWFl&rID=ODk2&qrs=RmFsc2U=&q=KHJwLlN0dWR5Tm86KDcwNzkpKU9SKGNhdGFsb2cuU3R1ZHlObzooNzA3OSkp&ph=VHJ1ZQ==&bckToL=VHJ1ZQ==&rrtc=VHJ1ZQ==

Resiliency Plan Steering Committee

The Resiliency Plan Steering Committee was stood up to advise the statewide resiliency plan but TxDOT hopes that it could be expanded in role/purpose to advise and coordinate on all related resiliency efforts.

2050 Freight Network Plan

The Texas freight mobility plan is currently being updated with a timeline for Commission approval in late fall 2022. The work includes a freight resiliency assessment and represents another piece of TxDOT's resiliency efforts.

Asset Management, Extreme Weather, and Proxy Indicators Pilot Final Report

The Asset Management, Extreme Weather, and Proxy Indicators Pilot Final Report was published in 2019 describing the findings from the FHWA study of an extreme weather risk framework in the TxDOT Houston District. The study examined flood risk and its impact on the state-maintained roadway system, concluding that 75% of the state-maintained system is at minimal risk, and 12% face strong risk from 100-year events. One major challenge identified in the study is the lack of robust modelling and analysis capabilities for evaluating alternative measures and efforts to improve resiliency (e.g. vegetation, frequent maintenance, flood walls, improved drainage, etc.). Several suggestions resulting from the study include: analysis of subsurface pavement performance; development of a statewide resiliency index; utilization of existing hydrological models; improved collaboration between climatologists, hydrologists, pavement engineers and other transportation specialists; inclusion of flood-related pavement damage into the condition score; creation of robust models for evaluating flood mitigation strategies; and study of the impact that routing decisions, road closures, and the elevation of affected roads has on the overall network. Figure 5-1 shows an excerpt from the report.

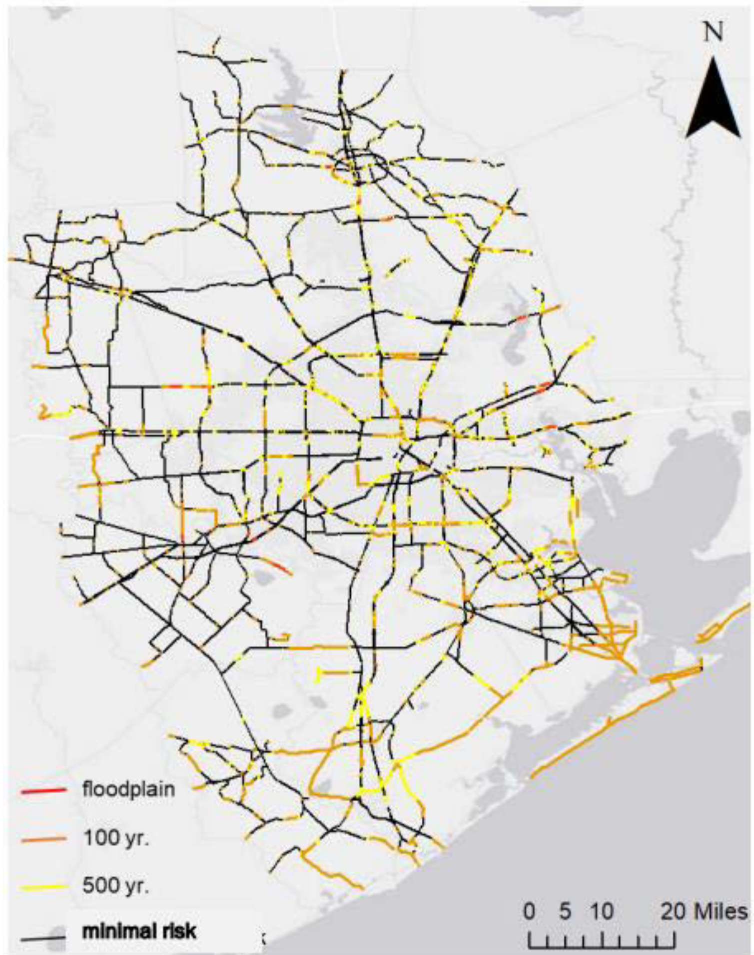


Figure 5-1. Houston District Road Network color coded based on FEMA Flood Risk Zones
Source: https://www.fhwa.dot.gov/asset/pilot/tx.pdf

Creating a Resilient Port System in Texas

The University of Texas at Austin finished a research project to create a resilient port system in Texas: assessing and mitigating extreme weather events last December. The Texas port system, situated along the coast of the Gulf of Mexico, plays a crucial role in the state and national economy. The Texas Gulf Coast is frequently exposed to extreme weather events, which pose a severe threat to the uninterrupted functioning of ports. Disruptions to port infrastructure systems incur significant economic costs to ports in terms of direct damages and import/export revenue and indirect losses to dependent industries given the strong reliance of those sectors on ports for their business continuity. Disruptions to port systems in Texas can also have significant macroeconomic impacts. It is therefore of utmost importance to enhance the resilience of the Texas port system against such events.

This project addresses five key objectives:

- Identify and characterize potential extreme weather events.
- Identify the network and port-level vulnerabilities of Texas ports and supporting infrastructure.
- Quantify the physical and economic risks posed by extreme events to Texas ports.
- Develop metrics and evaluate the resilience of Texas ports.
- Provide recommendations for improving Texas port system resilience.

Source:https://library.ctr.utexas.edu/Presto/content/Detail.aspx?ctID=M2UxNzg5YmEtYzMyZS00ZjBlLWIyODctYzljMzQ3ZmVmOWFl&rID=ODIw&qrs=RmFsc2U=&q=NzA1NQ==&ph=VHJ1ZQ==&bckToL=VHJ1ZQ==&rrtc=VHJ1ZQ==

Hydraulic Design Model Update

Responding to changing patterns of rainfall, TxDOT worked with researchers at TTI, using data from NOAA (National Oceanic Atmospheric Administration), to update their hydraulic design model. This research uses the latest available rainfall data which includes many new patterns of storm duration, frequency, and intensity. The new model improves the predictive accuracy of rainfall zones across the state which allows for effective and efficient hydraulic design of structures

Source:https://static.tti.tamu.edu/tti.tamu.edu/documents/0-6980-PSR.pdf).

Current Research

TxDOT is part of an ongoing project 0-7079 titled “Establish TxDOT Transportation Resilience Planning Scorecard and Best Practices”, which is seeking to develop a foundation of knowledge and tools for resilience planning in transportation through extensive research and analysis. TTI and the Urban Resilience AI Lab at Texas A&M has planned multiple stages and analyses for this project to present a full picture of Texas’s level of resilience:

- Researching current state of practice
- Assessing the vulnerability of the state highway system
- Measuring the accessibility to critical infrastructure
- Creating a transportation resilience scorecard
- Publishing best practices and measures for transportation resilience

Source:https://www.texasmpos.org/wp-content/uploads/2021/05/Mostafavi-TAMU-TTI-research-TX-Resiliency-Working-Group-March-30-2021.pdf

The project team has completed a system-level resilience assessment on road networks in Texas. They identified and analyzed four quantitative metrics that can capture different dimensions of road network vulnerability and criticality in resilience assessment and provide insights for transportation planning and project development. The four-criticality metrics capture different dimensions of vulnerability and criticality including: (1) the loss of connectivity of road segments in road networks, (2) vulnerability of road segments to extreme events such as flooding and hurricanes, (3) disrupted access to critical facilities in the districts, and (4) interdependence of road network with facility networks. These individual metrics of criticality and vulnerability will be combined into one measure to capture the overall criticality and vulnerability of road network links. Figure 5-2 shows the four criticality metrics from the resilience assessment.

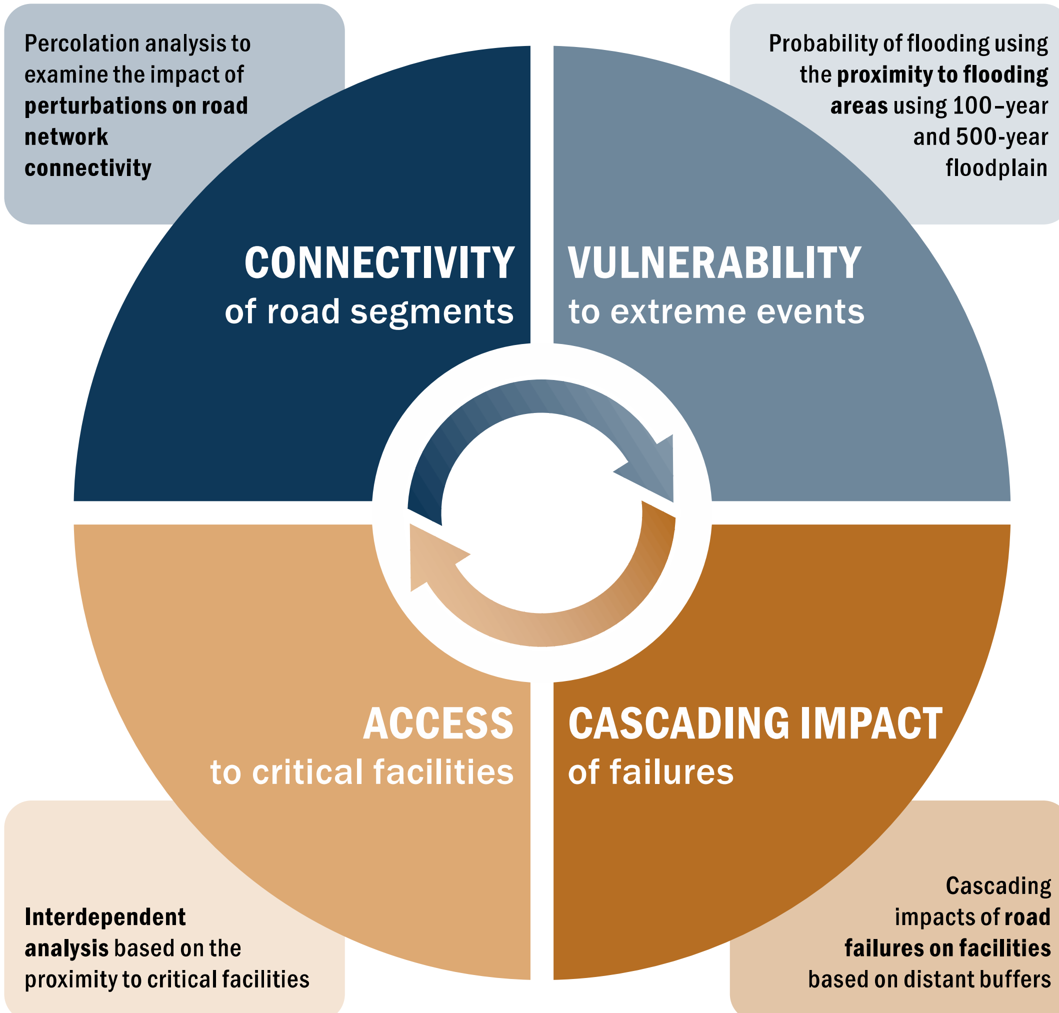
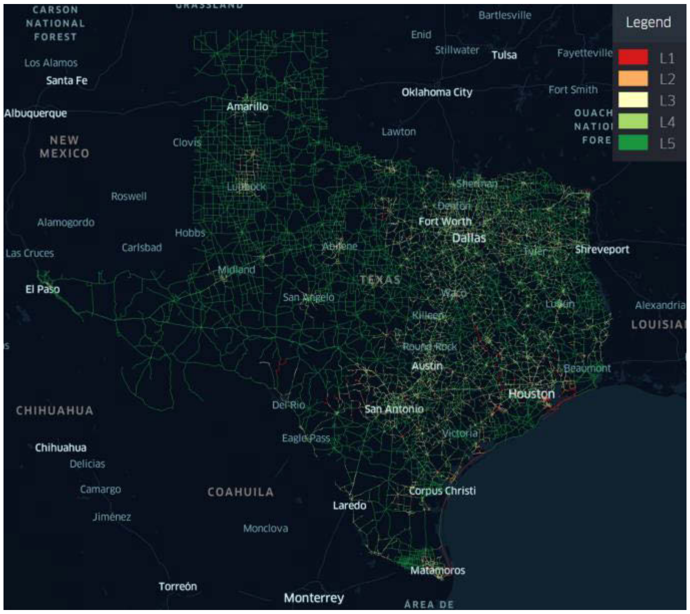
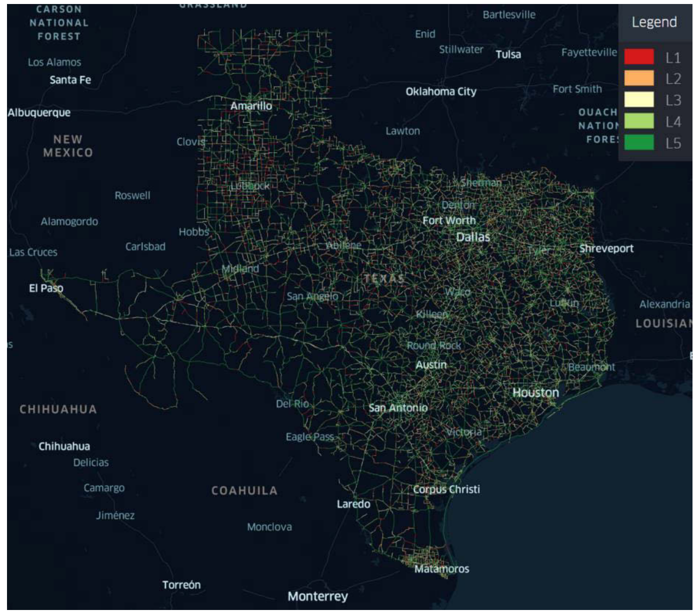


Figure 5-2. Criticality Metrics for Vulnerability and Resilience of the State Road Infrastructure Network

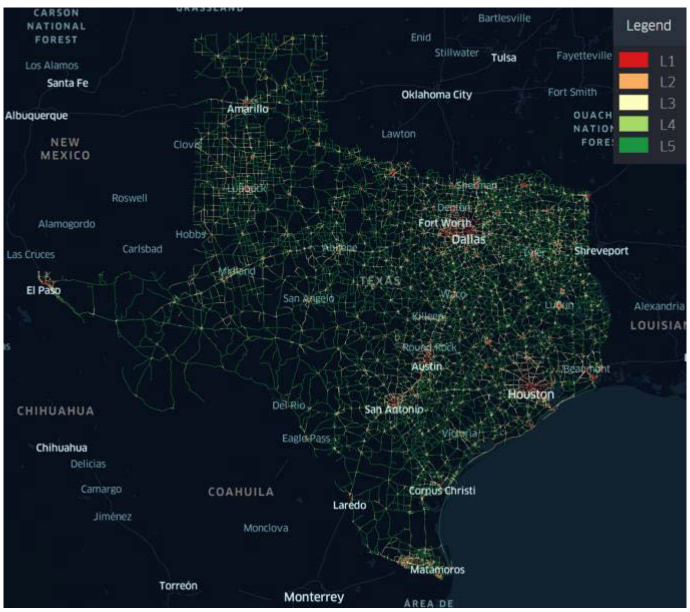
The project yielded four maps showing the criticality metrics across Texas's transportation network, shown in Figure 5-3.



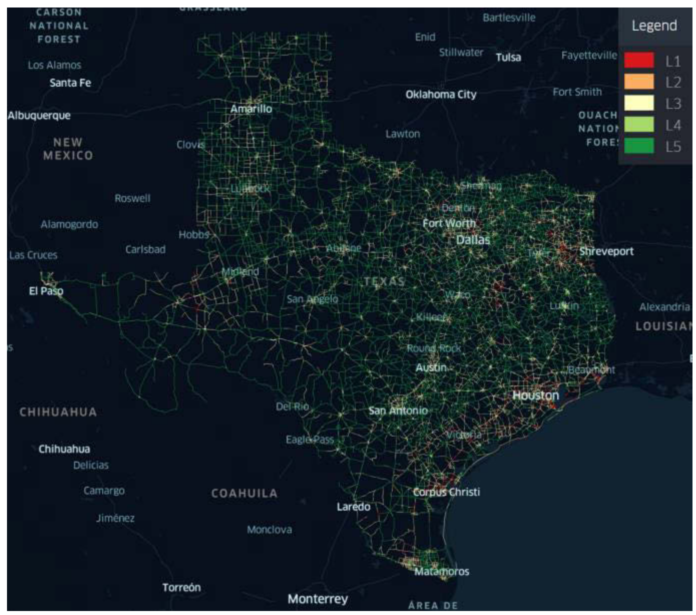
Criticality based on Connectivity of Road Segments



Criticality Metric Based on Vulnerability to Extreme Events



Criticality Metric Based on Proximity to Essential Facilities



Criticality Metric Based on Cascading Impact of Critical Facility Networks

Figure 5-3. Maps of Four Criticality Metrics

Another ongoing research project 0-7094 is researching the behavior of vulnerable Texas communities as they seek to evacuate from severe hurricanes and other weather threats. The researchers at Texas State University are developing models and using spatial analysis to identify and plan key evacuation routes, control traffic flow during these times, and evaluate the vulnerability of infrastructure. The final report will also include recommendations for critical roadway reinforcements.

Source:
https://library.ctr.utexas.edu/Presto/content/Detail.aspx?ctID=M2UxNzg5YmEtYzMyZS00ZjBlLWIyODctYzljMzQ3ZmVmOWFl&rID=ODgx&sID=MQ==&qrs=VHJ1ZQ==&q=KHJwLmNhdGRhdGU9WzIwMjEwMjIyMDAwMDAwIFRPIDIwMjEwMjI2MDAwMDAwXSk=&qcf=M2UxNzg5YmEtYzMyZS00ZjBlLWIyODctYzljMzQ3ZmVmOWFl&rrtc=VHJ1ZQ==

Flood-Related Pavement Resilience and Life Cycle Impact

As part of project 0-7079 described above, the research team is studying the exposure to flood hazards determined by the proximity of road segments to floodplains. The project uses the floodplain data from National Flood Hazard Layer (NFHL) provided by the Federal Emergency Management Agency (FEMA). FEMA defines flood zones according to varying levels of flood risk. Based on the definition of flood zones, the study distinguishes the 100-year floodplain, 500-year floodplain and the rest. The 100-year floodplain means there is a 1% annual flooding probability and is identified as high risk, while the 500-year floodplain means there is a 0.2% annual flooding probability and moderate risk. Regions located outside the 500-year floodplain will be identified as minimal risk or unknown risk. Flash floods are not considered.

As part of this research, the project team developed an interactive map with layers showing the criticality metrics on the Texas road network. The criticality level of the road segments is determined based their proximity to floodplains. A road section with its midpoint located in the 100-year floodplain is classified as Level 1 risk (L1). A road section with its midpoint located between 100 and 500-year floodplain is assigned to Level 2 risk (L2).

Figure 5-4 shows an example map criticality of road segments in terms of their proximity to floodplains, with L1 being most critical and L5 being least critical. The map illustrates that the most flood critical areas are in east Texas and coastal regions.

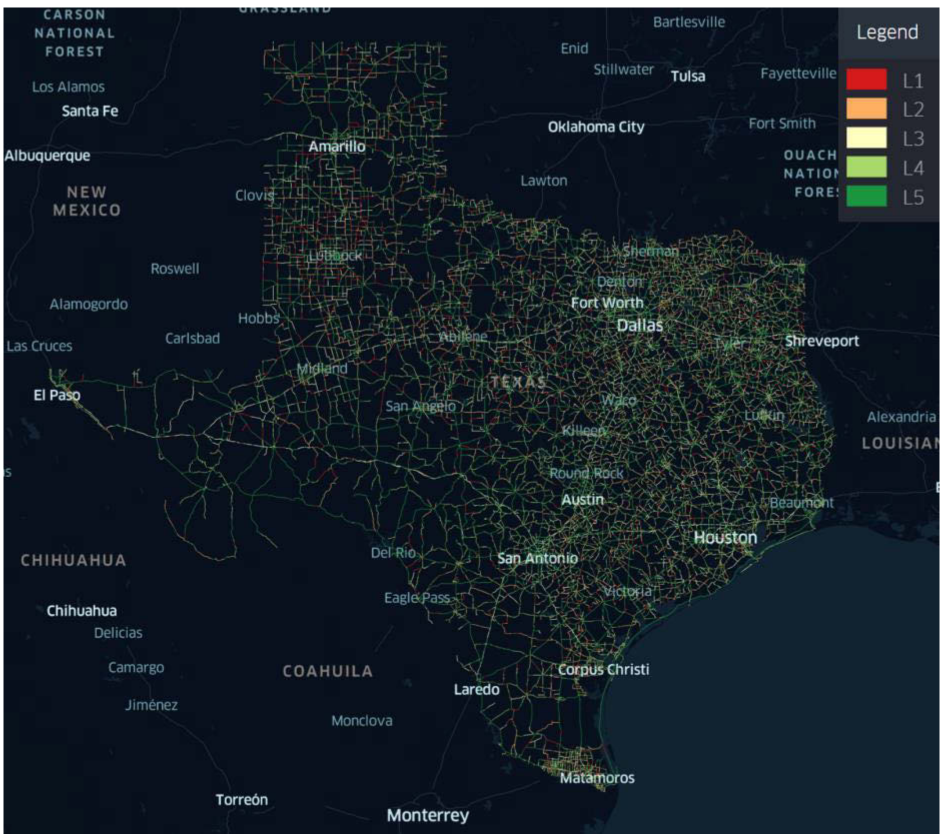


Figure 5-4. Texas On-System Road Segments Flood Criticality

Source: Project 0-7079 "Establish TxDOT Transportation Resilience Planning Scorecard and Best Practices"

Not all pavement structures are vulnerable to flood damage even if they are inundated in the water for a while. TxDOT's state-maintained highway network are built with a variety of pavement structures (e.g. CRCP, JCP, and different thickness of asphalt pavement etc.), and their vulnerability to flood are different. Based on a TxDOT pilot study for FHWA entitled "Asset Management, Extreme Weather, and Proxy

Indicators", thinner pavement types are potentially vulnerable to flood damage. They are identified as Type 6 (asphaltic concrete) and Type 10 (thin surfaced flexible pavement, surface treatment or seal coat) pavements according to TxDOT detailed pavement type classification. 14% of TxDOT state-maintained highway lane miles are Type 6 and 39% are Type 10. Figure 5-5 shows the thin pavement type roadway sections rated L1 and L2.

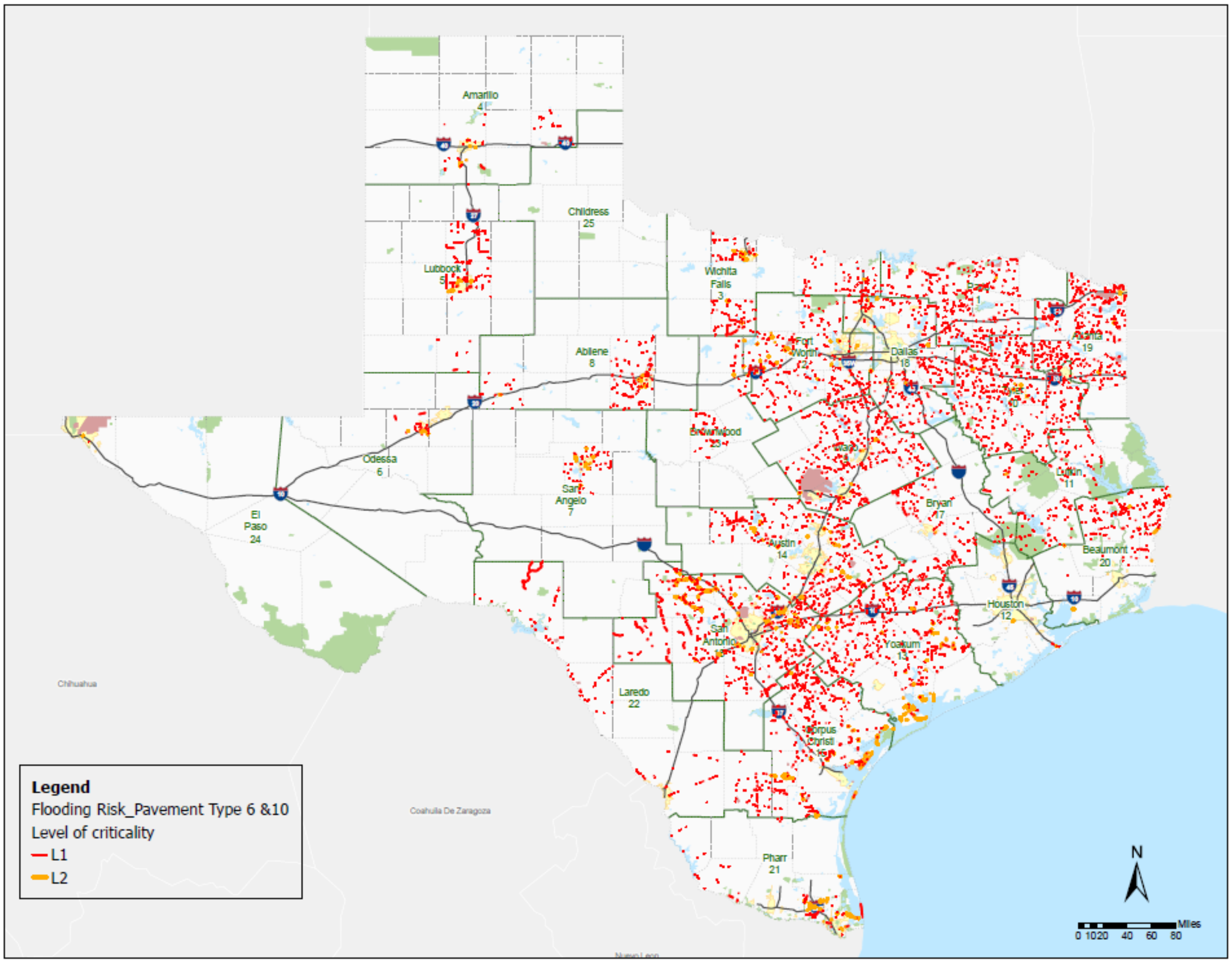


Figure 5-5. Texas On-System Thin Pavement Type Road Segments Subject to 100-year and 500-year Flood Risk
Source: Project 0-7079 "Establish TxDOT Transportation Resilience Planning Scorecard and Best Practices"

Table 5-2 summarizes the lane miles and percentages in the total on-system of Types 6 and 10 that are at L1, L2, and combined. These pavement sections provide candidates in the consideration of improving pavement network resilience in maintenance and rehabilitation treatment decision making.

Table 5-2. Type 6 and 10 Pavement by Flood Risk Levels

Pavement Detailed Types	L1		L2		L1+L2	
	Lane Miles	%	Lane Miles	%	Lane Miles	%
6	797	0.40%	205	0.10%	1,002	0.50%
10	2,445	1.22%	325	0.16%	2,771	1.38%

In addition to the pavement structural strength, the impact of the flood on pavement life is related to varying factors such as traffic levels, the flood event timing, etc. For example, the traffic volume increase due to post-flood recovery activities can result in extra impact on pavements. The different timing of a flood during a pavement service can have different implication on pavement life reduction. To quantify this, in-depth pavement analysis is needed with comprehensive input including materials, thickness, traffic etc. According to the pilot study, the life of a typical Type 10 pavement structure will be reduced by 4 to 8 years under low traffic levels with different flood timing scenarios. This analysis was based on the assumption of typical pavement structure and one specific failure criterion. For more accurate resilience-based life-cycle planning, further study is needed to analyze the pavement system with more accurate in-field structure, material, traffic, and environmental information.

FHWA Extreme Weather Resilience and Durability Pilots

Four Texas MPOs have participated in case studies sponsored by FHWA to improve the regional resiliency of transportation systems. They are the Capital Area Metropolitan Planning Organization (CAMPO) centered in Austin, North Central Texas Council of Governments (NCTCOG) centered in Dallas/Fort Worth, Houston-Galveston Area Council (H-GAC), and the Corpus Christi MPO.

CAMPO's study was completed in 2015, and it culminated in a report titled "Central Texas Extreme Weather and Climate Change Vulnerability." The report highlighted the potential vulnerability of specific assets in the CAMPO region, lessons learned, and methods for improving resiliency. The findings emphasized the need to coordinate across partnerships and municipalities when dealing with a severe weather event, the significance of non-climate-related factors in the impact of extreme weather (e.g., growth), and the understanding that the most vulnerable assets(e.g. lower classification roadways built to lower design standards) are likely not those critical to the transportation system. More specifically, the study prompted the formation of a Resilience Working Group (the Texas MPOs Resilience Working Group, TEMPO, later formed in December 2020) and the inclusion of more weather-related risks into asset management and project evaluation.

NCTCOG also completed their study in 2015 under a report titled "Climate Change/Extreme Weather Vulnerability Risk Assessment for Transportation Infrastructure in Dallas and Tarrant Counties." The study identified increased flood risk and heat damage for several asset types during the spring and summer months. Their recommendations include developing higher-precision forecasts for precipitation and temperature, logging infrastructure damage related to weather events, and simply collecting more data to identify additional impacts of the intensifying weather events.
Source:https://www.texasmpos.org/wp-content/uploads/2020/12/03.15.2020_MPO-Resiliency-Workshops_Final-Document-002.pdf

H-GAC published the final report for their FHWA case study on resiliency, titled "Resilience and Durability to Extreme Weather in the H-GAC Region Pilot Program Report" in 2021. The pilot study comprised a robust analysis of the road network and its risk of flood from rainfall, storm surge, and sea-level rise. The goals of the pilot were to evaluate the vulnerability and criticality of assets to extreme weather, make recommendations for local governments, and use analysis to aid project selection and future research. An online tool, the Regional Resilience Tool, was developed to display the criticality and vulnerability of road segments. This data also informed the selection of priority assets (high criticality and vulnerability measures). Twenty-five Adaption Strategies are suggested as options for local governments to protect important assets. Some of the challenges of the study were related to data availability, specifically data regarding assets historically impacted by flood events and flood depth damage repair costs. The vulnerability matrix from the study is included in Figure 5-6.

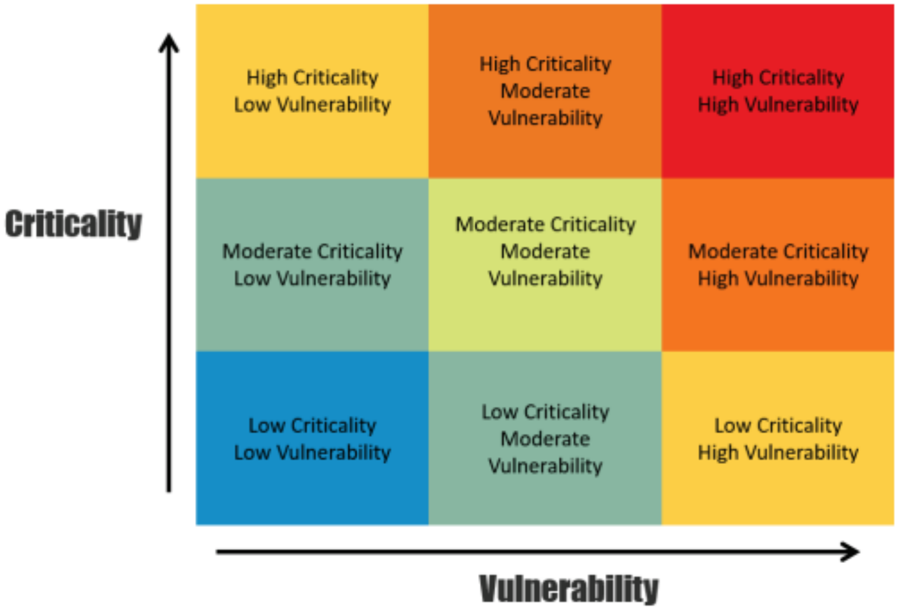


Figure 5-6. Criticality and vulnerability matrix from the H-GAC pilot study.

Source: https://www.h-gac.com/getmedia/4a9d1f74-a43c-4279-8f82-f11da502e1e8/H-GAC-Resiliency-Pilot-Program-Final-Report.pdf

Implementing and monitoring a nature-based shoreline protection feature along the western shoreline of the Laguna Madre was the purpose of Corpus Christi MPO's FHWA pilot program. The protection feature selected in the end was a riprap breakwater with fill for marsh grass on its landward side. This feature offers greater wave attenuation than the alternatives and is easily applied to sloped surfaces. Construction began in October 2020 and was completed in fall 2021. Following construction, the project entered a four-year monitoring stage to assess the impact on the shoreline habitat and protection against flooding. Figure 5-7 shows excerpts from the report.

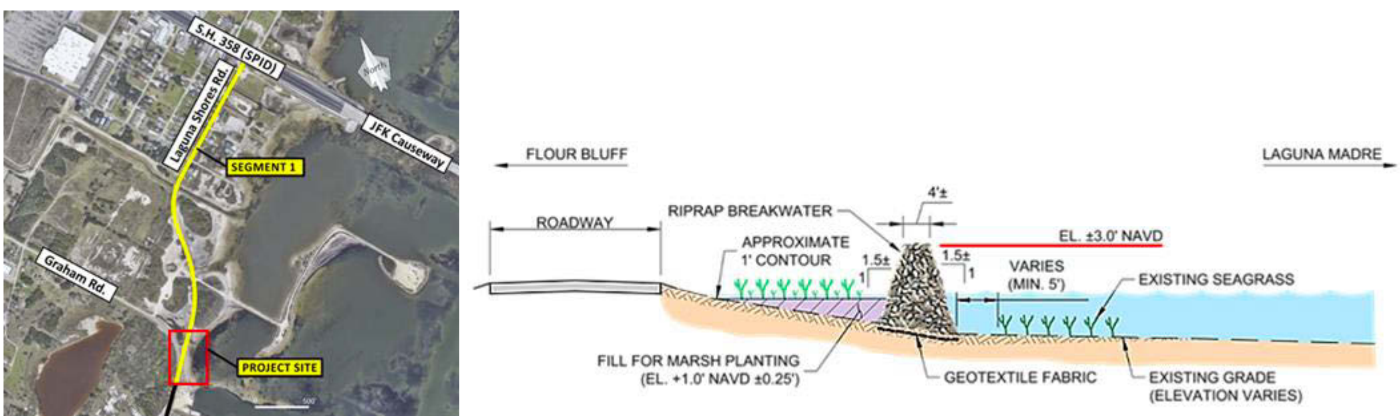


Figure 5-7. An overhead view of the project location in Corpus Christi; and an example of a riprap breakwater protection feature (not to scale).

Source: https://www.fhwa.dot.gov/environment/sustainability/resilience/pilots/2018-2020_pilots/corpus_christi_case_study/

Texas MPOs Resiliency Working Group

The Texas MPOs Resiliency Working Group was established in December 2020, with the goal of improving knowledge and access to resources for transportation resilience and resiliency planning. The group provides coordination across MPOs, TxDOT and local governments to identify resiliency planning best practices.

Source:https://www.texasmpos.org/resiliency-working-group/)

Addressing Resiliency in Regional Transportation Plans

The "Addressing Resiliency in Regional Transportation Plans" workshop in June 2019 featured 15-minute presentations from FHWA, Texas MPOs, and Texas A&M Transportation Institute (TTI) on their efforts to address resiliency in Texas. Topics included transportation planning, a five-step planning framework (define resiliency, goal set, measure performance, assess vulnerability, prioritize mitigation), MPO survey results, freight resiliency, and the results of efforts in MPOs (NCTCOG, CAMPO, Texarkana MPO, H-GAC, and Corpus Christi MPO). The workshop ended with small group discussions, sharing ideas on data sources, strategies, and challenges for incorporating resiliency.

Insights from the workshop included the following:

Data Sources and Tools

- Access to robust data is critical (local asset inventory, traffic, freight, modal, land use, socio-economic)
- Local agencies lack the models and personnel to model asset deterioration and response of transportation infrastructure to climate change
- Potential data sources include FEMA, USGS, US Army Core of Engineers, Floor Control Districts, Houston's TRANSSTAR, and local trucking companies.

Strategies for Promoting Resiliency

- Community support is very important in any discussion about resiliency.
- Development of Backage Roads to increase redundancy.
- Hardening components of the local road system to increase redundancy.
- Maintaining and operating the existing system to ensure resiliency.
- Retrofit vulnerable road segments that are critical to the transportation system.
- Pay attention to culvert sizing/replacement and culvert maintenance to ensure resiliency.
- Develop an inventory of culverts/stormwater system to increase the resiliency of the transportation system.
- Increase the design standards for driveways to protect the road system.

Challenges In Promoting Resiliency

- The need for a Resiliency Working Group to direct and guide the resiliency discussion in Texas.
- Lack of zoning (specifically in Houston) presents a challenge when planning for resiliency in regional transportation plans.
- The lack of robust data and models for vulnerability and risk assessments
- Inadequate funding to meet existing system needs, not considering resiliency priorities.
- Communication with both internal and external stakeholders to make resiliency relevant to decision-makers (education).
- A system approach is required when planning for resiliency, but there is a lack of understanding of the system and the inter-dependencies (inter dynamics) of the system.

- A robust inventory of the transportation infrastructure and the condition of the infrastructure are required for resiliency planning, but information is not available for key components of the system (e.g., culverts).
- A common understanding and goals are required for resiliency planning.
- There is a need to integrate resiliency in documents and manuals, such as the planning and design manuals.
- There is a need to collaborate with regional emergency operations centers; identify the correct contact person.

Source:https://www.texasmpos.org/wp-content/uploads/2020/12/03.15.2020_MPO-Resiliency-Workshops_Final-Document-002.pdf)

Risk Management Approach

The process for managing risk at TxDOT follows four steps:

1. **Identification** – develop a long list of potential risks to TAM using the knowledge of agency experts and documented risk registers from neighboring states
2. **Analysis** – organize the list into seven categories pertaining to different aspects of TAM; and rate the risks on a scale of 1-5 for likelihood and impact
3. **Evaluation** – discuss and review the risk scores to settle on a final list of high-priority items; and develop a mitigation plan for these risks
4. **Address** – implement the mitigation plan; assess the plan's success; and document lessons learned for future risk assessments

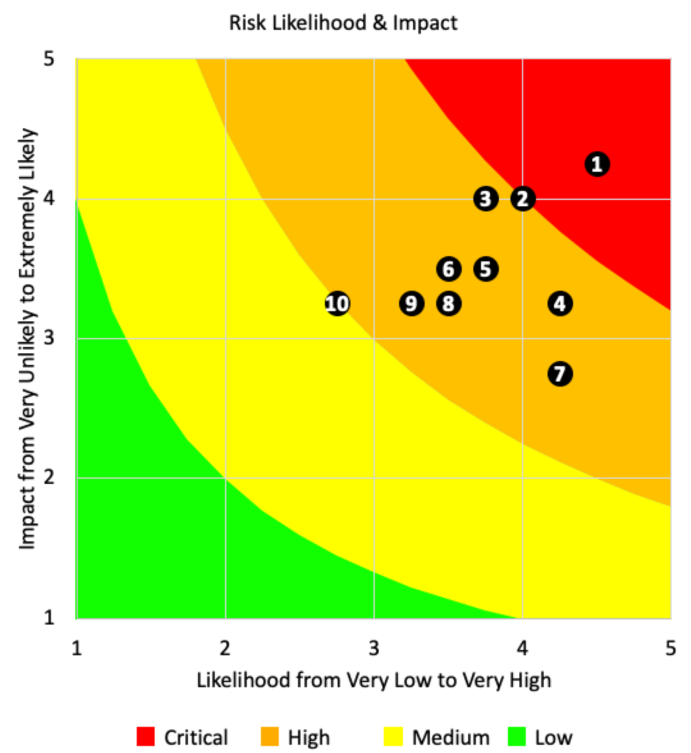


Figure 5-8. TxDOT's 10 identified risks ranked according to likelihood and impact.

In 2019, TxDOT convened a panel of subject matter experts (SME) in the SMEs TAMP Working Group to generate a list of 120 TAM risks separated into seven categories:

- System condition and performance
- Health and safety
- Environmental
- Economic
- Agency Function
- Legal and compliance
- Reputation and stakeholder interest

After consulting the list, and analyzing the risks, the SMEs TAMP Steering Committee rated the risks for likelihood and impact on a 1-5 scale and used the Criticality Score (the product of these two ratings) to establish a four-tiered scale: Low (1-4), Medium (5-10), High (11-19), and Critical (20-25). The six highest-priority risks were then chosen from this list and included in the 2019 TAMP.

In 2022, TxDOT's TAMP Working Group, with participants from Maintenance, Bridge, Transportation Planning & Programming, Traffic Safety, Finance, and the Districts, revisited the process used in 2019 and held a workshop to update and generate the new risk register. In addition to the 120 risks identified in 2019 and the risks selected for the 2019 TAMP, TxDOT also reviewed the Business Impact Analysis reports from their 25 districts and the risk registers of their 4 neighboring states (New Mexico, Oklahoma, Arkansas, and Louisiana).

Figure 5-8 shows the final list of ten risks for the 2022 Risk Register, also listed below in Table 5-3. These risks were selected from the larger list after scoring each on a scale from 1 to 5 for likelihood and impact. Five additional risks were evaluated but not selected for inclusion in the register. The colored bands represent the four-tiered scale, adjusted slightly from the 2019 TAMP. Each level and its corresponding Criticality Score range are as follows: Low (1-4), Medium (4-9), High (9-16), and Critical (16-25).

Risk Register

Table 5-3 shows the ten risks selected for the complete Risk Register through the risk prioritization process. Each of the risks in the table is prioritized based on the Criticality Score and discussions among the TAMP Working Group. Owners of each risk are the office(s) or department(s) identified within TxDOT which are best suited to managing the risk and implementing the mitigation actions.

Table 5-3. TAMP Risk Register

Risk (ID)	Description	Likelihood	Impact	Criticality Score	TxDOT Owner
Natural Disaster (1)	Occurrence of an unanticipated weather event or natural disaster (e.g. hurricane, tornado, snowstorm) resulting in system damage	4.5	4.25	19.1	Maintenance Division and Transportation Planning & Programming
Revenues & Funding (2)	Variability in revenue (sunset dates for Propositions 1 & 7 and FHWA reimbursement) and funding priorities cause variations in realized project delivery, project development, engineering, or construction	4.0	4.0	16.0	Transportation Planning & Programming Division and Finance Division
Heavy Truck Traffic (3)	Accelerated asset deterioration due to unexpected heavy truck traffic from increase in legal loads, energy sector or freight-intensive industry	3.75	4.0	15.0	Maintenance Division and Bridge Division
Material & Labor Costs (4)	Risk related to material and labor costs increasing unexpectedly	4.25	3.25	13.8	Construction Division
Staff Knowledge & Abilities (5)	Ability to maintain or develop staff knowledge and use of technology for asset management	3.75	3.5	13.1	Human Resources Division
Workforce Capacity (6)	Difficulty in project delivery execution with current workforce capacity	3.5	3.5	12.3	TxDOT Executive Leadership
Increasing Population (7)	Continued increases in state population accelerate existing asset deterioration	4.25	2.75	11.7	Maintenance Division
Long-Term Performance Decisions (8)	Slow to make decisions based on long term performance rather than short term gains	3.0	3.75	11.3	Maintenance Division and Bridge Division
Cyberattack (9)	Ransomware or cyberattack resulting in loss of data or network service	3.25	3.25	10.6	Information Technology Division
Public Health Emergency (10)	Occurrence of public health emergency which could affect funding, supply chain, and construction	2.75	3.25	8.9	Human Resources Division, Occupational Safety Division, and Strategic Planning Division

Risk Mitigation and Monitoring

Preventing the risks laid out in the risk register from occurring, and minimizing their impact if they do occur, is a central goal of TxDOT operations, both within asset management and across other TxDOT Districts and Divisions. The mitigation actions and strategies in this TAMP include policy and legislation, funding and spending practices, and technical research and analysis. TxDOT has outlined mitigation strategies and actions for each of the identified risks in Table 5-2. These mitigation options will be acted upon by the risk owner in Table 5-4 throughout the course of this TAMP.

Table 5-4. Mitigation strategies and actions for each of the prioritized risks.

Risk (ID) Description	Mitigation Strategies	Mitigation Actions
Natural Disaster (1) Occurrence of an unanticipated weather event or natural disaster (e.g. hurricane, tornado, snowstorm) resulting in system damage	1. Implement the triage strategy to prioritize asset response: use the tier system (pavement) and scour rating (bridge) to address major routes first in the event of a natural disaster or severe weather event. 2. Focus on design additions for high-risk construction and reconstruction projects to make pavements and bridges more resilient to extreme weather events. Specifically, elevate bridges and improve the subgrade and grade strength of pavement. 3. Make and practice plans for restoring service to normal levels as quickly as possible. 4. Assess evacuation routes to look for additions, deletions, and project needs. Also evaluate the impact of higher level of truck traffic on shoulders of these routes during/after a major evacuation effort.	1. Identify assets (via triage strategy) and reconstruct or rehabilitate those with greatest weather risk. 2. Use gap analysis of visual confirmation (CCTV) and/or communication channels via digital message boards to prioritize and mobilize response when event occurs. 3. Conduct research on effects of inundated pavements and structures to understand the impacts and damages following such events. 4. Update the hydraulic design criteria and guidance. 5. Develop a plan to track ongoing resiliency efforts and contingency funding scenarios. 6. Continue to implement TxDOT Notification System – Veoci system, which allows designated emergency management notification personnel to contact TxDOT employees and contractors with emergency information for hurricane and severe weather responses. 7. TxDOT Emergency Response App (TxERA) is utilized by those who work with the emergency operations center during emergency events. 8. Add more weather-related elements to the Highway Emergency Response Operator (HERO) program to assist motorists and clear minor crashes. The HERO program is managed by traffic management center to dispatch HERO operators to assist incidents. This is available regardless of weather. 9. DriveTexas.org shows road conditions, like traffic, crashes, construction, and weather-related updates as close to real time as possible. https://drivetexas.org/ 10. Coordinate strategies and actions with the Statewide Resiliency Plan

Risk (ID) Description	Mitigation Strategies	Mitigation Actions
Revenues & Funding (2) Variability in revenue (sunset dates for Propositions 1 & 7 and FHWA reimbursement) and funding priorities causes variations in realized project delivery, project development, engineering, or construction	1. Seek more reliable funding sources, including grant funding. 2. Improve project delivery forecast based on funding. 3. Balance expected funding in all areas of system performance.	1. Develop and maintain a list of prioritized projects that may be developed to accommodate funding scenarios and level letting volumes commensurate with funding. 2. Develop funding scenarios accounting for potential funding variability. 3. Continue practice of addressing funding volatility risks through an optimistic planning forecast, which allows for more projects to be developed if more funding is realized. Should less funding become available, certain projects are shelved for the next increase in funding. When reactivating a "shelved" project, efforts need to be taken to update the set of plans for the newest version of the specifications. 4. Adapt to shifts in project priorities with existing resources. 5. Prepare a contingency plan which identifies project priorities if the budget changes suddenly. 6. Establish robust targets for each key phase of project development authority to ensure portfolio health and flexibility. 7. Increase discipline in portfolio management process; and bring forecasting and budgeting of needs into alignment with short- and long-term priorities. 8. Provide timely and accurate feedback/testimony to legislators and policymakers on decisions that affect funding for asset management. 9. Clearly communicate needs and forecasts (for asset maintenance & new construction) with the Legislature, Administration, and the Commission. 10. Improve cost estimating procedures.

Risk (ID) Description	Mitigation Strategies	Mitigation Actions
Heavy Truck Traffic (3) Accelerated asset deterioration due to unexpected heavy truck traffic from increase in legal loads, energy sector or freight-intensive industry	1. Study and understand the legislation affecting heavy truck traffic (e.g. the Bipartisan Infrastructure Bill). 2. Refine the ability to predict asset performance as traffic increases. 3. Track, improve, and adjust traffic prediction models in Coordination with TPP, so asset management systems account for the increased impacts. 4. Extend research and look for examples from other states to fully understand vehicle impacts and identify new mitigation efforts. 5. Develop a management strategy for prioritizing energy sector corridors.	1. Collect and apply findings from TxDOT research regarding the energy sector's impact on pavement and bridges. 2. Participate in esp. House Bill 2223 research effort 3. Adjust the TAMP financial projections to account for the increased impact to asset deterioration. 4. Provide input to TxDMV on oversize and overweight permitting fees 5. Conduct outreach with lawmakers to clearly illustrate the costs and impacts of legal weight limits. 6. Test and apply new technologies (such as full-depth repair) and new materials (such as foamed-asphalt stabilized base) to sustain asset life despite the traffic increase.
Material & Labor Costs (4) Risk related to material and labor costs increasing unexpectedly	1. Improve material and labor cost estimates and increase the frequency of estimations. 2. Develop a plan of action for project managers and contractors to follow when faced with price increases.	1. Manage material on hand to reduce the risk of changing prices. 2. Apply the improved cost estimates and factor funding needs into the project selection process. 3. Get input from the districts to assist with costs & forecasts. 4. Improve project portfolio management through an extensive prioritized project list and better cost estimating procedures.

Risk (ID) Description	Mitigation Strategies	Mitigation Actions
Staff Knowledge & Abilities (5) Ability to maintain or develop staff knowledge and use of technology for asset management	1. Make it easier for providing merit increases and raises to employees. 2. Adopt more knowledge management practices across the agency, from high-level staff to lower levels (with an emphasis on non-engineering roles). 3. Increase flexibility of job profiles (to open career ladder) 4. Develop a succession plan to ease staff transitions. 5. Research current societal changes around workforce to understand the trends behind frequent job changes and low worker retention.	1. Build on current workforce efforts at TxDOT to ensure asset management needs are included. 2. Work with TxDOT knowledge management program to create TAM-focused knowledge capture and transfer mechanisms. 3. Work with TxDOT's training program to develop asset management training resources (this includes trainings provided through others). 4. Offer support for knowledge management programs to all staff. 5. Provide additional merit increases and raises to employees. 6. Specifically work to ease the process for non-engineers to seek and attain promotions. 7. Develop contingency funding scenarios for workforce. 8. Generate and follow plans for implementing replacement systems.
Workforce Capacity (6) Difficulty in project delivery execution with current workforce capacity	1. Research the societal changes and current HR policies that are causing a loss of workforce. 2. Identify areas within the project delivery procedure where efficiencies may be added and processes streamlined. 3. Consider improvements to compensation packages to compete for key workers.	1. Initiate an effort to get TxDOT leadership to act on addressing the need to make TxDOT jobs more competitive. 2. Update HR policies to adapt to the present workforce climate and incentivize workers. 3. Implement trainings for new and incoming workers to prepare them in the areas of construction, project management, and project delivery. 4. Work with the Legislature to continue to authorize more FTEs for the agency. 5. Execute identified efficiencies in the project delivery process.

Risk (ID) Description	Mitigation Strategies	Mitigation Actions
Increasing Population (7) Continued increases in state population accelerate existing asset deterioration	1. Explore TxDOT's current modelling capabilities to assess the level of detail in the existing models of population growth and improve the asset models to better understand the impacts of growth on all corridors. 2. Include the effect of population growth in long-term agency plans. 3. Assess evacuation routes to look for additions, deletions, and project needs. Also evaluate the impact of higher level of truck traffic on shoulders of these routes during/after a major evacuation effort.	1. Accelerate the installation of traffic counters and Weigh-in-Motion stations to improve the data collection and characterization of growth on major corridors. 2. Perform sensitivity analyses in Pavement Analyst to quantify the impact of population growth and increased traffic on the pavement condition. 3. Perform supplemental analyses to "backcast" performance. Understand retrospectively how well the models have performed and make updates based on the findings. 4. Develop new models as needed based on the sensitivity analysis and retrospective analysis. 5. Review the model assumptions for deterioration rates, extent of new construction, and need for functional improvements. 6. Update decision trees based on renewed needs from pavement conditions
Long-Term Performance Decisions (8) Slow to make decisions based on long term performance rather than short term gains	1. Generate buy-in from agency leaders and political leadership to support long-term performance over short-term gains. 2. Build a culture of support for long-term performance maintenance within the agency. 3. Strengthen connections between project evaluation and prioritization and the long-term performance outlook (specifically the Long Range Plan).	1. Develop and provide data-driven performance standards, metrics, and plans to Administration to foster support for project selection based on long-term performance. 2. Implement education and training programs to improve agency-wide knowledge on the benefits of long-term performance over short-term performance in maintenance decisions and project selection. 3. Update the asset management systems with population growth, industry modelling, and preventative maintenance goals to balance the need for investment in maintenance and new expansion projects. 4. Continue the 4-year pavement management plan and implement a 4-year bridge management plan. 5. Continue to maintain and improve TxDOT's Bridge Preservation Guide. 6. Expand pavement deterioration models with capacities to more accurately reflect long-term prediction

Risk (ID) Description	Mitigation Strategies	Mitigation Actions
Cyberattack (9) Ransomware or cyberattack resulting in loss of data or network service	1. Raise awareness among personnel to the risk and cost of cyberattacks. 2. Maintain up-to-date IT software, technologies, and systems and support a strong IT personnel and consistent funding. 3. Expand the security focus not only to employees but also to contractors and consultants. 4. Evaluate case for a statewide transportation operations center	1. Regularly educate and train personnel on the appropriate ways to mitigate risk for cyberattack including proper security for emails, passwords, and internet-connected hardware. 2. Work directly with the Chief Security Officer to continue the audit systems, understand the results, and apply safeguards. 3. Establish and uphold repercussions for personnel who do not follow the security guidelines. 4. Reword contractor and consultant contracts and add funds to the budget to improve security compliance. 5. Coordinate activities with the ITS strategic plan and the initiative to install more fiber/telecom in TxDOT corridors
Public Health Emergency (10) Occurrence of public health emergency which could affect funding, supply chain, and construction	1. Compile the lessons learned from the COVID-19 pandemic. 2. Establish contingency plans for future large-scale supply chain and workforce disruptions.	1. Interview the central office and district staff to document how different groups are adjusting their planning and staffing following the COVID-19 pandemic. 2. Update the existing pandemic playbook with findings from the lessons learned. 3. Disseminate lessons learned and the playbook across the state.

Resiliency Building Actions

As stated earlier in this chapter, resiliency building for extreme weather and natural disaster risks is TxDOT's top priority risk to address through this TAMP.

Texas is a large state with diverse weather conditions depending on the region. A single mitigation action will not serve all regions. TxDOT districts statewide are responding to the increase in weather related disruptions. Examples of these weather-related disruptions include:

- Flood-induced erosion or scour may leave facilities unable to safely function until temporary repairs could be made.
- Ferry boat operations may be impacted due to Coast Guard and port protocols for heavy weather events.
- Power outages can cause disruption to TxDOT's ITS infrastructure, interrupting communication systems, networks, and causing fuel pumps to be inoperable. Citywide power outages can cause fuel shortage for maintenance sections to fuel equipment needed for response.
- Power outages can cause facility issues including functionality loss of water supply, heating, and air conditioning. Building doorways, gates, and other electronic access can be inoperable due to power outages. Major water infrastructure damage can wipe out water supply and cause issues of waste disposal. Hazardous conditions make it impossible to complete incident mission goals.
- Vendor shortages in needed material to respond to winter weather, or getting fuel for emergency incidents.
- COVID-19 pandemic reducing the number of available employees to respond in an emergency and keeping those responding employees safe from exposure.
- Disruptions to port infrastructure systems exposed to extreme weather events incur significant economic costs to ports in terms of direct damages and import/export revenue and indirect losses to dependent industries given the strong reliance of those sectors on ports for their business continuity.
- Fire can cause temporary disruptions due to smoke blocking visibility. There can also be damage to components such as burned surfaces at vehicle fires. Another is burned guardrail post or damage to signs in ROW.
- Snow or Ice can cause temporary disruptions due to unsafe surface conditions. The freeze / thaw from winter weather can cause issues with heaving pavement. Snow plow / blade operations can also cause damage to road surface and traffic markings

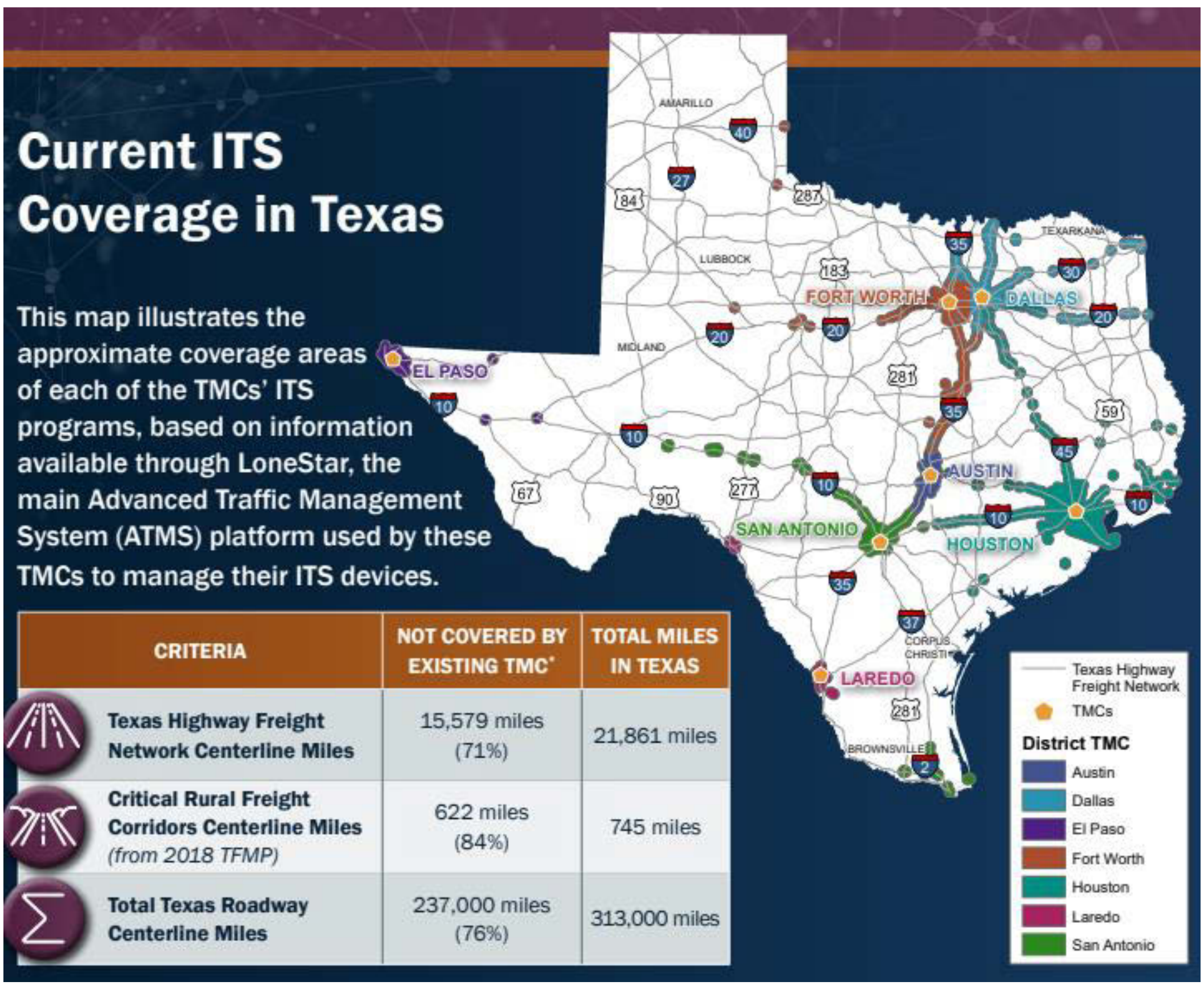
As described in Table 5-4, the following are the mitigation strategies that TxDOT has developed for its highest priority extreme weather risks.

- Implement the triage strategy to prioritize asset response: use the tier system (pavement) and scour rating (bridge) to address major routes first in the event of a natural disaster or severe weather event. TxDOT coordinates with other agencies (through the Texas Department of Emergency Management (TDEM)) to ensure any needs are met for transportation routes to electric facilities during the winter storms. TxDOT prioritizes electric facilities when pretreating assets before the winter storms.

- Focus on design additions for high-risk construction and reconstruction projects to make pavements and bridges more resilient to extreme weather events. Specifically, elevate bridges and improve the subgrade and grade strength of pavement where appropriate.
- Make and practice plans for restoring service to normal levels as quickly as possible.
- Review of evacuation routes

The following are the mitigation actions that TxDOT commits to implementing to address extreme weather risks.

- Identify assets (via triage strategy) and reconstruct or rehabilitate those with greatest weather risk.
- Use gap analysis of visual confirmation (CCTV) and/or communication channels via DMS to prioritize and mobilize response when event occurs. TxDOT's 2020 Freight Network Technology and Operations Plan reviewed ITS coverage across the state and produced a map showing the current extent, as seen in Figure 5-9. This action should be coordinated with the ITS Strategic Plan and STR's fiber initiative.



CRITERIA	NOT COVERED BY EXISTING TMC*	TOTAL MILES IN TEXAS
Texas Highway Freight Network Centerline Miles	15,579 miles (71%)	21,861 miles
Critical Rural Freight Corridors Centerline Miles *(from 2018 TFMP)*	622 miles (84%)	745 miles
Total Texas Roadway Centerline Miles	237,000 miles (76%)	313,000 miles

Figure 5-9. Current ITS Coverage in Texas

- Conduct research on effects of inundated pavements and structures to understand the impacts and damages following such events.
- Update the hydraulic design criteria and guidance.
- Develop a plan to track ongoing resiliency efforts and contingency funding scenarios.
- Continue to implement and improve Drive Texas, which communicates all disruptions to the public.
- Continue to implement Veoci hurricane and severe weather response plan and GIS tool. When a disaster occurs in Texas, TxDOT's priority is to keep the traveling public safe, track costs, be situationally aware, and communicate issues and asset damage. In the spring of 2020, TxDOT launched Veoci, our new virtual emergency operations center. Veoci is a powerful communication tool with workflows, task management, and response reports within the system. In addition, the system allows responders to join anywhere on any device and has an effective notification tool. During a disaster event, TxDOT district/divisions complete daily reports on resources committed that allow the emergency operations center to be situationally aware. Veoci provides an effective preparedness, response, and recovery plan to respond during events. Veoci has the capability for responders to upload pictures from their mobile or tablets in the field while geotagging location and date. For instance, a bridge asset is damaged during a hurricane, and the responder could take a picture and tag TxDOT's Bridge Division to make them instantly aware of the problem. A mapping feature lets us map the issues for a district/division overview of the impacted areas.
- Add more weather-related elements to the Highway Emergency Response Operator (HERO) program to assist motorists and clear minor crashes. TxDOT operates a free HERO patrol service program to clear minor crashes from area roadways and assist motorists in need. The goal of the HERO program is to improve safety and keep traffic flowing along highways in San Antonio, Austin, Houston, Dallas, Fort Worth and El Paso metro areas. Nationally, approximately 20 percent of all traffic incidents are secondary incidents. By removing stranded motorists from the roadway and providing motorists warning of stopped vehicles ahead, we can greatly reduce the number of these crashes. HEROs help clear roadways and restore normal traffic flow by relocating disabled vehicles to safety, removing minor crashes from the roadway, providing traffic and lane control at crash scenes, removing debris from travel lanes, and assisting first responders at crash scenes. HEROs also assist stranded motorists to change flat tires, inflate low tires, add gasoline and water, perform minor vehicle repairs, jump-start batteries, and provide drinking water and cell phone services to stranded motorists

Summary of Assets Damaged by Emergency Events

Federal Requirement

As part of a separate FHWA rule (23 CFR 667), state DOTs must identify assets repeatedly damaged by emergency events. Specifically, it states transportation agencies "shall conduct statewide evaluations to determine if there are reasonable alternatives to roads, highways, and bridges that have required repair and reconstruction activities on two or more occasions due to emergency events." The process and criteria used to determine whether any such assets were identified is discussed below.

TxDOT routinely considers recurring events in the planning, project development, and detailed design phases of their operations. These recurring events are reported for highways and bridges in this TAMP.

Criteria used to identify qualifying assets are shown below. Numerous data sources were used to determine whether a highway or bridge asset should be identified in the TAMP and for reporting in accordance with 23 CFR 667, or "Part 667." The following evaluation criteria were used:

- Asset is part of the state-maintained network (both NHS and non-NHS).
- Asset damage resulted from a natural disaster or other emergency declared by the governor or U.S. president.
- Asset was damaged on two or more occasions.
- Repeated damage occurred at the same location.
- Mode of asset failure or cause of repeated damage was similar.

TxDOT's Maintenance Division submits damage reports and reimbursement requests for projects and other expenses to FHWA following a declared disaster. FHWA determines reimbursement eligibility and a project's disposition.

The TxDOT Maintenance Division leads the efforts to identify assets addressed by Part 667. Other divisions are contacted when there are assets meeting the evaluation criteria. Maintenance Division staff will review emergency repair projects when data are available after the occurrence of a qualifying event. Data sources are the FHWA table of reimbursed projects and other TxDOT identified assets requiring emergency repair.

As asset damage recurrences appear, Division and District personnel responsible for project programming and development will be notified so that the appropriate project level design criteria and resiliency actions may be considered. This will afford the District the opportunity to program and potentially construct feasible solutions to reduce the probability of future damage.

Results of Part 667 Analysis - 2019

For the analysis in the 2019 TAMP, a table of emergency repair projects spanning from 1997 to 2018 was used to determine if any met any, a portion, or all criteria discussed. The table listed location and date of projects containing work addressing damaged assets pertaining to Part 667 and the amount reimbursed to the state. Additional steps were taken to determine whether each pavement or bridge asset had been included in prior emergency repair projects. Further filtering of projects was performed to determine if projects addressing the same asset are in response to separate events and whether the mode of failure was similar. An asset exhibiting failure more than once would be a candidate for reporting in accordance with Part 667.

Occasionally, more than one project are performed in response to the same event. For example, following the collision and damage to the Queen Isabella Causeway in 2001, primary bridge elements were replaced immediately. In 2003, a collision prevention system was installed. These are not considered recurrences because the projects were necessitated by the same event.

Based on the analysis performed for the 2019 TAMP, TxDOT did not have any NHS assets considered to have been repaired more than once in the period reviewed.

Results of Part 667 Analysis - 2020

The 2019 TAMP report considered only assets that are part of the National Highway System (NHS). In compliance with Rule §667.7(b) the Part 667 2020 report considered both NHS and non-NHS roads and bridges. For the analysis, a table of emergency repair projects spanning from 1997 to 2019 was used to determine if the projects met any, a portion, or all criteria discussed. No qualifying recurrences were found in the initial NHS analysis. On the state-maintained network, one bridge (SH82) and two sections of pavement (FM787 and SH316) were found to have suffered damage and required repairs more than one time in the timeframe of 1997 through 2019.

State Highway 82

The SH82 bridge (over Sabine Lake, near the Louisiana border) was damaged by Hurricane Rita in 2005, requiring repairs to its fender system and other components. The same bridge suffered damages caused by Hurricane Ike in 2008. A more resilient bridge was built in 2010. The new bridge has not been damaged by subsequent storms including Hurricane Harvey. This recurrence is considered to have been adequately addressed by the new bridge.

Figure 5-10. Sabine Lake Bridge Built in 2010 and Nearby Intracoastal Canal Figure

The nearby Intracoastal Canal bank has also faced problems. Several pavement failures have occurred on SH82 along the bank. Though this has not occurred more than once at the same location, it is noteworthy due to the similar mode of failure and likely solution. Erosion of the East bank is a continual issue due to ocean liner wake and the deepening of the canal through dredging. The bank is further eroded by tropical storms. Hurricane Harvey caused enough immediate erosion for the pavement edge to fail, as shown in Figure 5-11.

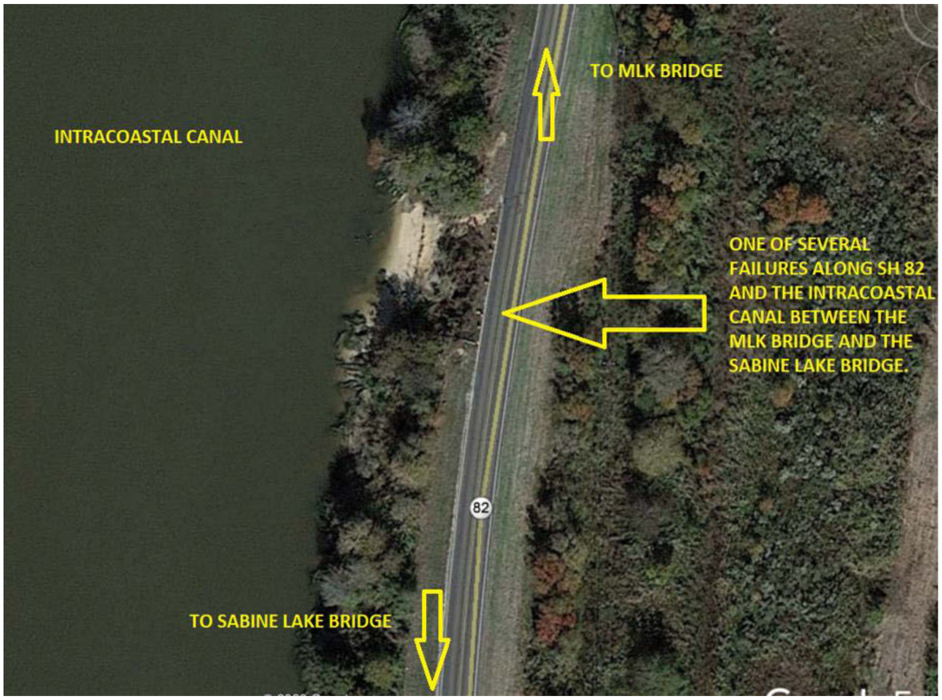


Figure 5-11. Pavement Failure due to Hurricane Harvey

The Port Arthur Maintenance Office of TxDOT's Beaumont District quickly repaired the bank and pavement to quickly reopen all lanes of SH82.

Figure 5-12. State Highway 82 Repairs

Beaumont District personnel wish to improve the SH82 Intracoastal Canal bank by applying a captured-riprap system similar to the one successfully utilized on State Highway 87. SH87 follows the opposite canal bank, parallel to SH82.

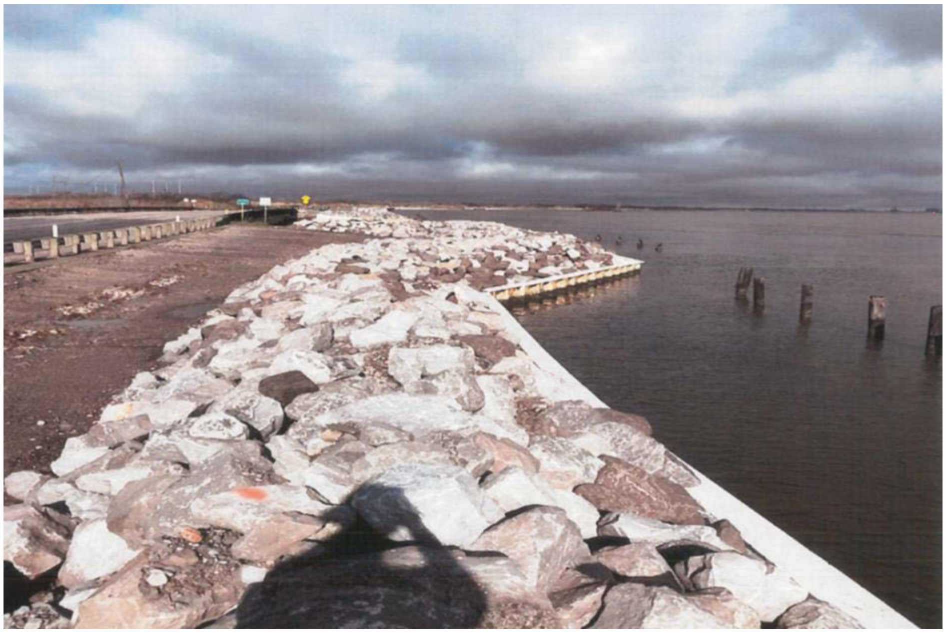


Figure 5-13. State Highway 87 Successful Canal Bank Stabilization

Farm-to-Market Road 787

FM787 near the Trinity River required repairs to the bridge and adjacent pavement in 2001 after Tropical Storm Allison. In 2002, the bridge was extended such that its northeast abutment is now roughly 150 feet further inland from the embankment. While the bridge has been sufficiently resilient to withstand storms (including Hurricane Harvey), the nearby section of pavement has required ongoing repairs.

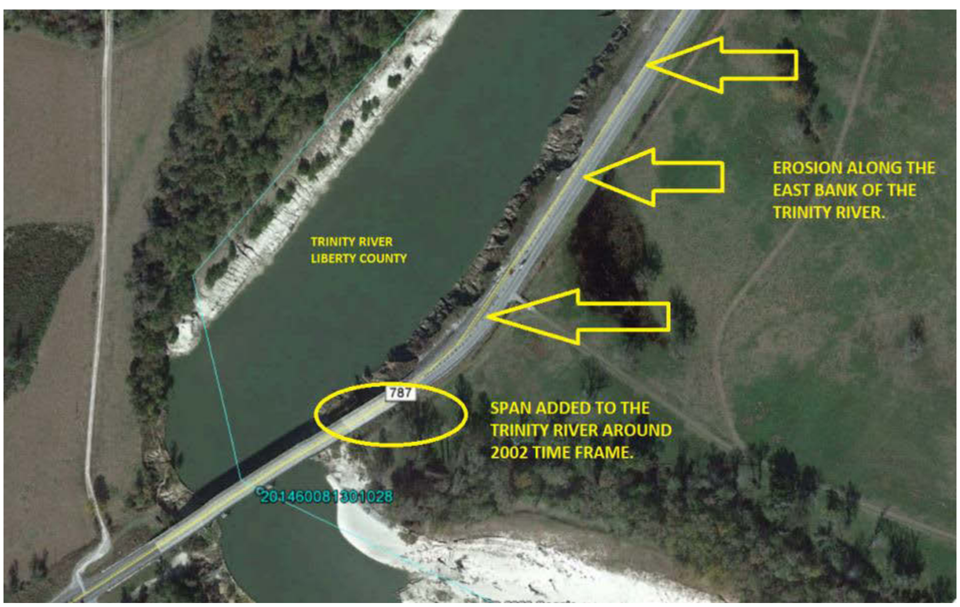


Figure 5-14. Farm-to-Market Road 787 at the Trinity River

While the roadway remains functional with one lane open, a $15.55M project has been initiated for the stabilization of the East bank of the Trinity River through extensive application of sheet piling and riprap. With the foundation stabilized, the pavement will be reconstructed and the facility will be reopened in its original two-lane configuration.

A river migration study has been completed. TxDOT's Beaumont District plans to relocate the bridge and roadway as funds become available. This will address the periodic flooding and gradual encroachment of the river.

State Highway 316

SH316 turns at Matagorda Bay to become a beachfront road. This section is vulnerable and faces recurring damage. The problem is compounded by the gradually receding coastline. TxDOT's Yoakum District keeps the edge repaired and has placed riprap for now. This site has been approved for funding through GLO to make permanent repairs to protect the coastline and the road bed.

Figure 5-15. State Highway 316 Storm Damage

Figure 5-16. State Highway 316 Riprap Placement

Update for this TAMP

In this TAMP, we continued to follow the same procedure as described before, including both NHS and non-NHS routes. Emergency repair projects spanning from 2019 to 2021 were extracted to determine if any met any, a portion, or all criteria discussed. There were no emergency repair projects performed on TxDOT's highway or bridge during the analysis period. This is in line with expectations as Texas was fortunate not to have suffered any serious weather events that affected TxDOT infrastructure during the analysis period.

Continued Monitoring

Maintenance Division staff will continue to review emergency repair projects as soon as data are available after the occurrence of a qualifying event. As this report is updated with new data, it will be distributed to the appropriate personnel responsible for the design, maintenance and repair of the affected assets. Appropriate project level design criteria and resiliency actions will be considered in future projects, reducing the probability of future damage. Once the root cause of the damage has been addressed and implemented, the road or bridge will be removed from the evaluation, though not exempted from scrutiny should there be another recurrence.

6. Financial Plan and Investment Strategies

The financial plan communicates the revenues available for asset management and how TxDOT expects to allocate them to assets and work types. The investment strategies bring together the asset performance projections and targets, life cycle planning, and risk mitigation strategies and actions with the available financial resources to make progress towards achieving state and federal performance goals.

Overview

TxDOT identifies its revenue sources and expected revenue available for transportation projects annually through its Unified Transportation Plan (UTP). The UTP, a 10-year plan that guides development of transportation projects, is authorized annually by the Texas Transportation Commission. The available funding for the 10-year period of the UTP is known as the planning forecast and is developed by TxDOT's Financial Management Division. The UTP not only contains potential funding levels for the 10-year period, but also authorizes the distribution of expected funds across 12 funding categories. These planned distributions link the goals, performance measures, and targets of the statewide long-range transportation plan with specific transportation projects, including projects related to maintaining pavements and bridges in a SOGR.

Because the UTP addresses statewide transportation projects of all types, (pavement, bridge, safety, mobility, connectivity, and congestion), funds available for pavement and bridge work have to be disaggregated from each category of funding. Each category contributes some amount to both pavement and bridge projects. TxDOT uses historical averages to calculate pavement and bridge funding from the category funding. This disaggregation of funding is based on many assumptions, not the least of which is that the percentage representation remains the same from year to year.

Funding Sources

Funding for transportation in Texas is generated from several federal, state, and other sources. Table 6-1 and Figure 6-1 list the funding sources available for transportation related TxDOT expenses. Future funding is projected based on financial analysis that includes historical trends, current statutes, the Comptroller's most current revenue estimates provided in the Biennial Revenue Estimate or Certification Revenue Estimate, current events, and other sources as appropriate.

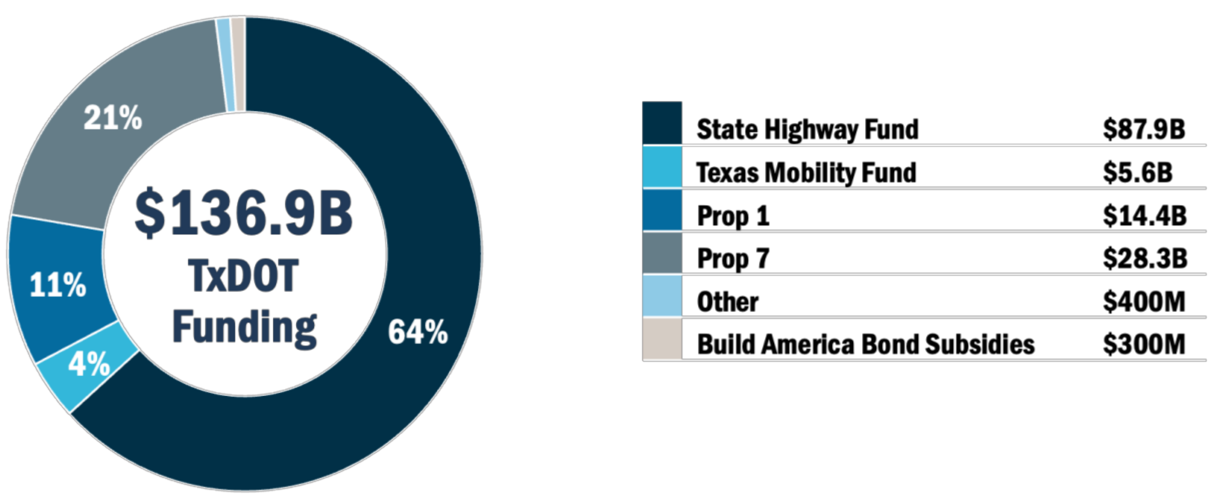


Figure 6-1. Total TxDOT Funding over 10-Year Period of TAMP

- **The State Highway Fund (SHF)** is the largest source of revenue for transportation in Texas. It consists primarily of revenues from the federal reimbursements, state gas and diesel fuel tax, vehicle registration fees, and a few other miscellaneous sources, as shown in Table 6-1. Federal highway reimbursement projections take into account the current federal highway authorization, continuing resolutions, rescissions on obligation authority and apportionment, and other requirements made by FHWA and the federal government for the use of those funds. The state motor fuel taxes consist of a 20 cents per gallon tax on both gasoline and diesel fuel. Vehicle registration fees vary based on the vehicle type, weight, and age. Texas receives federal funds from the Highway Trust Fund to be used on eligible projects.

- **Texas Mobility Fund (TMF)** revenues are derived from taxes and fees including driver's license fees, driver's record info fees, vehicle inspection fees, certificate of title fees, and others.
- **Proposition 1** is an amendment to the State of Texas Constitution, approved by the public in November 2014. The amendment directs a portion of the oil and gas severance tax from the Economic Stabilization Fund to the SHF at the beginning of each fiscal year. Transfers are set to expire in 2035.
- **Proposition 7** is another constitutional amendment passed by the Texas Legislature and approved by the public in November 2015. The Comptroller is directed to deposit $2.5 billion of the net revenue derived from the state sales and use tax in excess of $28 billion to the SHF each year. This provision is set to expire in FY 2032. Beginning in fiscal year 2020, the Comptroller is directed to deposit 35 percent of the revenues collected from the tax imposed on the sale, use, or rental of a motor vehicle that exceed $5 billion to the SHF each year. This provision is set to expire in FY 2029, but for planning purposes is assumed to be extended and is included in the UTP beyond that date.
- **Other revenues** include interest on the cash balance of various funds and toll revenue sharing.
- **Build America Bond** subsidies are determined by the debt service partial reimbursement agreement entered into with the Federal government and are only available for debt service.

Table 6-1. Total TxDOT Revenue ($ billions)

Source	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	Total
State Highway Fund	10.6	9.2	8.8	8.4	8.2	8.3	8.4	8.5	8.7	8.9	87.9
FHWA Reimbursements	5.6	4.2	3.7	3.3	3.0	3.0	3.0	3.0	3.0	3.1	34.8
State Motor Fuels Tax	2.6	2.7	2.7	2.8	2.9	2.9	3.0	3.1	3.1	3.2	29.0
Vehicle Registration Fee	1.6	1.7	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.0	18.1
Other Federal Funds	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	2.0
Other	0.5	0.5	0.5	0.3	0.4	0.4	0.4	0.4	0.4	0.4	4.0
Texas Mobility Fund	0.5	0.5	0.6	0.6	0.6	0.5	0.6	0.6	0.6	0.6	5.6
Prop 1	1.4	1.9	1.9	1.3	1.3	1.3	1.3	1.3	1.3	1.3	14.4
Prop 7	2.7	2.7	2.8	2.9	2.9	3.0	3.1	3.2	2.5	2.5	28.3
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Build America Bond Subsidies	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Total Funding	15.3	14.5	14.2	13.2	13.1	13.2	13.5	13.7	13.1	13.4	136.9

Source: TxDOT Long Range Revenue Forecast, September 1, 2021

Note: The Build America Bonds Subsidies reflect values associated with Prop 14 and Prop 12 bonds. TMF-related Build America Bonds Subsidies are included in the TMF revenue total.

Only a portion of TxDOT's total revenue is available for the UTP planning scenario. The UTP includes revenues from the SHF, Proposition 1, Proposition 7, and non-traditional funding. Non-traditional funds come from sources outside the regular scope of TxDOT funding, such as one-time contributions from local governments. As a result, the total dollar amount in the 2022 UTP is approximately $74.4 billion when non-traditional funding is included. Table 6-2 shows all revenues available for planning as defined in the 2022 UTP.

Table 6-2. 2022 UTP Planning Cash Forecast ($ billions)

Source	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	Total
State Highway Fund (SHF)	3.7	3.5	3.7	3.7	3.8	3.6	3.6	3.7	3.7	3.8	36.8
Prop 1: Oil & Gas Severance Tax	0.6	1.0	1.0	0.6	1.0	1.0	1.0	1.0	1.0	1.0	9.0
Prop 7: Sales & Use Tax	3.2	2.3	2.1	1.6	2.7	2.5	2.1	2.3	2.1	1.9	22.8
Non-Traditional Funding	1.1	1.5	0.2	0.5	1.7	0.2	0.1	0.3	0.1	0.1	5.8
Total	8.6	8.3	7.0	6.5	9.1	7.2	6.8	7.2	7.0	6.8	74.4

Source: 2022 UTP

Funding Uses

The Texas Transportation Commission allocates available UTP funding among 12 funding categories that address specific project types. For each project and program TxDOT intends to pursue during the UTP period, the UTP identifies the applicable funding category or categories from which the project or program is funded. A project's funding may be assigned from multiple funding categories, based on the type of project and its characteristics. Figure 6-2 lists the total funding authorizations for the 2022 UTP plan by funding category over 10 years and Table 6-3 shows the breakdown by category and by year.

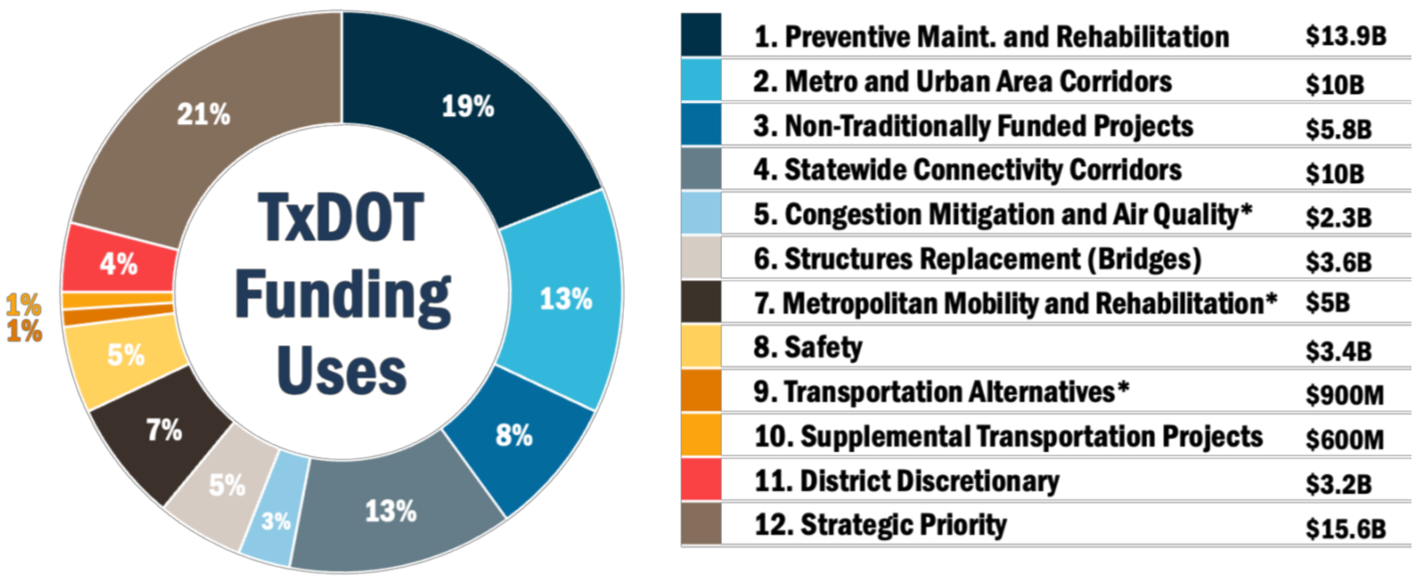


Figure 6-2. UTP Funding Authorization over 10-Years

Table 6-3. UTP Funding Allocation By Category ($ billions)

Source	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	Total
1. Preventive Maintenance and Rehabilitation	1.5	1.4	1.4	1.2	1.5	1.4	1.4	1.4	1.4	1.4	13.9
2. Metro and Urban Area Corridors	1.1	1.0	1.0	0.7	1.2	1.1	1.0	1.0	1.0	0.9	10.0
3. Non-Traditionally Funded Projects	1.1	1.5	0.2	0.5	1.7	0.2	0.1	0.3	0.1	0.1	5.8
4. Statewide Connectivity Corridors	1.1	1.0	1.0	0.7	1.2	1.1	1.0	1.0	1.0	0.9	10.0
5. Congestion Mitigation and Air Quality*	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	2.3
6. Structures Replacement (Bridges)	0.4	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.4	3.6
7. Metropolitan Mobility and Rehabilitation*	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	5.0
8. Safety	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	3.4

Source	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	Total
9. Transportation Alternatives*	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.9
10. Supplemental Transportation Projects	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.6
11. District Discretionary	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	3.2
12. Strategic Priority	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	15.6
Total	8.6	8.3	7.0	6.5	9.1	7.2	6.8	7.2	7.0	6.8	74.4

Source: 2022 UTP
Note: values may not sum due to rounding.

The impact of UTP funding categories can be sorted into five areas: pavement, bridge, congestion reduction, connectivity, and safety. Most categories of the UTP affect multiple impact areas. Of the total funds available for use in the UTP, nearly 30% are allocated for pavements and bridges. The remaining funds are planned for congestion reduction, connectivity, and safety. A summary of funding by impact area is shown in Figure 6-3 and in Table 6-4.

TxDOT's expected expenditures on highways and bridges total $22B over the period of the TAMP.

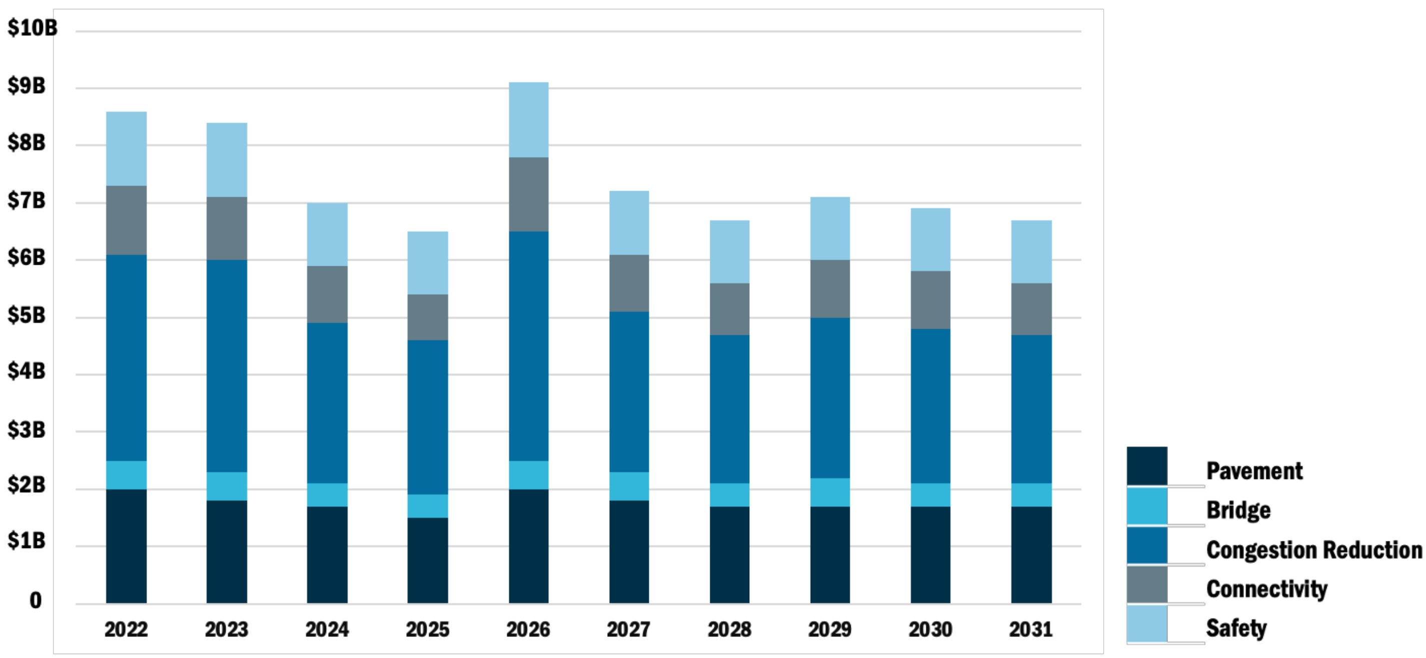


Figure 6-3. Estimated UTP Funding Allocation by Impact Areas

Table 6-4. Estimated Allocation of UTP Funding by Impact Area ($ billions)

Source	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	Total
Pavement	2.0	1.8	1.7	1.5	2.0	1.8	1.7	1.7	1.7	1.7	17.6
Bridge	0.5	0.5	0.4	0.4	0.5	0.5	0.4	0.5	0.4	0.4	4.6
Congestion Reduction	3.6	3.7	2.8	2.7	4.0	2.8	2.6	2.8	2.7	2.6	30.3
Connectivity	1.2	1.1	1.0	0.8	1.3	1.0	0.9	1.0	1.0	0.9	10.1

Source	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	Total
Safety	1.3	1.3	1.1	1.1	1.3	1.1	1.1	1.1	1.1	1.1	11.7
Total	8.6	8.3	7.0	6.5	9.1	7.2	6.8	7.2	7.0	6.8	74.4

Note: values may not sum due to rounding.

Expenditures on NHS pavements and bridges represent a subset of overall TxDOT pavement and bridge expenditures. Figure 6-4 and Table 6-5 show total spending by TxDOT on pavements, broken down by NHS and non-NHS assets.

Texas's expected NHS pavement asset management expenditures total $9.9B over the period of the TAMP.

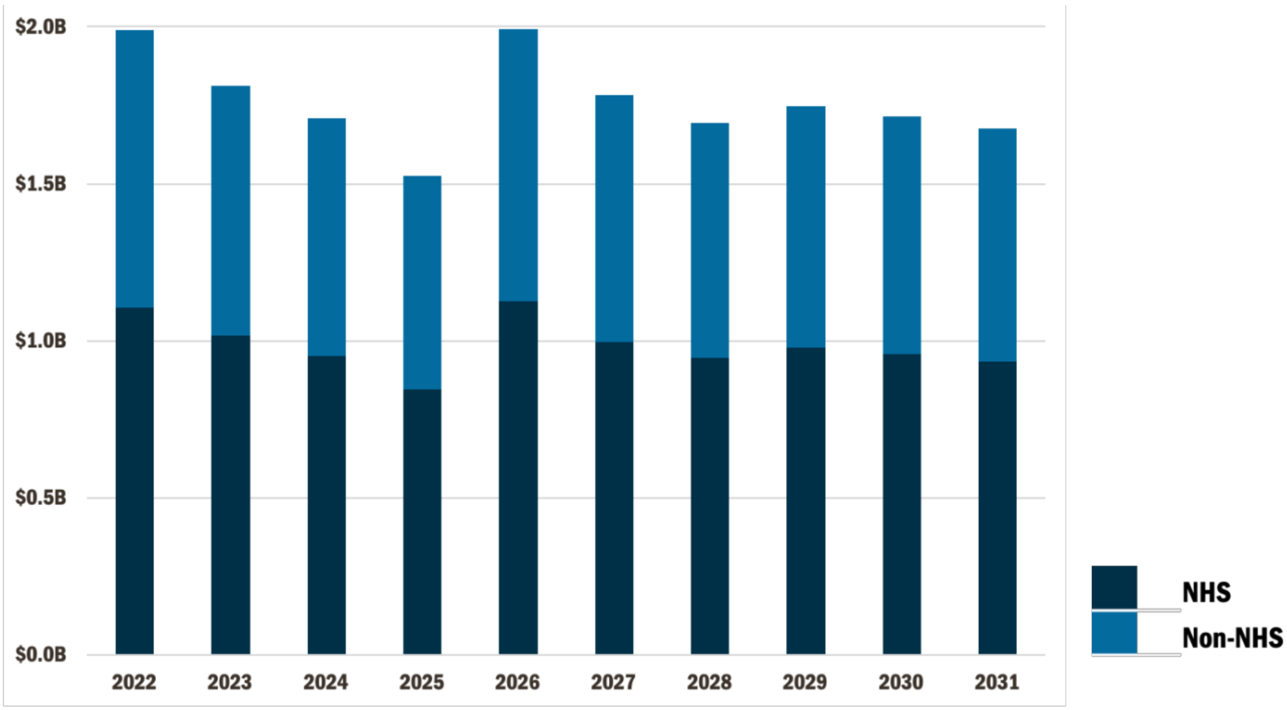


Figure 6-4. Estimated Expenditures on Pavement

Table 6-5. Estimated Pavement Expenditures ($ millions)

Source	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	Total
NHS	1,104.7	1,017.4	952.9	846.7	1,127.0	997.4	945.5	976.8	956.7	933.0	9,858.2
Non-NHS	883.3	793.7	754.9	679.0	866.5	784.9	749.7	770.6	758.5	743.8	7,784.9
Total TAM Eligible Pavement Funding	**1,988.1**	**1,811.1**	**1,707.8**	**1,525.8**	**1,993.6**	**1,782.3**	**1,695.2**	**1,747.5**	**1,715.1**	**1,676.8**	**17,643.2**

Bridge expenditures, shown below Figure 6-5 and Table 6-6, include total estimated spending on bridges, broken down by ownership (On-system or off-system) and NHS (NHS or non-NHS).

Texas's expected NHS bridge asset management expenditures are $3.0B over the period of the TAMP.

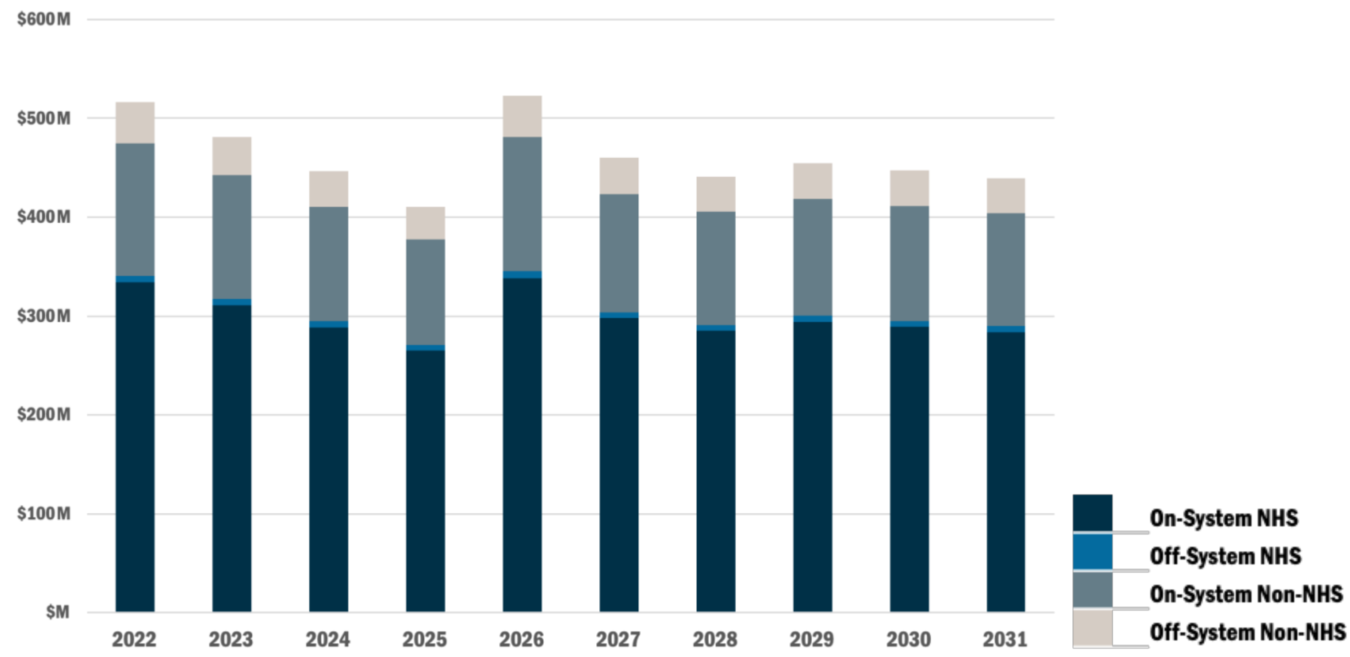


Figure 6-5. Estimated Expenditures on Bridge

Table 6-6. Estimated Bridge Expenditures ($ millions)

Source	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	Total
NHS Subtotal	340.7	317.5	294.7	270.8	345.3	303.9	291.0	300.1	295.2	289.8	3,048.9
On-System NHS	333.9	311.1	288.8	265.4	338.4	297.8	285.2	294.1	289.3	284.0	2,988.0
Off-System NHS	6.8	6.3	5.9	5.4	6.9	6.1	5.8	6.0	5.9	5.8	61.0
Non-NHS Sub-Total	175.5	163.6	151.8	139.5	177.9	156.5	149.9	154.6	152.1	149.3	1,570.7
On-System Non-NHS	134.2	125.1	116.1	106.7	136.0	119.7	114.7	118.2	116.3	114.2	1,201.1
Off-System Non-NHS	41.3	38.5	35.7	32.8	41.9	36.8	35.3	36.4	35.8	35.1	369.6
Total TAM Eligible Bridge Funding	**516.3**	**481.0**	**446.5**	**410.3**	**523.2**	**460.4**	**441.0**	**454.6**	**447.2**	**439.0**	**4,619.6**

Table 6-7 shows TxDOT's planned investments for TxDOT-owned pavement by FHWA work types. As TxDOT defined work types differ slightly from FHWA work types, this TAMP uses a crosswalk to translate TxDOT work into FHWA work types. TxDOT used data from FY22-25 from the UTP and TxDOTCONNECT and from FY22-23 from the Maintenance Management System (MMS). TxDOT took an average of project costs over the first four years of the UTP by work type, and applied those percentages to the UTP funding over the ten year period of the TAMP. Likewise, TxDOT took the average first two years of the MMS and carried those costs forward through the ten years of the TAMP. These values were used to estimate planned pavement investments by FHWA work type over the ten year period of the TAMP. Note that total planned investments by work type exceed the UTP totals in Table 6-5, as maintenance spending comes from the operating budget which is separate from the UTP.

Table 6-7. Estimated Investments in TxDOT-Owned Pavements by Work Type ($ million)

TxDOT Work Types	FHWA Work Types	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
New construction	Initial Construction	18.9	17.2	16.2	14.5	18.9	16.9	16.1	16.6	16.3	15.9
Routine maintenance	Maintenance	272.7	221.5	247.1	247.1	247.1	247.1	247.1	247.1	247.1	247.1
Preventive Maintenance	Preservation	876.2	780.9	757.2	689.4	863.5	784.9	752.5	771.9	759.9	745.6
Light, Heavy, and Medium Rehabilitation (excluding reconstruction)	Rehabilitation	1,154.6	1,036.4	989.1	888.1	1,147.6	1,030.4	982.1	1,011.1	993.2	971.9
Heavy Rehabilitation (reconstruction)	Reconstruction	126.5	115.2	108.6	97.1	126.8	113.4	107.8	111.2	109.1	106.7
Total		**2,448.8**	**2,171.1**	**2,118.2**	**1,936.2**	**2,403.9**	**2,192.7**	**2,105.6**	**2,157.9**	**2,125.5**	**2,087.2**

While TxDOT has limited data on locally owned NHS pavements, particularly regarding planned spending on those assets, TxDOT has developed a methodology to estimate work completed and money spent on local NHS pavements. TxDOT extracts a list of all NHS projects from TxDOTCONNECT and uses the GPS coordinates of each project to check if it is on the locally-owned network, as defined in the PMS. If a project falls in the proximity of the local network, the project costs are added to the total based on work type. The results of this process are shown in Table 6-8.

Table 6-8. Estimated Recent Local Spending on NHS pavements ($ million)

TxDOT Work Type	2020	2021
Heavy Rehab	$28.1	$15.5
Medium Rehab	$1.9	$20.0
Preventive Maintenance	$4.5	$0.6
(blank)	$0.0	$1.6

TxDOT Work Type	2020	2021
Total	$71.9	$99.4

Bridge work funded through the UTP can include any of the following work types defined by FHWA: initial construction, maintenance, preservation, rehabilitation, and reconstruction. Typically, a majority of these funds are used for initial construction, replacement, and rehabilitation work. Routine maintenance operations funds are typically used for maintenance and rehabilitation work.

TxDOT performed an analysis of projects going back to 2005 to calculate the average funding by UTP category dedicated to bridge work, and also the average spending by FHWA work type for each UTP category. TxDOT applied the historical percentages to expected bridge spending over the next ten years to predict investments by work type. Table 6-9 shows TxDOT's planned spending levels for bridges through the Department's primary bridge programs and the corresponding work types associated with those programs. The two biggest categories of expected bridge funding are Initial Construction and Maintenance.

Table 6-9. Estimated Investments in TxDOT-Owned Bridges by Work Type ($ million)

TxDOT Programs & Funding Sources	TxDOT Work Types	FHWA Work Types	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Other Funds	New Construction, Replacement, Safety, Widening	New Construction	130.0	121.1	112.5	103.3	131.7	116.0	111.1	114.5	112.6	110.6
Routine Maintenance	Preventive Maintenance, Minor Repair	Maintenance	138.7	129.2	119.9	110.2	140.5	123.7	118.5	122.1	120.1	117.9
Bridge Preventive Maintenance	Preventive Maintenance, Minor Repair,	Preservation	70.2	65.4	60.7	55.8	71.1	62.6	60.0	61.8	60.8	59.7
Bridge Maintenance and Improvement Program (BMIP)	Major Repair, Rehabilitation	Rehabilitation	70.2	65.4	60.7	55.8	71.1	62.6	60.0	61.8	60.8	59.7
Highway Bridge Program (HBP)	Replacement, New Construction, Replacement, Safety, Widening	Reconstruction	59.1	55.0	51.1	46.9	59.9	52.7	50.5	52.0	51.2	50.2
Total			**468.1**	**436.2**	**404.9**	**372.1**	**474.4**	**417.5**	**399.9**	**412.3**	**405.6**	**398.1**

TxDOT also calculated the average percentage of funding dedicated to NHS bridge projects and calculated historical percentages by work type. Those percentages differed from the investment trends for TxDOT-owned bridges. Table 6-10 shows TxDOT's planned spending levels for NHS bridges through the Department's primary bridge programs and the corresponding work types associated with those programs.

Table 6-10. Estimated Investments in NHS Bridges by Work Type ($ million)

TxDOT Programs & Funding Sources	TxDOT Work Types	FHWA Work Types	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Other Funds	New Construction, Replacement, Safety, Widening	New Construction	101.8	94.8	88.0	80.9	103.1	90.8	86.9	89.6	88.2	86.6
Routine Maintenance	Preventive Maintenance, Minor Repair	Maintenance	98.9	92.2	85.6	78.6	100.2	88.2	84.5	87.1	85.7	84.1
Bridge Preventive Maintenance	Preventive Maintenance, Minor Repair,	Preservation	49.1	45.7	42.4	39.0	49.7	43.8	41.9	43.2	42.5	41.7
Bridge Maintenance and Improvement Program (BMIP)	Major Repair, Rehabilitation	Rehabilitation	49.1	45.7	42.4	39.0	49.7	43.8	41.9	43.2	42.5	41.7
Highway Bridge Program (HBP)	Replacement, New Construction, Replacement, Safety, Widening	Reconstruction	41.9	39.0	36.2	33.3	42.4	37.4	35.8	36.9	36.3	35.6
Total			340.7	317.5	294.7	270.8	345.3	303.9	291.0	300.1	295.2	289.8

Asset Valuation

FHWA requires an estimate of asset value for NHS and any other pavement and bridge assets included in the TAMP. This TAMP uses a depreciated replacement cost methodology to estimate current asset valuations for all NHS and all other non-NHS state highway system pavement and bridge assets. The TAMP also includes an estimate of asset replacement value without adjustment for depreciation.

As shown in Table 6-11, the estimated current value of NHS system pavement assets is $43.0 billion, and the estimated current value of NHS bridges is $58.3 billion. The estimated current value of TxDOT pavement assets is $105.3 billion, and the estimated current value of on-system bridges is $75.5 billion.

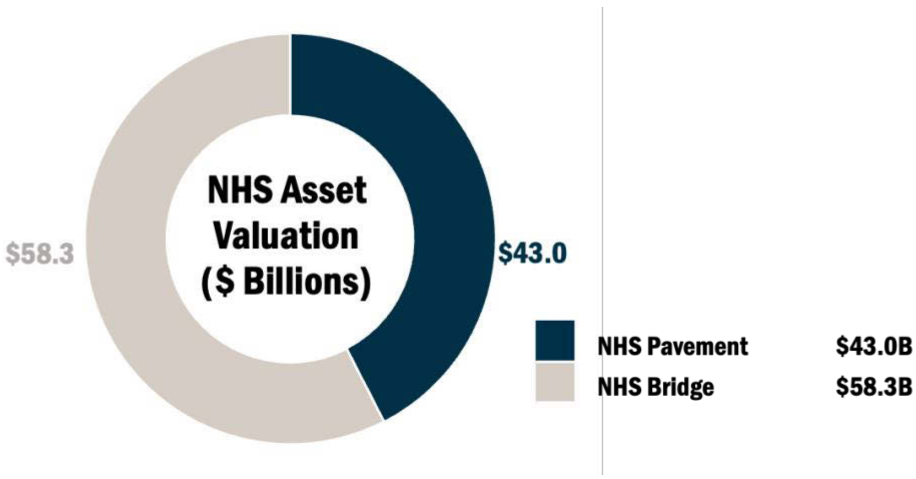


Figure 6-6. NHS Asset Current Value

Table 6-11. Asset Valuation ($ billions)

		Replacement Value	Current Value
Pavement	**All NHS**	$51.2	$43.0
	All On-System	$124.6	$105.3
Bridge	**All NHS**	$72.4	$58.3
	All On-System	$93.5	$75.5
Total	**All NHS**	$123.6	$101.2
	All On-System	$218.1	$180.7

Estimated replacement costs include only material in place and do not include right of way, non-bridge drainage structures, and other appurtenances.

Pavement Valuation Approach

Estimates of current pavement value are based on replacement costs and remaining service life (RSL). The replacement costs are taken from the 4-year pavement plan report and represent the average unit cost for "heavy rehab" for asphalt and concrete pavement projects across the state. “Heavy rehab” mainly includes thick overlay and reconstruction by TxDOT’s definition. The unit cost includes material, labor, and mobilization for the pavement projects.

TxDOT calculates RSL based on current conditions for each pavement segment. RSL is the estimated number of years until the pavement cannot provide acceptable serviceability, defined by thresholds for critical distresses assigned to all pavement sections in every performance category. 50 years is the maximum RSL, regardless of condition. Service life is defined as the estimated number of years it takes for new pavement to reach unacceptable serviceability.

TxDOT uses Pavement Analyst to perform the current valuation calculations. The pavement network is segmented into homogeneous sections, with respect to several attributes including traffic level, pavement type, environmental zone, condition score classification, county and district. For each homogeneous pavement section, the Depreciated Replacement Cost is calculated as

$$Depreciated\ Replacement\ Cost = \frac{RSL}{Service\ Life} \times Lane\ Miles \times Unit\ Cost$$

Total current asset valuation is the summation of depreciated replacement costs for all sections.

For NHS off system pavement valuation, because there are no deterioration models and relevant performance prediction input variables available, an approximate estimation approach is applied. It is assumed that the NHS off-system pavements have a similar average remaining life as the on-system pavements. This assumption is based on the fact that similar design and materials are used on the off-system pavements and they sustain the similar traffic and climatic environment as the on-system pavements in Texas.

Bridge Valuation Approach

TxDOT estimates bridge asset value using a depreciated replacement cost methodology similar to the approach for pavement. The depreciated replacement cost for a bridge is estimated as follows:

$$Depreciated\ Replacement\ Cost = Percent\ Life\ Remaining \times Deck\ Area \times Unit\ Cost$$

Percent life remaining is calculated for each NBI component rating and the minimum value is used for the bridge. Table 6-12 shows the percent life remaining for each component rating for two different age groups. The percentages shown in Table 6-12 were developed based on deterioration models used in TxDOT’s implementation of BrM. The models are used to estimate time spent in each rating, and also used to determine the total amount of time for each asset type.

Table 6-12. Crosswalk of NBI Ratings and Remaining Service Life

Bridge Age (years)	Rating	% Remaining Service Life By Component Type			
		Culverts	Deck	Superstr.	Substr.
0-34	9	100%	100%	100%	100%
	8	99%	96%	96%	96%
	7	98%	92%	91%	93%
	6	88%	73%	78%	78%
	5	65%	41%	51%	52%
	4	16%	22%	28%	30%
	3	5%	5%	5%	5%
	2	0%	0%	0%	0%
	1	0%	0%	0%	0%
	0	0%	0%	0%	0%
35+	9	100%	100%	100%	100%
	8	96%	96%	95%	95%
	7	94%	94%	92%	92%
	6	87%	82%	82%	77%
	5	64%	60%	56%	50%
	4	22%	37%	33%	26%
	3	5%	5%	5%	5%
	2	0%	0%	0%	0%
	1	0%	0%	0%	0%
	0	0%	0%	0%	0%

Unit replacement costs are based on statewide bridge unit cost reports from 2018, 2019, and 2020. These costs only account for bridge-specific bid items (ignoring mobilization, traffic control, demolition, etc.), and underestimate the total direct cost of replacement. Additional corrections are made to estimate total project cost more accurately. First, a factor of 2.0 is applied to account for additional bid items (e.g. traffic control and mobilization)—assuming bridge bid items correlate to approximately 50% of total project costs. Second, replacement projects are assumed to cost a minimum of $100,000. Without this value floor, the unit cost model yields unreasonably low results for small structures.

Investment Strategies

Investment Strategy Development

The investment strategy approach TxDOT has taken is one of fiscal constraint. Based on the funding projected to be available for pavement and bridges, life cycle planning, risk management and resiliency building, and scenarios with funding levels that are most likely to be available, investments are modeled to determine the strategy most feasible to maximize performance of the assets at a minimum practicable cost. In the TxDOT-wide investment strategy development process, asset management competes with numerous other priorities that are aligned with other goals and objectives.

FHWA requires states to "discuss how the plan's investment strategies collectively would make or support progress toward":

- Achieving and sustaining a desired SOGR over the life cycle of assets
- Improving or preserving the condition of the assets and the performance of the NHS assets
- Achieving the state DOT targets for asset condition and performance of the NHS
- Achieving the national goals identified in statute

As a result of existing TxDOT planning and programming processes, TxDOT has identified its investment strategies in various documents including:

- TTP (Texas Transportation Plan) 2050
- UTP (Unified Transportation Program)
- STIP (State Transportation Improvement Program)
- Annual Letting Schedule

Each of these documents contains products or explanations of the planning and programming processes that represent TxDOT investment strategies. The different documents cover different time periods and contain varying levels of detail, as shown in Figures 6-7 and 6-8.

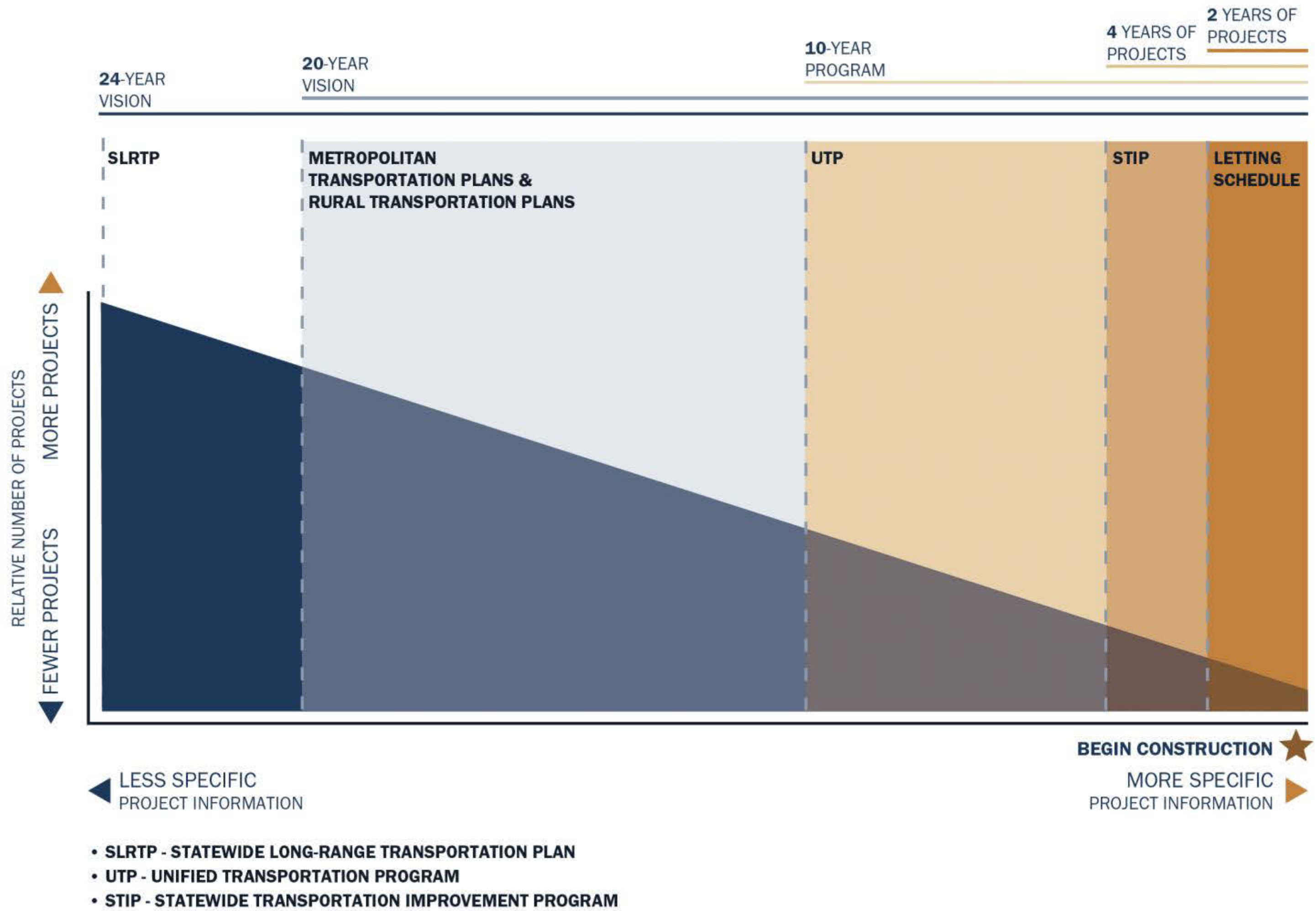


Figure 6-7. Planning and Programming Documents and Products

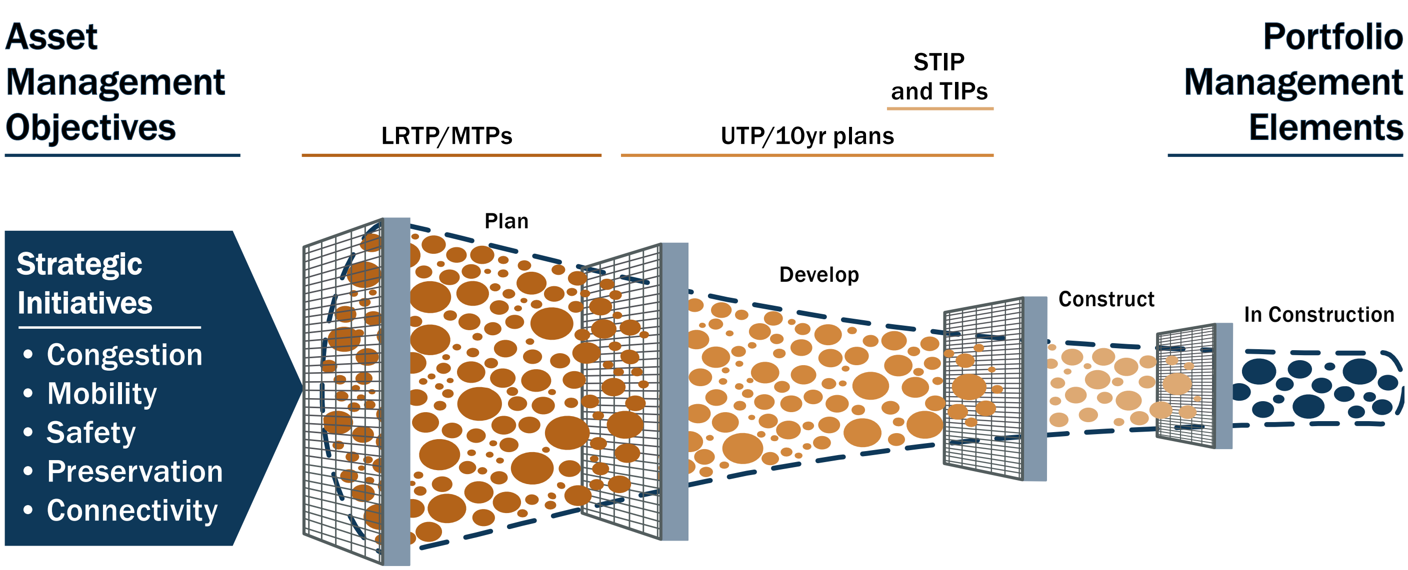


Figure 6-8. Planning, Development, and Construction Process

The unique document for Texas that defines many of the investment strategy considerations is the UTP. This document identifies information with which analyses will be made and provides decision makers information that will help ensure the most effective projects are delivered to meet the many state and federal objectives, including provisions for maintaining NHS asset in “a state of good repair.”

Planning and Programming Process

The UTP is a standalone document created annually and requires Texas Transportation Commission approval. The UTP contains a catalog of projects that are planned to be constructed and/or developed within the next 10 years and is used to identify projects included in the STIP. Preliminary engineering work, environmental analysis, right-of-way acquisition, and design work are all included as project development activities. While the UTP is an essential planning tool that guides long-term transportation project development, it is not a budget and does not guarantee that a project will be built. The investment strategies identified in this TAMP support all TxDOT objectives but in particular “Preserve Our Assets,” “Deliver the Right Projects,” and “Optimize System Performance.”

Each annual UTP adoption uses updated planning forecasts and investment strategies that are based on past system performance and system key performance objectives. These forecasts guide funding distribution, project selection, and formation of the new UTP. After the UTP is adopted, the performance of the state’s system is monitored and evaluated to help adjust the next update. Each year, this continual-improvement process is used to update the 10-year list of projects, as shown in Figure 6-9.

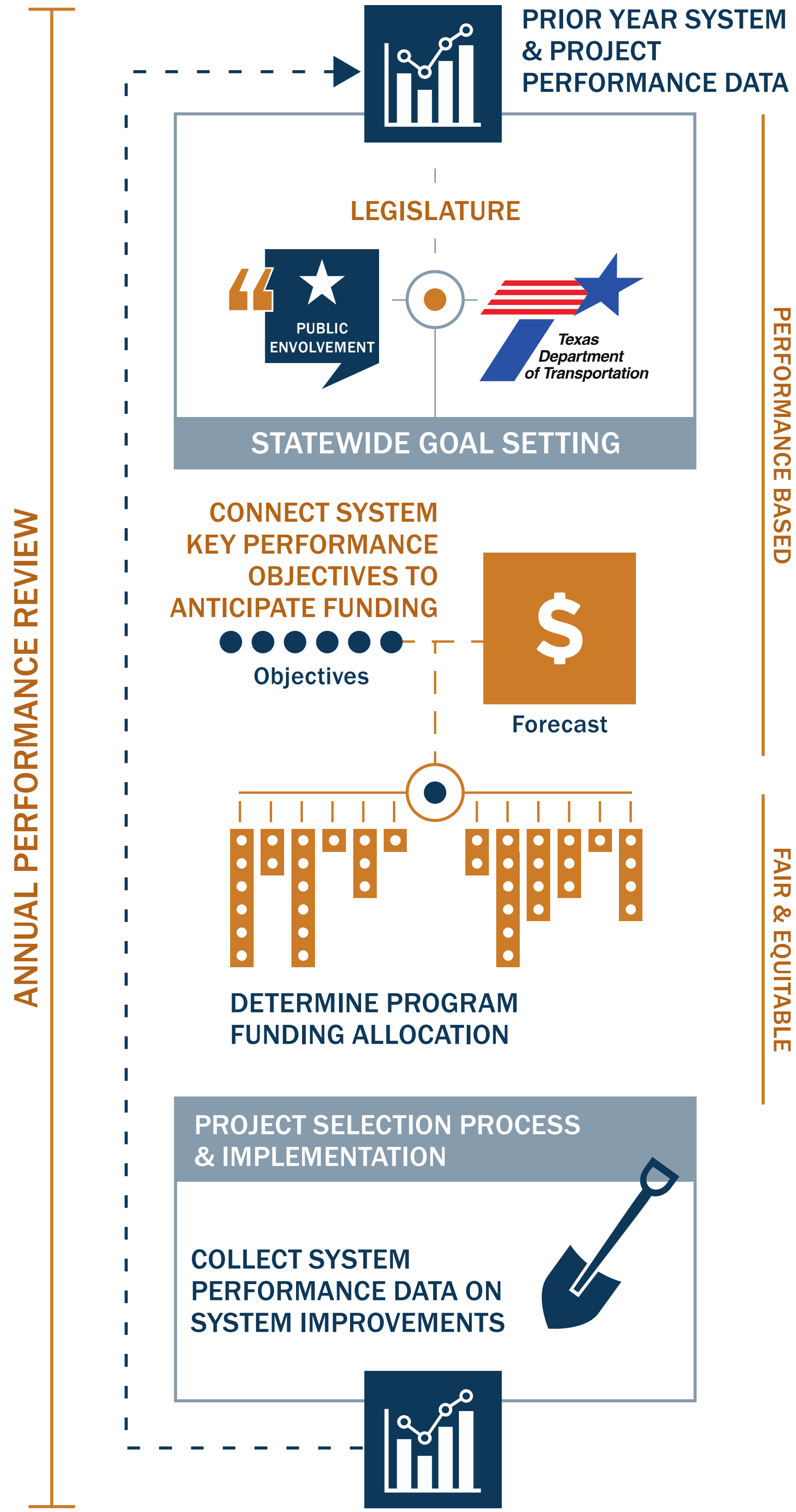


Figure 6-9. TxDOT System Performance Management Process

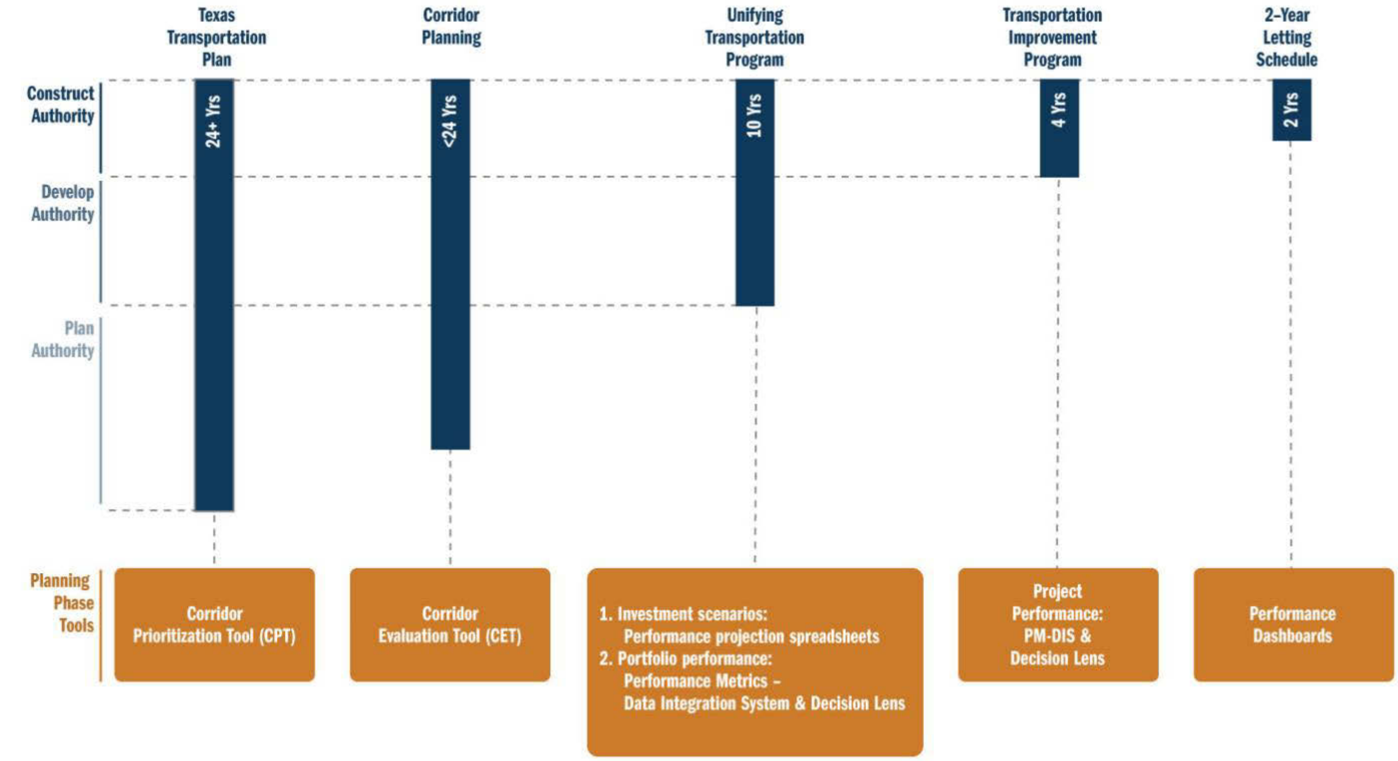
TxDOT’s UTP is developed using a sophisticated performance-based and data-driven process for determining priorities for investment across projects, program areas and districts. This approach has served TxDOT well in determining overall funding priorities.

As presented in the Financial Plan, funding sources available for projects are distributed into 12 separate funding categories. From these 12 categories, funding for constructing, maintaining, and preserving pavement and bridge assets is made available. Specific projects for pavement and bridge work are identified at the local TxDOT district level addressing district priorities including maintaining the condition of roadways and bridges. Districts should analyze the impact of project prioritization to determine the optimal mix of project cost and impact on regional or statewide roadway system performance. The optimization routines available through TxDOT’s pavement management system, identified in Chapter 3, Life Cycle Planning, are used to determine these impacts. Districts should also consider risks to the system, as described in Chapter 5, Risk Management, when prioritizing projects.

Prioritized projects are submitted for funding consideration though TxDOT’s Transportation Planning and Programming Division. Once projects are accumulated from all districts, a scoring process is used to rank and identify projects proposed to be funded. Fund expenditures are optimized to make the most use of leveraged federal and local funds by identifying combinations of projects that satisfy multiple TxDOT objectives. Technologies that use an analytical hierarchical process have been implemented to assist with the optimization of funds and system performance.

Prioritizing Investment Strategies

The UTP is a collaborative process between TxDOT, MPOs, the public, and other local transportation partners that evaluates system performance and directs resources where they are needed most. There are two approaches to development: a top-down or a bottom up approach. Historically, funding has been distributed through the 12 categories in a top down process. To be a purely performance-driven program, the project selection process would work from the bottom up assessing a financially unconstrained list of projects and selecting projects with the highest performance scores and return on investment, without regard to project type or location. However, to be fair and equitable to the entire state and meet the funding category mandates, TxDOT uses a hybrid approach. An evaluation tool is used to implement an iterative top-down and bottom-up approach to select projects that provide the best value, both statewide and locally. Figure 6-10 shows examples of evaluation tools for different phases of TxDOT’s planning and programming process.



Source: Peter Smith TRB Presentation, 2019

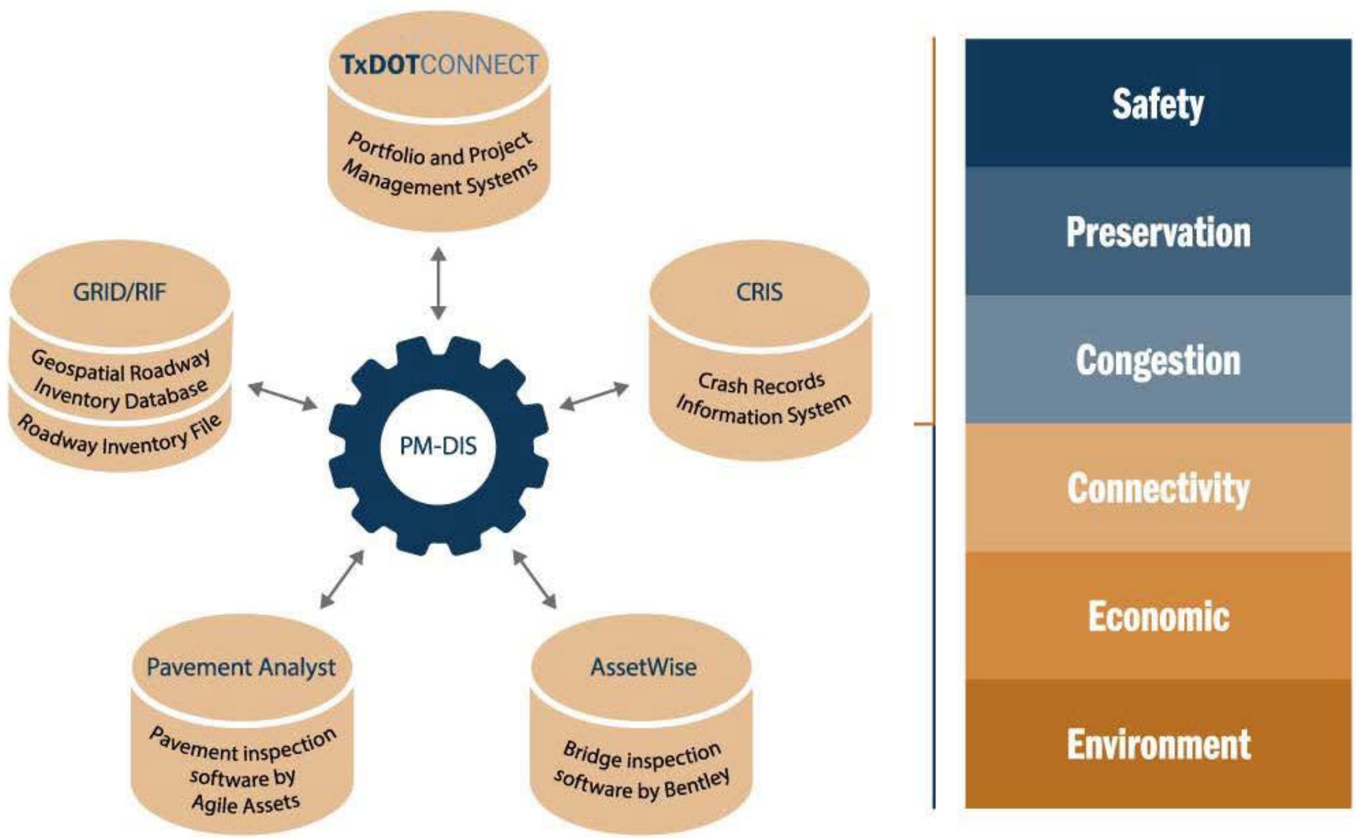
Figure 6-10. Planning Evaluation Tools

Identifying project-specific data that align a project's performance benefits with the statewide objectives is critical to this process. Data-driven criteria are established for each system key performance objective and are used to quantify each project's contributions to system performance. This process helps objectively evaluate projects to be included in the plan. As input into the evaluation tool, each project's performance data are estimated for the relevant criteria. The evaluation tool combines the performance metric data, input from stakeholders on the relative weights of the system key performance objectives, and a performance-metrics scoring matrix to predict the overall performance of the system of projects. The tool provides a performance score for each project. According to the UTP, this process allows a fair comparison of the relative importance of each project. Using this tool, a program of projects can be analyzed, sensitivity analyses can be run, and projects can be selected and prioritized based on their performance scores.

Performance Metrics: Data Integration System (PM-DIS) is TxDOT's primary project prioritization system. PM-DIS determines the relative value of projects for preserving or improving the TxDOT highway system, based on six categories of performance measures: Safety, Preservation, Congestion, Connectivity, Economic, and Environmental. As shown in Figure 6-11, the system draws on five data sources to perform its calculations:

- TxDOTCONNECT was developed by TxDOT in 2018 to be its primary system of record for development and maintenance project information, enabling more modern storage and access. TxDOTCONNECT provides data and update access outside the TxDOT network and opens the agency to more modernization of the project information user interface. The system generates a standardized report that can be exported for use in other systems.

- TxDOT's Crash Records Information System (CRIS) stores reported crash details with records dating back to 2011. CRIS provides public access reports which can be tied to roadways and associated with highway projects found in TxDOTCONNECT. Data in CRIS is used by PM-DIS to predict future crashes and the impact of planned preventive measures.
- AssetWise, developed by Bentley Systems, Inc., is the primary bridge condition system tracking bridge status and historical rebuilds. The state is making efforts to improve the system's data linkage and how it is used to support maintenance and capital improvement decision making processes.
- Pavement Analyst, developed by AgileAssets, is used to track current and historical pavement conditions statewide. The most current ride and distress scores are kept, along with all previous recordings. The system can predict future conditions and other scenario analysis.
- Geospatial Roadway Inventory Database (GRID) is the primary source for characteristics of roadways. GRID is a web application created by TxDOT to replace legacy mainframe applications with a database and mapping services for detailed location identification. Using GRID, TxDOT annually publishes its roadway inventory data in a variety of common GIS and tabular formats, including the Roadway Inventory File (RIF). Data in the RIF includes all roadway inventory attributes by segment including system classification, ownership, functional classification, lane mileage, traffic volume, and truck percentage.



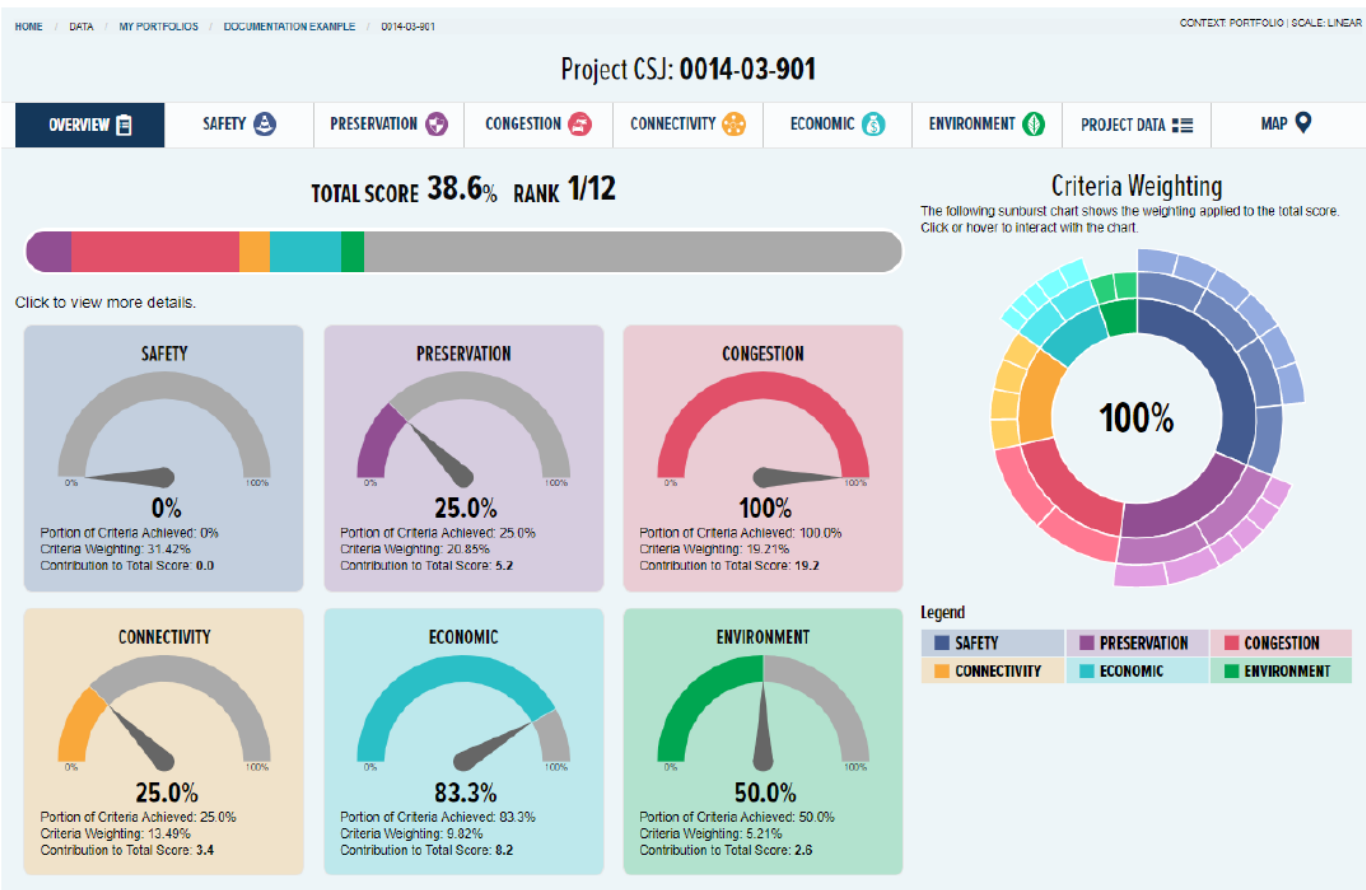
Source: TxDOT PM-DIS Description

Figure 6-11. TxDOT PM-DIS Data Sources and Performance Areas

The Preservation category contains metrics regarding the preservation of bridges and pavements. For bridge conditions, the system determines a project's "Reduction in Structurally Deficient Deck Area" and

"Deck Area Receiving Preventive Maintenance". For pavement conditions, "Reduction in Poor Lane Miles" and "Lane Miles Receiving Preventive Maintenance" are measured each by ride and distress scores. Each of these metrics is built using current condition data from AssetWise or Pavement Analyst using a historical deterioration model.

PM-DIS generates scores based on all its metrics to prioritize projects on the highway system. Asset maintenance is 20.85% of a project's total standard score in prioritization scenarios, a figure that identified through a stakeholder working group analysis using Decision Lens to coordinate stakeholder priorities. Figure 6-12 shows an example project summary.



Overview Tab of a Portfolio Project

Source: TxDOT PM-GIS System User Guide Pg 27

Figure 6-12. Example Overview Tab of PM-DIS Portfolio Project

When complete, portfolios in PM-DIS are transferred to Decision Lens for final step analyses and scenario comparisons. Scores and prioritization scenarios developed in PM-DIS, refined in Decision Lens, and sometimes refined further with other metrics are considered for project selection during the compilation of the 10-year UTP and the 4-year STIP.

The group assembling the UTP uses additional metrics in the prioritization beyond those of PM-DIS to create a hybrid score, including the state's top 100 congested roadways, V/C ratios, key rural corridor status, population density, and more.

Investment Strategies and National Performance Goals

TxDOT's Transportation Asset Management Plan seeks to improve and enhance Texas' transportation assets in furtherance of national and state goals. As discussed in Chapter 1, the TAMP and TxDOT's focus on asset management are in concurrence with several of the Department's agency goals and objectives. With regard to national priorities, the following table highlights how the TAMP supports each of the goals established in 23 USC 150(b). Pivotal in the pursuit of each of these goals is TxDOT's ability to achieve a state of good repair for public transportation assets in Texas. Table 6-13 provides a crosswalk between TxDOT's investment strategies and national performance goals.

Table 6-13. Investment Strategies and National Goals

National Performance Goal	Description of TAMP Strategies to Achieve Each Goal
(1) Safety To achieve a significant reduction in traffic fatalities and serious injuries on all public roads.	Strategies included in the TAMP support the goal of promoting safety outlined in TxDOT's Goals and Objectives, the UTP, the STIP, and other planning documents. Maintaining pavements and bridges in a state of good repair ensures that the public will encounter fewer roadway segments with poor friction, deep rutting, or other forms of deterioration that reduce safety. With these improved conditions, drivers are less likely to be involved in collisions where roadway condition was a contributing factor.
(2) Infrastructure condition To maintain the highway infrastructure asset system in a state of good repair.	The primary goal of TxDOT's investment strategies is to keep transportation assets in a sustainably acceptable condition throughout their lifecycle. This goal coincides with one of TxDOT's strategic goals to preserve our assets as well as the federal goal; both of which are also supported by the UTP, STIP, and other planning documents. Risks are considered when making investment decisions for assets. Using data-informed performance management planning techniques, TxDOT is able to manage transportation assets with a focus on long-term conditions.
(3) Congestion reduction To achieve a significant reduction in congestion on the National Highway System.	Through these strategies, TxDOT expects to reduce the long-term costs of maintaining assets while sustaining the same level of network performance. These strategies correspond to those used in TxDOT's UTP which balances the need for funds aimed at asset management with the need for funds aimed at congestion reduction.

National Performance Goal	Description of TAMP Strategies to Achieve Each Goal
(4) System reliability To improve the efficiency of the surface transportation system.	Strategies included in the TAMP aim to minimize the hazards resulting from adverse weather conditions and reduce the number of collisions where road conditions were a factor. A reduction in collision-related and weather-related traffic diversions will improve system resiliency and reliability, improving the quality of service provided to the traveling public and the freight industry.
(5) Freight movement and economic vitality To improve the National Highway Freight Network, strengthen the ability of rural communities to access national and international trade markets, and support regional economic development.	Sustaining asset conditions in a steady state of good repair ensures the quality of assets in the long-term, preventing unexpected cases of advanced deterioration which might otherwise require detours for roadways with heavy truck traffic. Strategies in the TAMP aim to make asset conditions more predictable for rural communities and the freight industry and reduce the need for closures and lengthy detours.
(6) Environmental sustainability To enhance the performance of the transportation system while protecting and enhancing the natural environment.	TxDOT's investment strategies included in the TAMP aim to improve asset conditions through an optimal focus on preservation and maintenance. Properly balancing preservation and maintenance with replacement projects will decrease the need for excess construction materials. Additionally, minimizing partial closures and detours to consistently maintain highway throughput will reduce the amount of idle time spent on public roadways, reducing vehicle-related emissions.
(7) Reduced project delivery delays To reduce project costs, promote jobs and the economy, and expedite the movement of people and goods by accelerating project completion through eliminating delays in the project development and delivery process, including reducing regulatory burdens and improving agencies' work practices.	Strategies outlined in the TAMP will help to make more predictable the needs for more extensive rehabilitation and replacement projects which tend to have a larger impact on the public when delayed. Having additional time for planning these projects will allow for increased coordination between TxDOT and other stakeholders. With some of the most-common reasons for significant project delays being utility coordination, environmental coordination, and change orders, increased planning time should help to mitigate these hurdles.

Pavement Investment Strategies

For pavements, TxDOT implemented the requirement for a Four-Year Pavement Management Plan. Every district is required to develop a fiscally constrained comprehensive pavement management plan for all pavement-related activities. Districts consider pavement life cycle plans, risks, and the financial plan in developing these plans. The plan covers all routine maintenance, Preventative Maintenance (PM), Light Rehabilitation (LR), Medium Rehabilitation (MR), and Heavy Rehabilitation (HR) work for all the pavements within the district. The plans are reviewed annually by a committee established by TxDOT administration to ensure that the maximum maintenance resources are directed toward pavement operations and roadway work to provide the maximum benefit to the agency.

As a part of the STIP in the transportation planning and programming process, the Four-Year Plan for pavement provides investment strategies on an annual basis. The planned number of lane miles treated for each work type/treatment level is reported in each of the four planning years. It is recommended that PM is the predominant work type used to preserve the network's performance. In addition, rehabilitation work is used to maintain or reduce lane miles in the poor condition. Both strategies jointly contribute to the SOGR of TxDOT pavement network. This also is directly tied to the national Infrastructure Condition goal: to maintain the highway infrastructure asset system in a SOGR.

The Four-Year Plan allows the district to appropriately allocate resources through long-term planning to meet their management objectives. From the plan, a district may identify their highest priority projects and work. In the most recent four-year pavement plan, the statewide planned number of lane miles treated for each treatment type and planning year is reported, as shown in Figure 6-13. This shows that Preventive Maintenance is the predominant work type used to preserve the network's SOGR at TxDOT. Years 2024 and 2025 do not include all future pavement work like seal coat, which is why the preventive maintenance appears to decline after 2023.

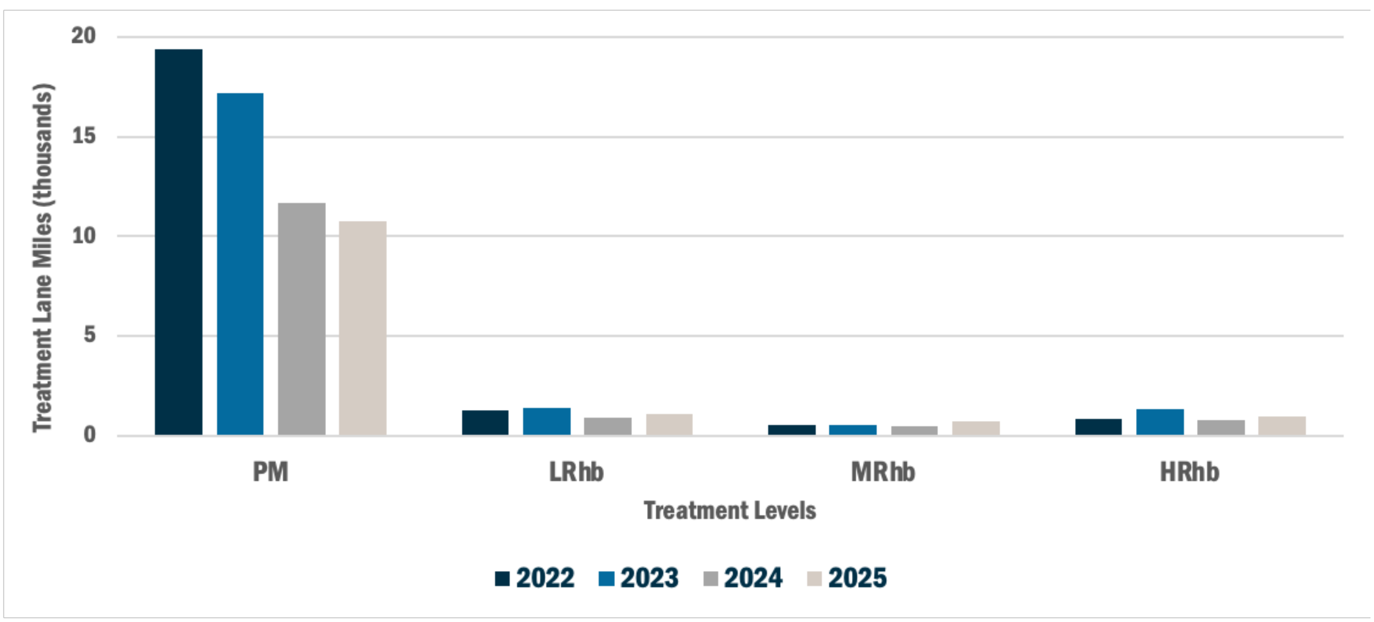


Figure 6-13. Four Year Plan (2021): Quantity of Lane Miles by Treatment Type

Bridge Investment Strategies

TxDOT coordinates bridge management planning and programming amongst the Bridge Division, Maintenance Division, and all 25 districts. Through several funding programs and processes, the agency is able to balance each district's needs with available funding while keeping focus on the health of the network as a whole. The four primary funding programs for bridge management each focus on a distinct class of projects:

- Highway Bridge Program (HBP) – Replacing or rehabilitating bridges that are not cost-effective to maintain. Planned annual target of $230million.
- Bridge Maintenance and Improvement Program (BMIP) – Repairing and rehabilitating bridges from poor or fair condition to good or near-good condition. Planned annual target of $55million.
- Bridge System Safety Program (BSSP) – Replacing or retrofitting bridges to improve safety and resiliency of the facility. Planned annual target of $70million.
- Bridge Preventive Maintenance Program (BPM) – Maintaining and repairing bridges to prevent accelerated deterioration, minimizing or addressing long-term-maintenance concerns. Planned annual budget of $15million.

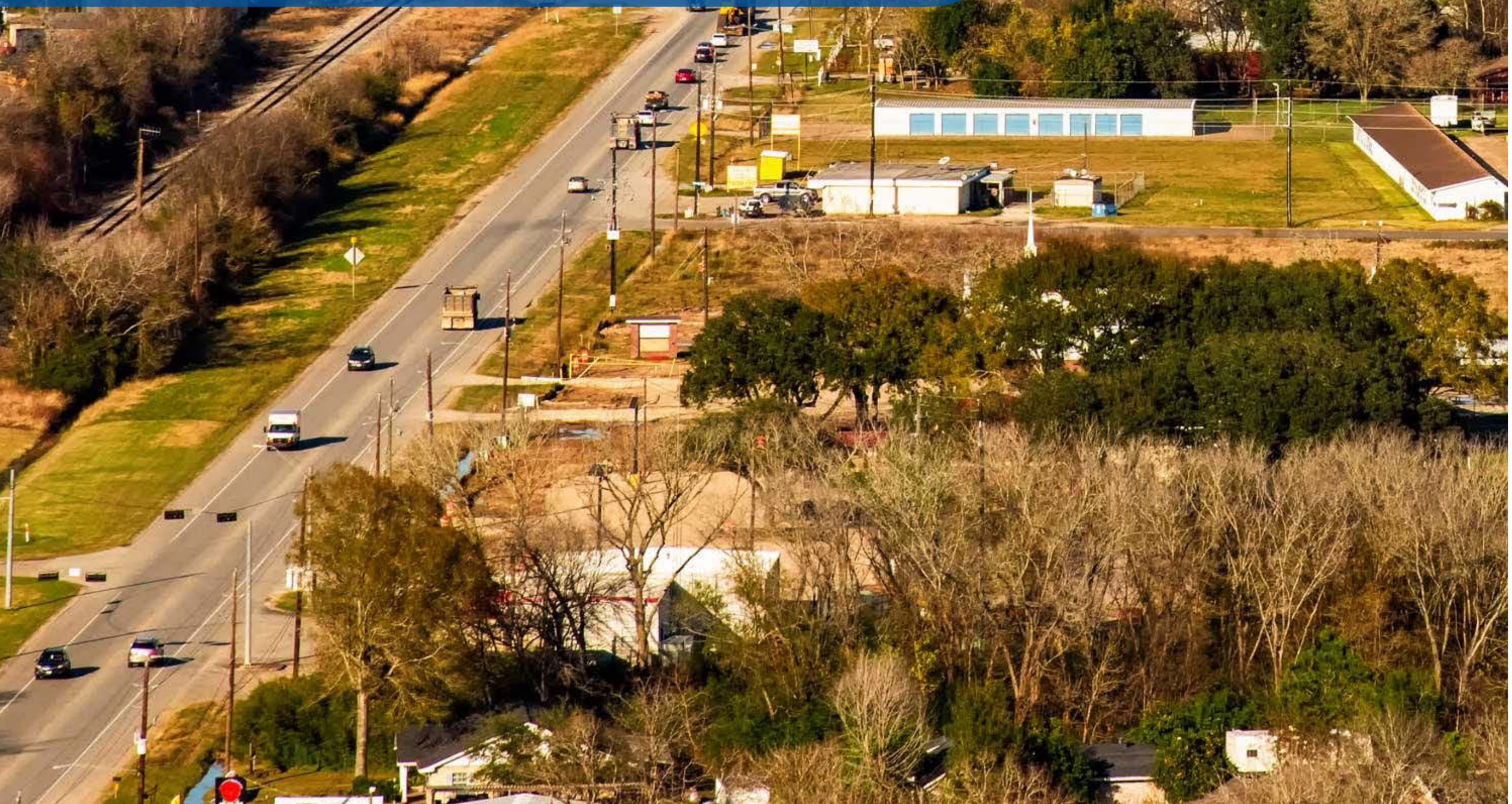
Throughout the year, TxDOT identifies and selects projects for each of these programs by reviewing current bridge conditions and taking into account life-cycle costs and potential risks of project alternatives.

Beginning in 2022, districts must develop annual Four-Year Bridge Plans to communicate their bridge management practices and investment strategies amongst these four funding programs and other funding sources. These Plans are reviewed and discussed with TxDOT leadership to ensure bridges are being managed in a way that is consistent with TxDOT goals throughout the state.

In addition to these programs, in-house maintenance activities are leveraged at the district level wherever possible. Often to address maintenance inspection findings and follow-up actions from routine safety inspections, in-house bridge maintenance work enables districts to quickly address minor problems before repair contracts are needed. Since 2020, TxDOT has made significant progress in responding to follow-up actions in a timely fashion thanks in large part to increased in-house maintenance activities.

7. TAMP Implementation and Integration

Implementing TAM at TxDOT is a continuous improvement effort. It includes documenting where progress has been made and also identifying areas for future action. By further implementing and integrating TAM into TxDOT's processes and practices, the agency will be improving decision-making related to preserving asset conditions over the life cycle of an asset at minimum cost.



Overview

This chapter includes a summary of the strong alignment between TxDOT's TAMP and its planning documents and processes. In addition, it documents TAM and TAMP implementation since 2019 and suggests potential future actions for further progress.

TAMP Integration

TxDOT 2021-2025 Strategic Plan

The TxDOT strategic plan identifies action plans over a five-year period to make progress towards TxDOT's goals, including Preserve Our Assets. One of the actions included is to "implement asset management practices for state roadways and equipment and continue resiliency planning activities." The TAMP is the documentation of asset management implementation in Texas and includes a new focus on resiliency planning, particularly in Chapter 5, Risk Management.

TxDOT Unified Transportation Program (UTP)

The UTP, described in detail in Chapter 6, Financial Plan and Investment Strategies, is a 10-year plan that identifies the major sources and anticipated uses of funding, including for asset management. The TAMP uses the UTP as the basis for its financial plan and investment strategies, and includes the same asset preservation measures as the UTP. By using the UTP funding, the TAMP reflects a consistent vision of estimated future funding for asset management in Texas.

Texas Transportation Plan 2050 (TTP)

The TTP is TxDOT's thirty year transportation plan which guides planning and programming decisions for the statewide multimodal transportation system. One of the six goals of the TTP is Preserve Our Assets: "Deliver cost-efficient preventive maintenance for the transportation system that keeps Texas roads, bridges, and other infrastructure and technology in good repair." The TAMP supports that goal and the TTP recognizes the TAMP as "TxDOT's primary planning mechanism for developing strategies to optimize investment in pavement and bridges by identifying a sequence of activities to continue or reach a state of good repair at minimum cost." In addition to supporting asset management, the TTP also emphasizes the value of risk management and the importance of investing in resiliency, which is reinforced in the TAMP.

Texas Freight Mobility Plan (TFMP) 2018

The TFMP is a comprehensive plan that includes a listing of freight corridors, a description of how the plan will meet national freight goals, strategies to mitigate congestion, and a freight investment plan. While the 2018 TFMP predates the 2019 TAMP, the documents have significant overlap, including inventory and condition of pavements and bridges, with a focus on the Interstate. Asset Preservation and Utilization is a goal of the TFMP, with pavement and bridge performance measures supporting evaluation of the goal.

The Freight Plan suggests developing and incorporating resiliency measures in transportation planning, policy and infrastructure investment decisions. One potential area for improved alignment in the future would be to integrate critical freight corridors into the TAMP, reporting their condition and prioritizing investments to maintain a state of good repair.

TAMP Implementation

TxDOT has made strong progress in a number of TAMP implementation areas, including implementing its new bridge management system, moving from a worst-first approach to a preservation focus, development of four year pavement and bridge plans, and a number of resiliency efforts. Opportunities for additional improvement include completing implementation of BrM, improving confidence in forecast of FHWA performance measures for NHS pavement, cross-asset prioritization, and increased coordination between TxDOT and stakeholders (e.g. MPOs, RPOs, local governments) for the TAMP. This TAMP also defines a series of risk mitigation strategies and actions in Chapter 5, Risk Management, that are part of the TAMP Implementation work.

Implementation progress and potential future actions are defined below, organized by TAMP topic area.

Inventory and Condition

Progress Since 2019 TAMP

- Development of its pavement data quality management plan
- Implementation of a new Bridge Maintenance Module in AssetWise, which allows the agency to better track bridge work
- Shared pavement and bridge data with MPOs in GIS format
- Data improvements in work history, surface age, and structural data

Potential Future Actions

- Continue improving coordination with local partners

Life Cycle Planning

Progress Since 2019 TAMP

- Connecting TxDOT's bridge management tools to support life cycle planning.
  - The BrM production system is deployed and TxDOT has nearly completed work to connect its bridge inspection system to BrM, the last big milestone in implementation. NBI deterioration models have been incorporated in the system, potentially allowing for bridge element level deterioration modeling in the future. The process of implementing treatments in the system is 70% complete.
- Making the transition from the previous worst-first approach to a preservation focus for both pavement and bridge
- Factoring in future changes in environmental conditions and extreme weather for life cycle planning purposes has led to numerous changes in processes. For example:
  - NOAA Atlas 14 study showing increased precipitation in Texas has led to updated designs to mitigate flooding
  - Updating winter maintenance processes to use additional brine water to mitigate winter weather impact
  - Changing reinforcing types and surfacing NHS bridges with multi polymer overlays (targeted to NHS bridges in areas with higher use of deicing chemicals)

    - Focusing on short span bridges and pile structures by increasing scrutiny of bridges that are scour critical and have short spans and catch debris easily. TxDOT is prioritizing to replace the most vulnerable of those with longer spans and to elevate bridge elements above the channel.

Potential Future Actions

- Complete implementation of BrM
- Incorporate resiliency project findings into pavement life cycle planning
- Refine asset valuation approach

Performance Management

Progress Since 2019 TAMP

- Improved communication and alignment of goals across the agency, including districts and central offices
- Created internal TxDOT dashboards on Tableau for use across the agency
- Created external TxDOT dashboards on Tableau to share data with stakeholders

Potential Future Actions

- TxDOT has the capability to predict performance using FHWA measures for NHS pavements, and is working to improve confidence in the results as it is a new process
- Add consideration of new needs created by system expansion

Risk Management

Progress Since 2019 TAMP

- TxDOT has undertaken a number of existing risk and resiliency related efforts and documents which are described in greater detail in Chapter 5, Risk Management
    - FHWA Extreme Weather Resilience & Durability Pilots
    - Texas MPOs Resiliency Working Group
    - Statewide Resiliency Plan
    - Asset Management, Extreme Weather, and Proxy Indicators Pilot Final Report
    - Addressing Resiliency in Regional Transportation Plans
    - Hydraulic Design Model Update

Potential Future Actions

- Risk actions are described in detail in Chapter 5, Risk Management, including mitigation strategies and actions for each of the ten risks in the risk register

Financial Planning and Investment Strategies

Progress Since 2019 TAMP

- Development and implementation of TxDOTCONNECT, TxDOT's new financial management system. As described in Chapter 6, Financial Plan and Investment Strategies, TxDOTCONNECT is the primary system of record for development and maintenance project information.

- Four-year bridge and pavement plans. As described in Chapter 3, Life Cycle Planning, TxDOT and its Districts develop management plans for pavements and bridges that analyze expected spending and performance over a four year-period.

Potential Future Actions

- Work to assess TxDOT's bridge and pavement in a more integrated fashion, to prioritize allocations across assets
- Improve tracking and mapping of expenditures to assets and outcomes

Coordination with Stakeholders and Partners

Progress Since 2019 TAMP

- TxDOT has continued to improve communication with its local and regional partners, particularly through its involvement in various working groups focused on extreme weather events, and the development of GIS data to improve communication regarding projects
- TxDOT has continued to coordinate with MPOs on TAM and performance management

Potential Future Actions

- Improve coordination of project development with planning and programming, both within the agency and with local and regional partners
- Improve communication with local entities on off-system NHS assets
- Improve TAM communications with external partners through fact sheets, pamphlets, and other means