Submitted to:

OHIO AUDITOR OF STATE
KEITH FABER

PERFORMANCE AUDIT OF THE OHIO DEPARTMENT OF TRANSPORTATION

RFP Reference Number: AOS 2019-002

Pavements Program Evaluation Report

February 23, 2021

Submitted by:

The Kercher Group, Inc.

and supported by

pfm

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GLOSSARY

AASHTO ..... American Association of State Highway Transportation Officials

AOS ..... Auditor of State

CAGR ..... Compound Annual Growth Rate

CSF ..... Critical Success Factors

DO ..... Division of Operations

DOT ..... Department of Transportation

DQMP ..... Data Quality Management Plan

ELLIS ..... ODOT designed web-based project management application

FHWA ..... Federal Highway Administration

FY ..... Fiscal Year

GARVEE ..... Grant Anticipation Revenue Vehicle

GIS ..... Geographic Information System

HCAP ..... Highway Capital Improvement

HPMS ..... Highway Performance Monitoring System

LTPP ..... Long-Term Pavement Performance

NCHRP ..... National Cooperative Highway Research Project

NHS ..... National Highway System

ODOT ..... Ohio Department of Transportation

OPE ..... Office of Pavement Engineering

PCR ..... Pavement Condition Rating

PMS ..... Pavement Management System

STIP ..... State Transportation Improvement Program

TAM ..... Transportation Asset Management

TAMP ..... Transportation Asset Management Plan

TP ..... Transportation Policy Division

TPM ..... Transition Probability Matrices

VMT ..... Vehicle Miles Traveled

PAVEMENTS

Executive Summary

The Kercher/PFM consulting team (Kercher) is pleased to provide this performance audit report on the Ohio Department of Transportation's (ODOT) pavement program. This document is one of three (3) such reports (the others covering the bridge and maintenance management functions of ODOT) produced by the Kercher team under contract to the Ohio Auditor of State (AOS). These reports are components of a comprehensive performance audit of ODOT being performed in compliance with HB 62 of the 133rd General Assembly of Ohio.

Good governance of a state's pavement network begins with developing a program around the core principles of Transportation Asset Management (TAM). According to AASHTO, those principles are as follows:

- Recognizing the economic value of assets
- Achieving economic efficiency and the optimization of expenditure over the asset's life cycle
- Understanding the role of the agency as "steward" of the assets[1]

Major Findings

Kercher's analysis of the ODOT Pavement program found the following:

- ODOT's overall spending and resulting pavement conditions is equivalent to or even more efficient than most of its peer states.
- Overall, pavement conditions are good and ODOT is using economical treatments to sustain its pavement conditions.
- ODOT is using a state-of-the-art computerized pavement management system to identify economical pavement investments, which is a best practice compared to peer states.
- ODOT's project selection process includes matching a percentage of pavement treatments and locations to the pavement management system output, which is a best practice among peers.

However,

- The pavement analysis performed may be underestimating the budget needed over the next 10 years to sustain network pavement conditions compared to historical trends.
- ODOT computerized pavement management system may require additional setup and calibration to more accurately predict future funding needs. ODOT will need to maintain long-term competency among staff to fully leverage its forecasting capabilities.

Major Recommendations

ODOT should analyze its use of the pavement management system to ensure funding sources are considered in the analysis, and its unit costs and deterioration curves are accurate, so that the model can be used to plan needed investments that are most economical over the long term

[1] AASHTO Transportation Asset Management Guide, A Focus on Implementation-Executive Summary, https://www.fhwa.dot.gov/asset/pubs/hif13047.pdf, June 2013.

Introduction

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- Understanding the role of the agency as "steward" of the assets[2]

Kercher's focus within this section of the report was on determining the effectiveness of various aspects of ODOT's TAM program for pavement. Again, AASHTO[1] generally describes an effective program as one that:

- Takes a network view
- Aligns with strategic directions
- Aligns leadership within the agency
- Communicates with stakeholders
- Makes data-driven, informed decisions
- Integrates agency programs and budgets
- Monitors outcomes
- Focuses on continuous improvement

This audit reviews the effectiveness of these processes by comparing past expenditures on pavement projects to network conditions at both the state and district network levels, as well as comparing predicted funding needs to predicted network performance.

Approach

The Kercher team used the following, common approach in performing the review for the respective performance audit reports:

- Performed a baseline analysis of ODOT
- Identified and interviewed a sample of peer states

[2] AASHTO Transportation Asset Management Guide, A Focus on Implementation-Executive Summary, https://www.fhwa.dot.gov/asset/pubs/hif13047.pdf, June 2013.

- Reviewed reference resources for additional best practice guidance/information
- Benchmarked ODOT against peer state practices and best practice guidance
- Identified potential practice improvement opportunities considered applicable to ODOT
- Provided results of the benchmarking exercise
- Recommended practice changes (if any) and identified potential benefits

Kercher produced this report in three (3) stages and a final report as described below:

1. ODOT Baseline Task
2. Peer State / Best Practice Task
3. Draft Final Report
4. Final Report

ODOT provided comments to each draft. Kercher addressed these comments as appropriate when creating the additional report content; as such, each draft included additional refinements of previously submitted information.

Report Organization

This report is organized around the review areas identified in the request for proposal (RFP) for this project. This design was intended to simply efforts to find specific areas of interest.

Within each topic area, the report generally is organized around the following headings:

1. Topic Introduction
2. Baseline Task
3. Peer State / Best Practice Review
4. Recommendations, Projected Impacts and Anticipated Benefits

The following text provides a general introduction to each of the heading areas. Specific information related to each of these headings is found in each review area.

Topic Introduction

In each review area, Kercher describes the significance of the subject to the overall performance of the DOT pavement program. This discussion is intended to provide context for comparing the ODOT approach in each practice area to peers and best practice.

Baseline Task

Kercher carried out the baseline phase of the audit by conducting interviews with the ODOT Transportation Policy Division[3] (TP) and district staff who are involved with the pavement program. This review included considerable review of ODOT pavement performance measures at both a statewide and district level. Details on the performance measures are found in Section A. This information was vetted

[33] "TP" primarily refers to the noted ODOT offices in Figure 1 but can include other units in the Transportation Policy Division.

with ODOT as part of the report review process and served as basis for the peer state/best practice review process described below.

Peer State / Best Practice Review

The Kercher team, in consultation with ODOT, selected the following six (6) states for benchmarking pavement programs with ODOT. As detailed in Section C, population, traffic, and climatic region among other considerations provided the basis for this selection.

1. Kentucky
2. Maryland
3. New York
4. Pennsylvania
5. West Virginia
6. Wisconsin

The Kercher team benchmarked ODOT's pavement program against these peers in the following areas:

- Data collection practices
- Analysis processes
- Software application usage
- Budgetary processes
- Project selection practices

Table 1 provides comparative highway statistics for ODOT and the peer states being used for benchmarking. The "data source" designation identified in Table 1 corresponds with the FHWA website data naming convention used. This information is derived from the most current, comparative 50-state data available from the FHWA website at the time of this project (2018).[4] As reported on the FHWA site, The mileage and lane mileage shown includes roadways owned by the State highway agency, but excludes roadways owned by State toll, State park and other State agencies. In other sections of the report, ODOT and the peer states systems are described using differing terms, depending on the identified data source.

[4] FHWA 2018, website: https://www.fhwa.dot.gov/policyinformation/statistics/2018/ps1.cfm

Table 1: Comparative Highway Statistics

State		Ohio	Kentucky	Maryland	New York	Pennsylvania	West Virginia	Wisconsin
National Highway System (NHS) Centerline Miles[5]		5,179	3,282	1,767	6,042	6,376	1,898	5,326
Estimated NHS Lane Miles[6]		19,856	12,335	7,616	19,739	20,944	5,993	16,190
Planned Average NHS Pavement Spending (10-year average)[7]		$601.0	$193.8	$253.0	$300.0	NA[8]	$144.7	NA[9]
Planned $/Mile		$30,268	$15,711	$33,221	$15,198		$24,145	
Interstate Current Condition	**Good**	60%	66%	60%	42%	66%	83%	59%
	Poor	0%	0%	1%	3%	1%	0%	2%
Non-Interstate Current Condition	**Good**	47%	45%	34%	19%	35%	61%	36%
	Poor	1%	1%	7%	9%	2%	0%	6%

Kercher conducted this outreach via a series of phone and virtual interviews conducted over a period of several weeks. Each interview averaged between 1-2 hours, following a prepared interview guide that was provided to each DOT in advance of the call.

[5] From FHWA HM-40 dataset, https://www.fhwa.dot.gov/policyinformation/statistics/2019/xls/hm40.xls, sum of rural and urban mile owned by State Highway Agency.

[6] Extrapolated from FHWA HM-43 dataset, https://www.fhwa.dot.gov/policyinformation/statistics/2019/xls/hm43.xls, based on the ratio of centerline miles owned by State Highway Agency, applied to the respective total rural and urban lane miles for each state.

[7] From 2019 Transportation Asset Management Plans (TAMP) for each state.

[8] Planned 10-year investments in bridge and pavement assets not separately identified.

[9] Planned 10-year investments in bridge and pavement assets not separately identified.

The ODOT Director assisted in encouraging these states to participate in this effort by writing a letter to his counterpart at each DOT. This assistance significantly helped in gathering this information.

In addition to the time spent directly participating in the interview, most state participants required some level of preparation time. In many cases, additional phone calls and/or email were used to provide supplemental information. Not every DOT was able to answer all questions but even an inability to provide an answer was meaningful within the context of this benchmarking effort.

Participating DOTs were offered a copy of the peer states information gather through this effort. This information is summarized in Appendix B: Peer States / Best Practice Findings.

Analysis

In this section, Kercher compared and contrasted ODOT practices with those of the peer states as well as any relevant guidance information from AASHTO, FHWA, NCHRP or resources related to these areas. The consulting team used its professional judgment in identifying applicable best practice in these review areas. This provides the basis for the identified "Recommendations, Projected Impacts and Anticipated benefits".

Recommendations and Benefits

Kercher identified any recommendations in these sections. In cases where ODOT already is employing best practice, the team's recommendation indicates that ODOT should continue accordingly. In cases where Kercher perceives that ODOT could benefit from change, the appropriate recommendation is identified along with the anticipated benefit of this change.

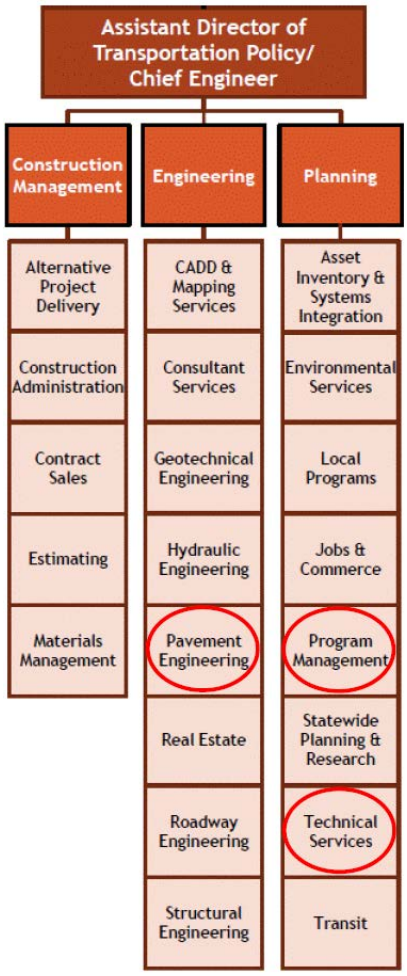
Organizational Approach

ODOT has a robust pavement management program. The ODOT Transportation Policy Division[10] (TP - see Figure 1), districts, and counties all play a role in the pavement management process.

The process has evolved over time from past practices that relied more heavily on experience and judgment to make funding and project selection decisions. Since 2017 however, ODOT has implemented a data driven approach to program development and project selection.

[10] "TP" primarily refers to the noted ODOT offices in Figure 1 but can include other units in the Transportation Policy Division.

Figure 1: Transportation Policy Division Units Interviewed



A. 10-year Trendlines - Expenditures versus Conditions

Baseline

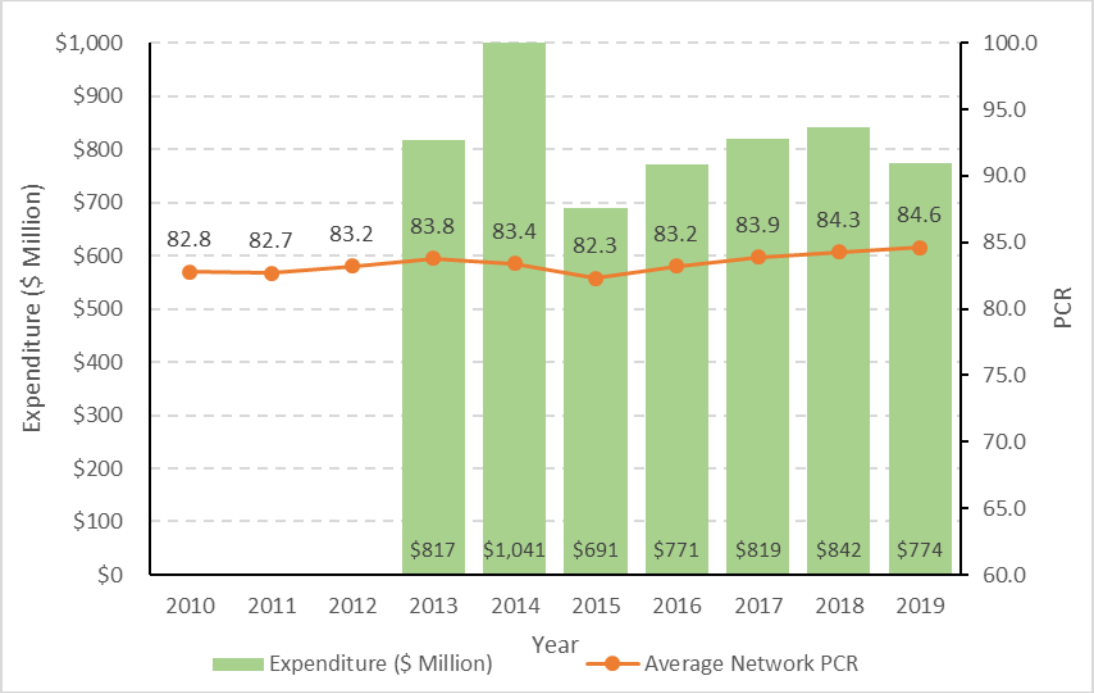
ODOT provided the audit team with a significant amount of data as part of the data request on the project. The data includes past Pavement Condition Rating (PCR) network averages from 2010 to 2019[11], at the statewide level and for each district.

Figure 2 contains a graph of expenditures versus network PCR for the entire state for the years of ODOT data that were provided[12]. ODOT's source of the expenditure data was its ELLIS system and covered the years 2013 to 2019.

[11] Data Provided by ODOT: Data to calculate Avg Weighted PCR-1.accdb

[12] Data Provided by ODOT: 2013 to 2026 Bridge and Pavement Project Data - Ellis.xlsx

Figure 2: Statewide Historical Condition vs. Expenditures



Variance by District

Figure 3 compares ODOT expenditures versus PCR conditions for each district. As indicated, when reviewing the resulting allocation of funds to each District, it appears that funding allocation is not tied to the percentage of the network lane mileage managed within each District. Instead, the allocations can vary significantly from one District to another and from one year to the next. Although the yearly allocation is maintained relatively level over this time, it may be beneficial to perform optimization analyses that constrain the funds by District to ensure each District gets an equitable allocation of funds. The challenge with performing optimization analyses with few constraints is that it leaves open the possibility that results may not align with agency policies.

Figure 3: District Historical Condition versus Expenditures

Peer States / Best Practice Findings

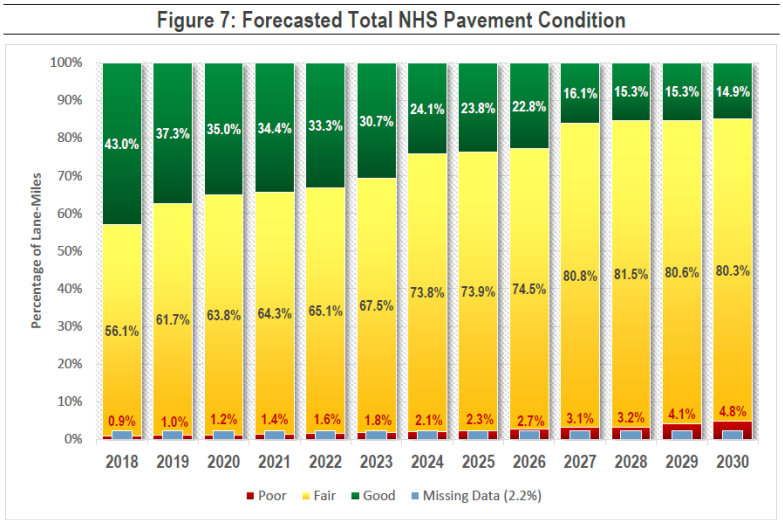
Each peer state was asked to provide similar trend data to what ODOT previously provided, relating expenditures to projected conditions of the network. The following graphs provide some insight into the metrics being reported and the information that is deemed important to the peer states.

Kercher notes that there is no practice standard for reporting this information. Accordingly, states tend to report different metrics. Accordingly, nearly every state has a somewhat different way of visualizing the conditions of the pavement network and the funds necessary to meet their performance targets. As such, significant care and caution is needed in comparing this information between states.

Pennsylvania

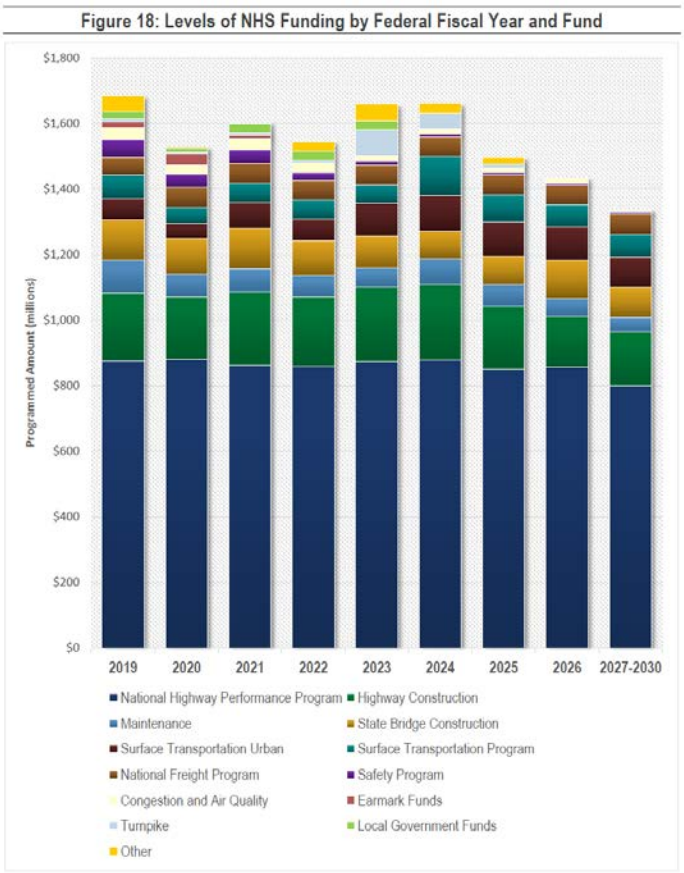
Figure 4 and Figure 5 are sourced from the PennDOT TAMP:

Figure 4: PennDOT Forecasted NHS Pavement Condition



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

Figure 5: PennDOT Forecasted NHS Funding



Source: MPMS, 2019

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

Kentucky

From the KYTC TAMP, Figure 6 shows historical and Figure 7 shows projected Interstate conditions. Figure 8 shows projected Interstate funding:

Figure 6: KYTC Historical Interstate Pavement Conditions – 2008-2018

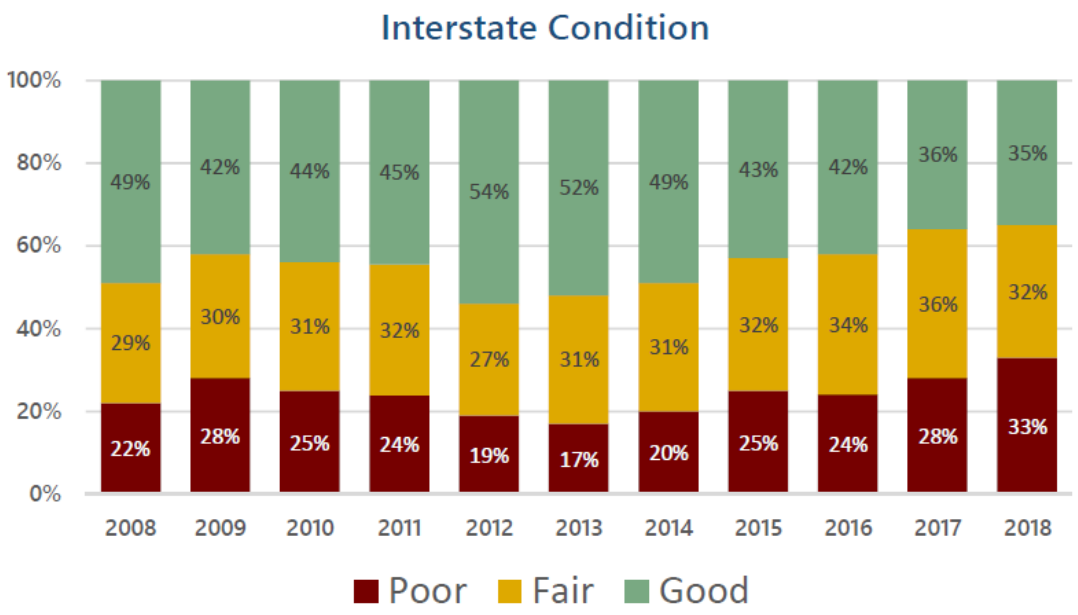


Figure 3-14. Interstate pavement conditions

Figure 7: KYTC Projected Interstate Pavement Conditions

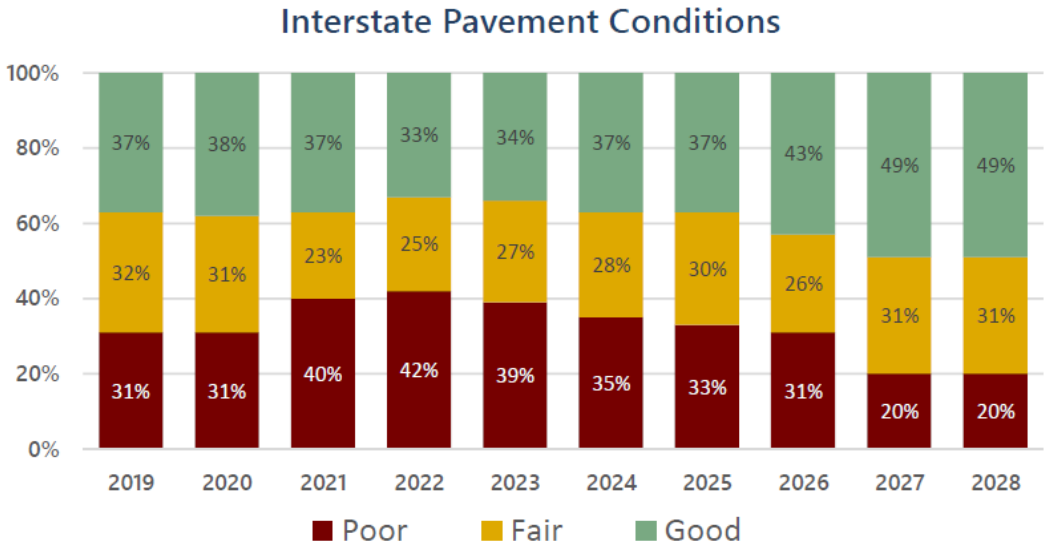


Figure 6-4: Interstate pavement conditions

Figure 8: KYTC Projected Interstate Funding

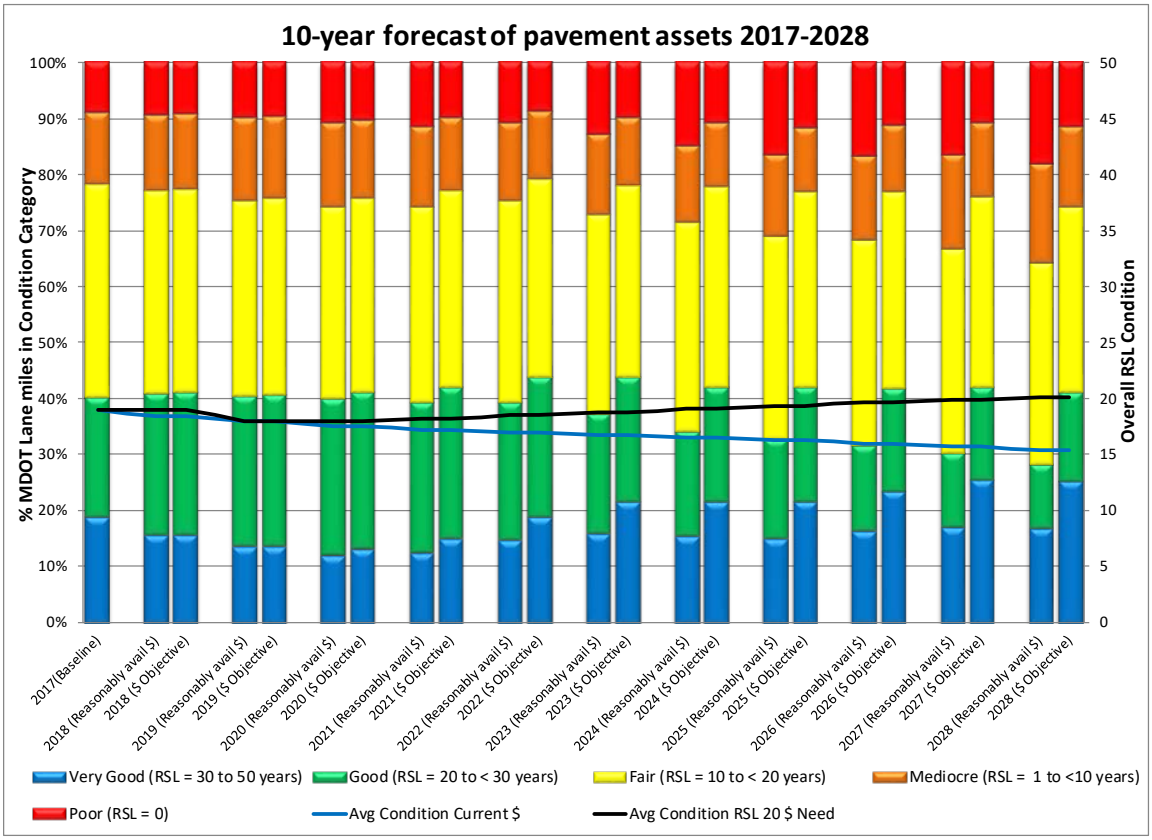
Table 6-9: Anticipated FY 2019-2028 interstate system pavement investment needs ($ millions)

Work Types	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	10-Year Total
Maintenance	—	—	—	—	—	—	$2	$2	$1	$1	$6
Preservation	$48	$43	$81	$86	$148	$214	$197	$223	$254	$250	$1,458
Rehabilitation	$24	$21	—	—	—	—	—	—	—	—	$45
Replacement	—	—	—	—	—	—	$16	—	—	—	$16
Total	**$72**	**$64**	**$81**	**$86**	**$148**	**$214**	**$215**	**$225**	**$255**	**$251**	**$1,611**

Maryland

Figure 9 is a 10-year forecast of the Maryland DOT pavement. "Reasonably Available" funding is estimated at $256M/year and the "Objective" (desired) funding is projected at $315M/year.

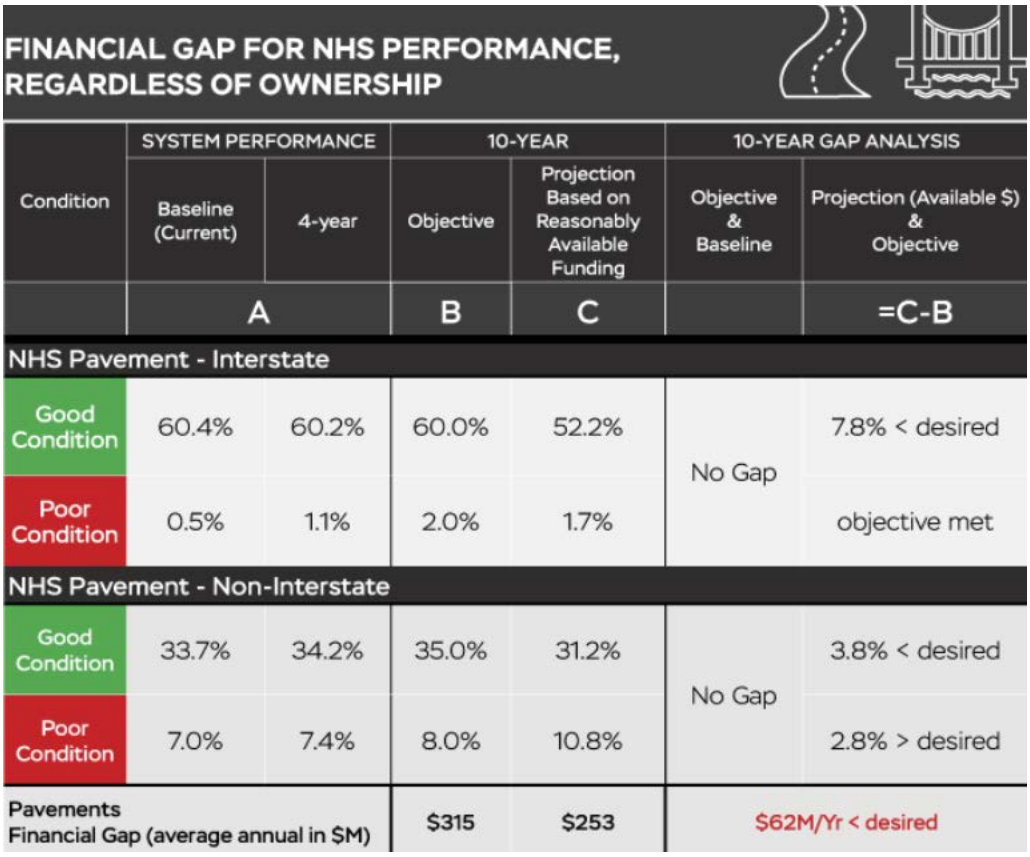
Figure 9: Maryland Pavement Funding



MDOT uses its GIS application to present the information from its TAMP. Figure 10 is sourced from the MDOT TAMP at the following website:

https://maryland.maps.arcgis.com/apps/MapJournal/index.html?appid=e99ba9fdd5e34598a491750f2e557d36

Figure 10: Funding and Financial Gap



FINANCIAL GAP FOR NHS PERFORMANCE, REGARDLESS OF OWNERSHIP

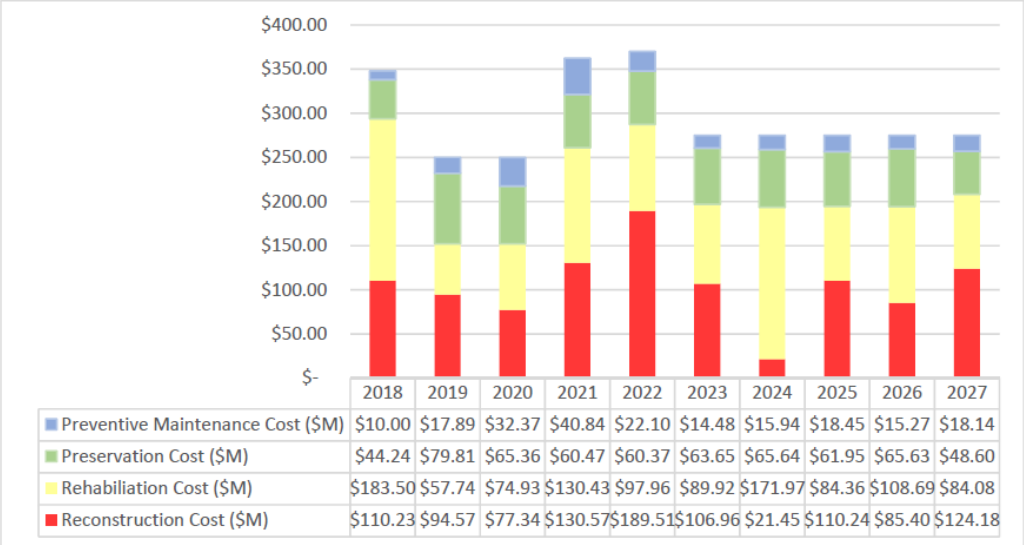
Condition	SYSTEM PERFORMANCE		10-YEAR		10-YEAR GAP ANALYSIS	
	Baseline (Current)	4-year	Objective	Projection Based on Reasonably Available Funding	Objective & Baseline	Projection (Available $) & Objective
	A		B	C		=C-B
NHS Pavement - Interstate						
Good Condition	60.4%	60.2%	60.0%	52.2%	No Gap	7.8% < desired
Poor Condition	0.5%	1.1%	2.0%	1.7%		objective met
NHS Pavement - Non-Interstate						
Good Condition	33.7%	34.2%	35.0%	31.2%	No Gap	3.8% < desired
Poor Condition	7.0%	7.4%	8.0%	10.8%		2.8% > desired
Pavements Financial Gap (average annual in $M)			$315	$253	$62M/Yr < desired	

New York State

Figure 11, from the New York State DOT (NYSDOT) TAMP, depicts future projected NHS pavement expenditures. Figure 12 indicates the projected lane miles by treatment type.

Figure 11: NYSDOT Pavement Spending Projections

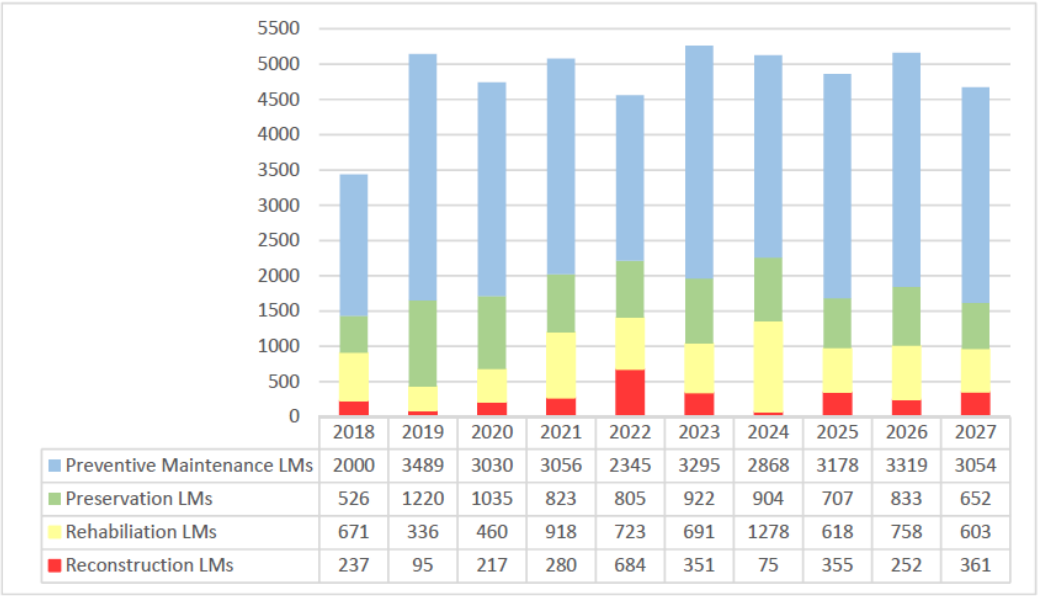
Figure 7.10 Annual NHS Pavement Construction Spending by FHWA Treatment Type at $300M Avg. Annual Spending



	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Preventive Maintenance Cost ($M)	$10.00	$17.89	$32.37	$40.84	$22.10	$14.48	$15.94	$18.45	$15.27	$18.14
Preservation Cost ($M)	$44.24	$79.81	$65.36	$60.47	$60.37	$63.65	$65.64	$61.95	$65.63	$48.60
Rehabiliation Cost ($M)	$183.50	$57.74	$74.93	$130.43	$97.96	$89.92	$171.97	$84.36	$108.69	$84.08
Reconstruction Cost ($M)	$110.23	$94.57	$77.34	$130.57	$189.51	$106.96	$21.45	$110.24	$85.40	$124.18

Figure 12: NYSDOT Pavement Treatment by Lane Miles

Figure 7.11 Annual NHS Pavement Lane Miles of Construction by FHWA Treatment Type at $300M Avg. Annual Spending



	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Preventive Maintenance LMs	2000	3489	3030	3056	2345	3295	2868	3178	3319	3054
Preservation LMs	526	1220	1035	823	805	922	904	707	833	652
Rehabiliation LMs	671	336	460	918	723	691	1278	618	758	603
Reconstruction LMs	237	95	217	280	684	351	75	355	252	361

West Virginia

Figure 13, from the WVDOH TAMP, shows the projected pavement expenditures on the NHS. Figure 14 shows the projected NHS conditions for both Interstate and non-Interstate NHS roads.

Figure 13: WVDOH Pavement Finding Projections

FIGURE 39: SCENARIO 1 - BASELINE FUNDING

Capital Program NHS and Non-NHS Expenditure Projections (millions $)	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028	FY 2029
Pavements Program (NHS)	$141.7	$131.7	$283.2	$128.0	$127.6	$127.5	$127.3	$131.7	$131.3	$131.1	$131.1
Turnpike Pavements Program (NHS)	$122.7	$29.9	$24.9	$25.3	$25.5	$25.8	$26.1	$26.4	$26.7	$27.0	$27.0
Pavements Program (Non-NHS)	$111.7	$103.8	$223.3	$100.9	$100.6	$100.5	$100.3	$103.8	$103.5	$103.3	$103.3
Total	$376.2	$265.4	$531.5	$254.2	$253.8	$253.8	$253.7	$261.8	$261.4	$261.4	$261.4

Figure 14: WVDOH Projected NHS Interstate and Non-Interstate Pavement Conditions

FIGURE 41: SCENARIO 1 - PROJECTED FHWA CONDITION METRICS FOR BASELINE FUNDING SCENARIO ON INTERSTATE PAVEMENTS

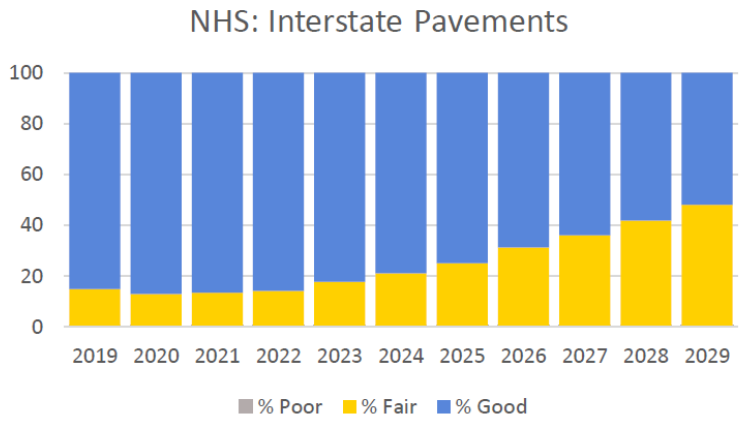
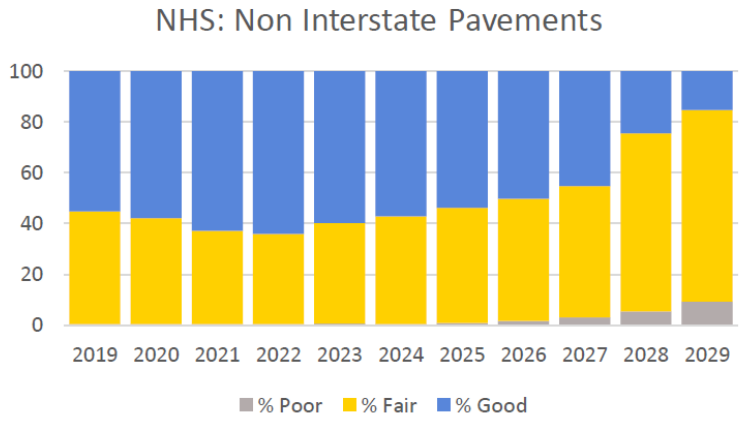


FIGURE 42: SCENARIO 1 - PROJECTED FHWA CONDITION METRICS FOR BASELINE FUNDING SCENARIO ON NON-INTERSTATE NHS PAVEMENTS



Analysis

As indicated, Ohio does have comparable or better pavement conditions than peer states as measured by the uniform national pavement performance measures. These relatively good conditions exist despite ODOT having substantially more truck traffic than the peer states.

Recommendations and Benefits

1. ***Include any pertinent budgetary rule constraints when performing PMS optimization scenario analyses***

   - Currently PMS analyses appear to be unconstrained
   - Consider adjusting the PMS analysis configuration to ensure optimization results better match ODOT's business processes

   Benefit:

   - Should produce more realistic, actionable results and reduce the amount of change needed by the districts to produce a practical workplan
   - Adding budget constraints should help in more clearly defining how expenditures are planned and tracked

B. Pavement Conditions

Baseline

ODOT uses an internally developed, manual data collection process that includes the calculation of a pavement health score called the PCR (Pavement Condition Rating). PCR is the driving factor in ODOT for identifying treatment recommendations and reporting network performance.

PCR scores are comprised of the collection of various distresses, the determination of dominant severity, and measurement of extent of each distress, for asphalt and concrete surfaced roads. The process is detailed in ODOT's PCR manual.[13]

In addition to the PCR process, FHWA mandates that ODOT (like all states) collect Highway Performance Monitoring System (HPMS) data on the National Highway System (NHS). The HPMS process requires collection of pavement condition data in a specific format as defined by the HPMS Field Manual.[14]

ODOT collects HPMS data with internal forces using pavement condition data collection equipment that is manufactured and maintained commercially. The system used by ODOT includes a Laser Rut Measurement System (LRMS). The HPMS data is collected on 1/10th mile intervals. Federal metrics for percent *Good*, *Fair* and *Poor* are calculated from HPMS measurements of cracking percent, rutting, International Roughness Index (IRI), and faulting and reported to FHWA as required in 23 CFR 490.

ODOT's Office of Technical Services developed the FHWA-required Data Quality Management Plan (DQMP)[15], which documents the procedures for managing pavement data quality, among other data sets. According to ODOT staff, the DQMP process for pavement data is general and mostly involves reviewing

[13] ODOT Pavement Condition Rating System, April 2006
http://www.dot.state.oh.us/Divisions/Planning/TechServ/TIM/Documents/PCRManual/2006PCRManual.pdf

[14] Highway Performance Monitoring System Field Manual, Federal Highway Administration, December 2016, https://www.fhwa.dot.gov/policyinformation/hpms/fieldmanual/

[15] Data Provided by ODOT: ODOT_DQMP_20180630_FINAL.docx.

values that are outliers (too high or low), or in different wheel paths. It is a visual review of automated data based on experience and staff judgment.

ODOT's biggest challenge with the DQMP reportedly has been the verification and certification of equipment. Providing automated crack detection capability also has been a challenge. The automated data collected for HPMS is not used in the ODOT PMS at this time.[16]

Peer States / Best Practice Findings

Each peer state interviewed for the study indicated that they have different ways to define network health and forecast conditions. According, the descriptive comments that follow should be interpreted within this context.

Kentucky

The Kentucky Transportation Cabinet (KYTC) owns three (3) automated data collection vehicles that were procured commercially, and were purchased during 2009, 2011, and 2013. KYTC replaced LRMS to Location Referencing and Condition Survey (LRCS). The State has a two-year inspection cycle, and still utilizes visual assessments. KYTC is currently working with the University of Louisville on an automated data project.

KYTC's DQMP process is detailed and involves reviewing values that are outliers. Personnel check through all the data and perform sample inspections. KYTC lacks a robust data quality plan for downward pavement distress data collection but maintains documentation on this.

Rating frequency is every year or every other year depending on what is being inspected such as interstate, parkway or other.

Maryland

MDOT SHA has two ARAN (Automatic Road Analyzer) vans for pavement condition data and all data collection is done in-house. Crews are responsible for collecting ride quality, and 3D imagery for collecting structural and functional cracking. Maryland uses this for HPMS and TAMP reporting as well as their own reporting. Skid trucks are used to collect friction data.

For DQMP, Maryland pavement management has action steps as well as a field exploration division. They use a tool that develops check lists into one excel file for QC and QA checks. Specific items are checked and initialed.

Rating is done annually for HPMS. For some smaller sections (less than a mile), rating might be conducted every 2 or 3 years.

New York State

NYSDOT uses 1-10 rating system and uses automated data collection vendors to collect the pavement network condition data. Typically, NYSDOT rarely observes a highway with a condition less than 5. Data is collected annually on the state system, whereas local roadway which are federally eligible are surveyed biennially.

All pavement data is in a linear referencing system, which is given to the data collection consultant. Information is reviewed in GIS to make sure there are no questions or discrepancies before the data collection process begins.

[16] ODOT Staff Interview Notes, March 2020.

The DQMP includes initially doing benchmark readings. It is ensured that the calibrations of the vendor's vehicles are correct and accurate. NYSDOT conducts year to year comparison of road segments. If variance is more than established threshold of 10%, data is sent back for investigation and recollection, as needed.

Pennsylvania

Pennsylvania has had an automated data collection program for pavement since 1996 with a contracted vendor who provides data, and manual service for guardrail damage and drainage. NHS data is collected annually, whereas Non-NHS surveys are conducted every 2 years. Guardrail and drainage are on a 4-year cycle.

DQMP includes QA review of pavement images sent by the vendor, and the process has built-in quality checks for matching condition and measurement values. If values are not within a certain range, data is flagged and has to be verified by the vendor.

West Virginia

Data is collected with a van equipped with Pavemetrics Laser Crack Measurement System (LCMS), a Ladybug 360-degree camera with panning and zooming capabilities, an Applanix POS-LV Inertial Navigation System (INS), and a Surface System and Instruments (SSI) CS9300 inertial profiler compliant with ASTM E950 Class I Profiler, AASHTO M328, R54, R56, and R57. Data is collected according to the AASHTO standards and the HPMS Field Manual. The data collected includes roughness (IRI), rutting, faulting, crack analysis, shoulder type and width, global referencing data, highway centerline geometrics, and digital roadway images. Data is collected on the following schedule.

- Interstate - dual direction collected annually.
- NHS - primary direction collected annually.
- HPMS Sample Sections - collected on a biennial cycle.
- HPMS Sample Section Geometry - collected once every five (5) years.
- APD (Appalachian Development Highway System) - dual direction collected annually.
- Non-NHS U.S. Routes - primary direction collected on biennial cycle.
- County Routes - primary direction collected once every five (5) years.

Wisconsin

Wisconsin owns two Pathway profiling vans that they use to collect pavement condition network wide. They also have a Pavement Development Unit (PDU) that analyzes this data and summarizes it. Data collection is sample based for pavement distresses. They are working on automated collection, but most historic procedures are manual. Wisconsin does have the capability for conversion to full automation, but for now is using a hybrid of both automated and manual data collection. With new tools, production has improved, and rating can now be completed annually.

PDU has a DQMP consisting of pre-collection, collection, processing, and post processing phases. Wisconsin primarily utilizes this to cross check between automated collection and quality control of the samples.

Analysis

Table 2 summarizes Peer States' data collection practices compared to Ohio.

Table 2: Data Collection Practices

	Ohio	Kentucky	Maryland	New York	Pennsylvania	West Virginia	Wisconsin
Data Collection Process	Manual	Both	Automated	Automated	Automated	Automated	Manual
In-House or Vendor?	In-House	In-House	In-House	Vendor	Vendor	Vendor	In-House
Collection Cycle	State Routes: Annual Local Fed Aid: Biennial	Biennial	NHS: Annual Smaller Routes: 2-3 Years	State System: Annual Local Fed Aid: Biennial	NHS: Annual Non-NHS: Biennial	NHS: Annual Non-NHS: Biennial County: Every 5 Years	Annual

As described, each state manages different metrics of pavement and network condition. Unlike bridge management, where the national standard of NBI means all states are reporting the same information, it is common practice within pavement management for agencies to follow unique processes. Some variation in metrics tracked are identified below:

1. According to Kentucky's TAMP, KYTC tracks three (3) pavement condition metrics: 1) Remaining Service Interval (RSI), 2) IRI, and 3) Asset Sustainability Ratio (ASR).
2. Maryland manages many condition metrics including Structural Crack Density (SCD), Functional Crack Density (FCD), IRI, Rutting, Skid, Faulting, and others to assess pavement conditions.
3. According to New York's TAMP, NYSDOT tracks Surface Rating (using a 10-point scale where 10 is the best condition) and IRI.

Maryland and New York have notable approaches to managing their respective pavement networks through performance metrics. Maryland converts metrics into remaining service life and lane mile years and sets performance targets for the districts. There are no consequences for not hitting targets; however, the following incentives are provided for exceeding preventative maintenance targets:

- Offering general bonus funds for discretionary regional purposes
- Providing innovation bonus funds for using certain preservation treatments
- Giving a 40 percent funding increase for specific projects

New York State uses a model to project what is achievable within each district in terms of condition, cracking, backlog, and average surface rating. These projections are then provided to the districts. If a region's proposed plan varies significantly from the plan and associated projections provided, that region is required to re-work its plan. It is common for the project selection process to have many iterations prior to final acceptance with state DOTs.

Federal Guidance

With the federal legislation 23 CFR 490, there is a concerted effort made by FHWA to try to ensure better accuracy and repeatability in the reporting of federal pavement condition metrics for IRI, Rutting, Cracking, and Faulting. The legislation only covers the reporting of NHS condition, and as part of that legislation, FHWA now requires each state DOT to develop and certify a DQMP. With the push from FHWA, state DOTs have begun formalizing data quality, accuracy, and repeatability processes. Part of that

process has been adopting automated data collection tools to work towards objective and repeatable condition data measurements.

Recommendations and Benefits

2. Develop a plan for migrating to automated data collection

- Other State DOTs have done this in recent years and developed data conversion processes to align historical condition data to new practices in their pavement management programs
    - The sooner ODOT moves to this method, the quicker it will build a history of automated data for modeling in ODOT's pavement management program
    - Will require calibration of the equipment to collect the PCR distresses effectively
- Should help in more clearly defining how expenditures on the pavement network and National Highway System (NHS) are allocated and tracked
- Potentially consider an alternative condition metric that relies more on the raw cracking measurements taken from the automated process which has shown to yield more consistent, accurate, and repeatable results than using manual survey distresses

Benefits:

- Objective measurement of pavement condition compared to manual methods
    - Manual data collection is susceptible to subjective results between individual raters
    - Reduces the impact of employee turnover and the volume of PCR training needs
- Should provide more consistent PCR rating over time
- Cost of automated data collection should be offset by these benefits
- Improves safety conditions during survey because the work is performed at regular traffic speeds
    - Manual survey causes differential speed conditions putting raters in a potentially unsafe environment

3. Formalize the DQMP process to define clear limits for accuracy and repeatability for the various measurements taken

- While ODOT has noted in the DQMP[17] that quality control for cracking is not as mature as for IRI, ODOT could consider the following:
    - Create a startup procedure for calibrating and certifying equipment at least for cracking measurements
    - Identify control sections for repeat run verification
    - Create pass/fail criteria for data accuracy and repeatability within limits

Benefits:

- Better accuracy and repeatability in the raw identification and measurement of cracks
- Higher quality data yields better treatment recommendations

[17] Data Provided by ODOT: ODOT_DQMP_20180630_FINAL.docx, see Note, Page 8.

- Keeps ODOT in compliance with FHWA 23 CFR 490 condition metrics for 1/10th mile data collection

C. Proposed Peer States

Basis for Selection

Part of the benchmarking aspects of this project included a requirement to compare ODOT to peer states and industry best practice in each review area. Kercher used the following criteria as the basis for recommending candidate peer states for this effort:

- Population
- Truck VMT
- Climate Zone
- Data Collection Practices
- PMS Software Use
- Kercher DOT Experience
- ODOT Identified Peers

Population – Kercher reviewed the FHWA *Highway Statistics 2018 Selected Measures* for peer states list, which includes population from 2010[18].

Truck VMT – Kercher reviewed the FHWA *Highway Statistics 2018 Selected Measures* for peer states list which includes Vehicle Miles Traveled (VMT) values and Percent Truck Values that was used to calculate Truck VMT[8].

Climate Zone – Kercher utilized the Long-Term Pavement Performance (LTPP) Climate Zones (see Figure 15) as the basis of this criteria[19].

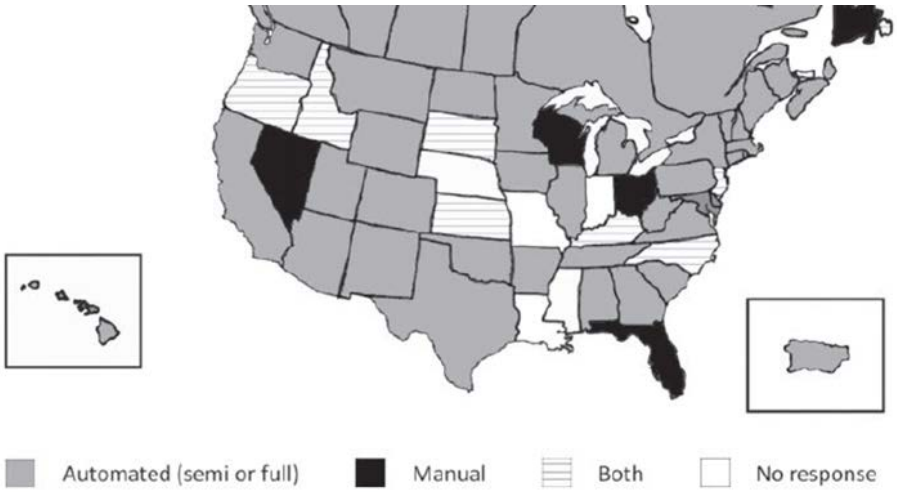
[18] Selected Measures for Identifying Peer States, 2018. Federal Highway Administration, https://www.fhwa.dot.gov/policyinformation/statistics/2018/ps1.cfm

[19] Evaluation of Long-Term Pavement Performance (LTPP) Climatic Data for Use in Mechanistic-Empirical Pavement Design Guide (MEPDG) Calibration and Other Pavement Analysis, Federal Highway Administration, FHWA-HRT-15-019, May 2015, https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/15019/008.cfm

Figure 15: LTPP Climate Zones

Data Collection Practices – Kercher utilized the National Cooperative Highway Research Project (NCHRP) Synthesis 531 – Automated Pavement Condition Surveys to identify the latest state DOT practices[6] (see Figure 16).

Figure 16: NCHRP Synthesis 531 - Condition Data Collection Practices



Pavement Management System (PMS) Software Use – Kercher looked for state DOTs that are utilizing the same pavement management software as ODOT as well as states that are utilizing other software with comparable optimization analysis capabilities.

Kercher DOT Experience – Kercher prioritized state DOTs in which the consulting team had prior experience with their pavement programs. The reason for this was to expedite the access to relevant information for this study due to the project schedule limits.

ODOT Identified Peers – Kercher felt it was important to have ODOT identify agencies they would consider peers for pavement practices. The agencies that were identified were already on Kercher's list.

Table 3 and Table 4 summarize the state DOTs used as peer states for benchmarking purposes along with the respective selection criteria values for each:

Table 3: Peer State Criteria-1

Peer State	Population (2010)	Truck VMT	Climate Zone	Manual Data Collection?
Ohio	**11,537,000**	**12,526,000,000**	**Wet/Freeze**	**Yes**
Kentucky	4,339,000	6,499,000,000	Wet/Freeze	Yes/No
Maryland	5,774,000	4,100,000,000	Wet/Freeze	No
New York	19,378,000	8,737,000,000	Wet/Freeze	No
Pennsylvania	12,702,000	10,313,000,000	Wet/Freeze	No
West Virginia	1,853,000	2,712,000,000	Wet/Freeze	No
Wisconsin	5,687,000	7,090,000,000	Wet/Freeze	Yes

Table 4: Peer State Criteria -2

Peer State	Same PMS?	Kercher experience?	ODOT identified?
Ohio	**Yes**	**No**	
Kentucky	No	Yes	No
Maryland	No	Yes	No
New York	No	Yes	No
Pennsylvania	Yes	No	Yes
West Virginia	Yes	Yes	Yes
Wisconsin	No	No	Yes

D. Review ODOT Forecasts

Baseline

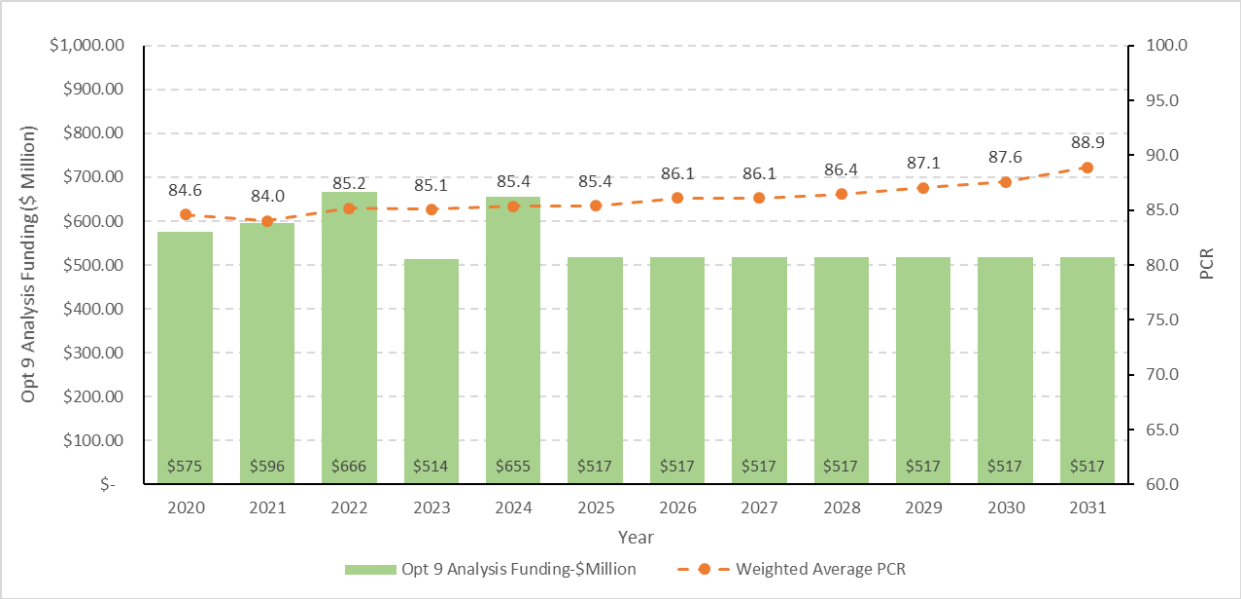
ODOT provided the audit team with a significant amount of data as part of the data request on the project. This information included ODOT's PMS optimization projections that forecast funding levels and predicted PCR values on pavement projects from 2020 through 2031.[20]

ODOT uses optimization analyses from its PMS to run multiple funding level scenarios and determine the optimal funding amount that achieves the performance goals of maximizing average weighted PCR score while minimizing the percentage of deficient lane miles. ODOT annually analyzes these scenarios separately for the Priority and General System networks.

[20] Data Provided by ODOT: General.xlsx and Priority.xlsx

Figure 17 contains a Kercher-prepared graph of ODOT-provided expenditures versus conditions for the entire State, forecasted for 2020-2031[21]. ODOT runs various budget optimization scenarios in the PMS. The data provided below comes from ODOT's final accepted optimization scenario, denoted as Opt 9. Kercher provides this information as an example of the analysis process used by ODOT to determine funding needs from these forecasts.

Figure 17: Statewide Forecasted Condition vs. Optimization Analysis Funding



E. Compare ODOT Modeling and Forecasting Practices to Peers

Baseline

Before 2017, ODOT used engineering judgment to select pavement projects and forecast budgetary needs. In 2017, ODOT completed its implementation of commercially available PMS software. The change to a data driven approach for optimizing project selection is a significant improvement in pavement management practices that provides more transparency and objectivity in funding decisions made by ODOT.

The current ODOT PMS supports performing strategy optimization analysis, which the consulting team considers best practice. This approach gives ODOT the option to determine the use of funds that maximizes network condition (benefit), subject to various budget constraints (costs). These benefits and costs can then be used to make project work plans with optimized treatment strategies for the pavement network.

The consulting team considers the ODOT system to be one of the better of the software packages on the market that provides strategy optimization analysis. There are currently 23 State DOTs utilizing the same software package as ODOT for managing system pavement assets.

[21] Ibid.

ODOT has incorporated the use of "Transition Probability Matrices" (TPM)[22] for use in its PMS. This PMS configuration enhancement was developed for ODOT by the University of Toledo. Compared to typical industry practice, this is a very sophisticated and complex method of modeling and forecasting pavement performance. As described below, this approach provides some significantly enhanced capabilities.

The use of TPMs within its PMS allows ODOT to model and forecast future conditions of each section of roadway and by extension, the entire network.[23] In turn, TPMs are subdivided by the following pavement network attributes:

- System (General or Priority)
- Statewide and District (All or D1-D12)
- Pavement Type (2, 3, 4)
- Activity Code (TPMs for Codes 25, 50, 60, 100, 110, Linear models for all other Activity Codes)
- Distress Code (16 Distresses)

TPMs are defined as 10x10 Markov matrices, where the probability of a change from one distress deduct severity and extent condition state value to another, is a function of its current state. In pavement condition terms, a severity is "how bad" the condition is, while an extent is "how much" is present. In reviewing Table 5 and Figure 18 below, the deduct levels of LO, LF, LE, and so on, denote a pairing of severity and extent where the values of severity (L=Low, M=Medium, H=High), and extent (O=Occasional, F=Frequent, E=Extreme). Therefore, a value of LO would be a pavement condition of Low/Occasional, meaning relatively good condition while the other extreme of HE, or High/Extreme would denote very poor condition. Distress deducts are then predicted into the future to define the modeling of the distress.

Table 5 is an example of a 10x10 General System matrix for the Statewide network, Pavement Type 3, Activity Code 100, Distress Code 1.

Table 5: Markov Matrix Sample from ODOT PMS Setup

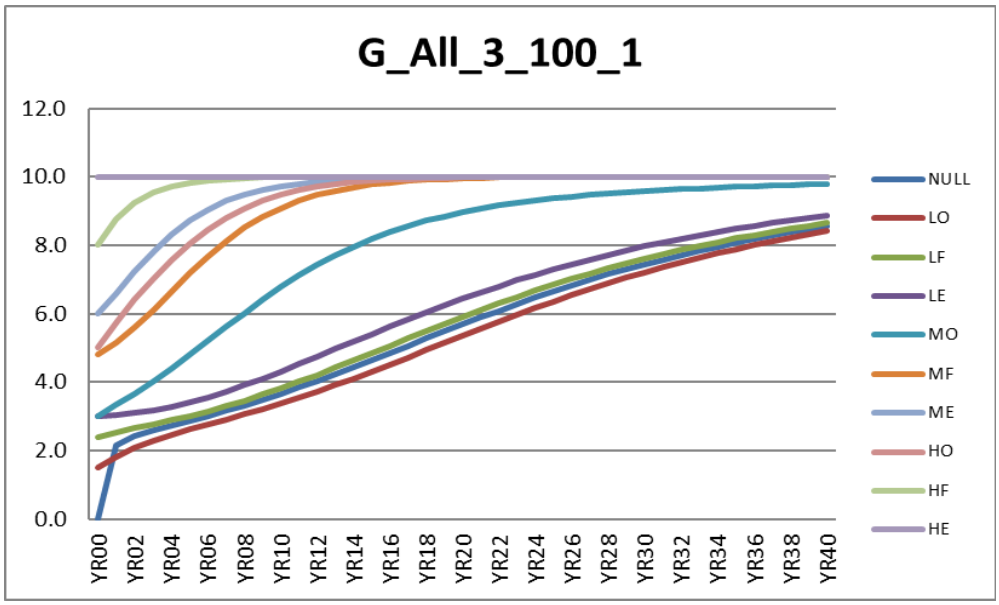
Pavement Section Information					Transition Probability Matrix										
Priority	District	Pavement Type	Activity Code	Distress Code	Deduct Level	NULL	LO	LF	LE	MO	MF	ME	HO	HF	HE
G	All	3	100	1	**NULL**	0.0462	0.4274	0.1188	0.4043	0.0004	0.0028	0.0000	0.0001	0.0000	0.0000
G	All	3	100	1	**LO**	0.0000	0.6528	0.3330	0.0103	0.0035	0.0000	0.0000	0.0003	0.0000	0.0000
G	All	3	100	1	**LF**	0.0000	0.0000	0.7891	0.1767	0.0322	0.0016	0.0000	0.0004	0.0000	0.0000
G	All	3	100	1	**LE**	0.0000	0.0000	0.0000	0.9344	0.0435	0.0177	0.0000	0.0041	0.0002	0.0000
G	All	3	100	1	**MO**	0.0000	0.0000	0.0000	0.0241	0.8113	0.1264	0.0000	0.0302	0.0080	0.0000
G	All	3	100	1	**MF**	0.0000	0.0000	0.0000	0.0000	0.0000	0.6303	0.2562	0.1114	0.0022	0.0000
G	All	3	100	1	**ME**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.7078	0.0000	0.2922	0.0000
G	All	3	100	1	**HO**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2430	0.6208	0.0958	0.0403
G	All	3	100	1	**HF**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6132	0.3868
G	All	3	100	1	**HE**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000

[22] Also known as a "Markov matrix", among other terms. See https://en.wikipedia.org/wiki/Stochastic_matrix for description.

[23] Data Provided by ODOT: Ohio Deduct Workbook_2019_12_16 (Performance Prediction Curves).xls

The TPM example results in the performance trends identified in Figure 18 when 40 years of predicted deduct values are plotted for each severity and extent combination. These model subdivisions result in 389 unique 10x10 Markov Matrices.

Figure 18: Predicted Deduct Values Sample from ODOT PMS Setup



Challenges with using TPMs

The most challenging part of managing TPMs is knowing which coefficients to use in the matrix for each condition state transition. Obtaining accurate values proves to be quite difficult when relating the models to conditions found in the field. However, the degradation models were developed based upon ODOT's robust historical condition data along with ODOT's historical project data, each of which is necessary to develop these types of models. Where robust historical data was not available, linear models were used.

ODOT manages the project selection and network performance process predominantly using PCR along with other condition indicators; however, the current modeling at the severity and extent of each distress may result in a disconnect in interpreting the output. In the ODOT TP interviews, staff indicated the complexity of managing the models with significant effort required to update them.[24] However, ODOT respondents indicate that in most cases, the resulting project recommendations coming from its PMS tend to align with expectations.

Peer States / Best Practice Findings

Each peer state interviewed for the study indicated that they have different ways to define network health and forecast conditions. According, the descriptive comments that follow should be interpreted within this context.

Kentucky

KYTC has been using AgileAssets for its PMS since 2000 and a PMS since 2004-06. The KYTC deterioration models use variables based on visual distress evaluation. The University of Louisville created these models, based on 15-18 years of historical data. Index conditions are calculated using an approach that

[24] ODOT Staff Interview Notes, March 2020.

models all distresses individually. KYTC uses traditional deterministic deterioration models rather than Markov TPM modeling.

Maryland
MDOT SHA utilizes data management program and a commercially available optimization system called *Roadcare*. MDOT SHA's database analysis processes were developed internally.

MDOT SHA has performance models to predict future needs that are based on past historical data. Some models are linear while others are exponential; all are used to predict future conditions over time. The predictive models are developed in-house, mainly using onsite consultants. Data validation is done based on severity; if pavement has more linear cracks, it is identified as higher severity by default. MDOT SHA uses traditional deterministic deterioration models rather than Markov TPM modeling.

New York State
Historically, NYSDOT collected pavement information in an Access database. However, NYSDOT has plans for "go live" with the pavement data portion a new PMS system within a few months.

For ease of understanding, NYSDOT translates the collected pavement data into a 10-point scale for modeling. NYSDOT considers the following factors in the pavement statistical analysis:

1. Location in state
2. Treatment in place
3. Condition of pavement at the time of the treatment

Of note, NYSDOT does not use ADT in this model due to a lack statistically significant difference in the performance predictions that could be attributed to ADT. NYSDOT uses traditional deterministic deterioration models rather than Markov TPM modeling.

Pennsylvania
PennDOT uses a customized version of the commercial PMS system, *dTIMS*. The PennDOT pavement analysis process includes modeling IRI and OPI on a scale from 0-100. A deterministic analysis basis is used with typical deterministic deterioration curves; all other analysis is based on Markov transition probability.

PennDOT used IRI analysis prior to implementing the dTIMS software. This information was used in developing the TPM matrices with the dTIMS vendor. Typically, consultants have been used to develop PennDOT's pavement models.

West Virginia
WVDOH uses dTIMS and model created by Deighton with input from the Agency. This practice includes validating deterioration curves, treatment triggers, and treatment costs. This process is reviewed annually and revised as needed (including a currently ongoing effort to calibrate and validate the models). WVDOH uses traditional deterministic deterioration models rather than Markov TPM modeling.

Wisconsin
WisDOT uses an internally developed PMS. 10 years of WisDOT data was used in developing the distress curves used in this model.

Current WisDOT practice includes working with the asset and performance management department to communicate with the regions. WisDOT then makes upgrades as needed to the deterioration logic while considering the model design.

WisDOT has initiated an effort to incorporate machine learning (artificial intelligence) in developing new pavement deterioration models. Model validation is being conducted at the distress level.

WisDOT uses traditional deterministic deterioration models rather than Markov TPM modeling.

Analysis

Table 6 summarizes Peer State's performance modeling practices compared to Ohio

Table 6: Pavement Modeling Practices

	Ohio	Kentucky	Maryland	New York	Pennsylvania	West Virginia	Wisconsin
Uses Optimization?	Yes (dTIMS)	Yes (AgileAssets)	Yes (RoadCare)	Yes (AgileAssets)	Yes (dTIMS)	Yes (dTIMS)	Yes (Homegrown)
Modeling Type	Probabilistic	Deterministic	Deterministic	Deterministic	Both	Deterministic	Deterministic
In-House or university/ consultant developed?	University	In-house /University	In-house Consultants	In-house	In-house /Consultant	Consultant	In-house

As indicated, all peer states use optimization-based pavement management systems with the ability to incorporate deterioration models.

Peer states vary in their optimization modeling processes. For instance, PennDOT uses a combination of deterministic and probabilistic modeling. Conversely, Kentucky, New York, and Maryland only use deterministic modeling.

Like ODOT, each of the peer states allocates funding to their districts/regions in a manner intended to optimize impact to the condition of the overall system. Each state also uses a cost-benefit analysis (a best practice), though some states have more sophisticated processes than others.

NYSDOT's approach to optimization is noteworthy in that includes 'importance' weighting factors in its calculation of 'benefit', as defined below:

Benefit = 'The area between the curves' x 'ADT on roadway' x 'corridor importance factor'

From a programmatic standpoint, NYSDOT's approach is to analyze major metrics and the change in percent of Vehicle Miles Traveled (VMT) in terms of 'good' or 'excellent', in respect to the backlog of unmet needs. (NYSDOT representatives note that backlog sometimes fluctuates due to other factors too.)

Comments

Figure 2, presented previously in this document, shows that roughly $800 million per year has historically been spent to maintain the weighted average PCR in a relatively steady state. However, Figure 17 shows that a budget of approximately $520 million per year is projected to increase the weighted average PCR in the future. The consulting team perceived that the identified funding differences could suggest a potential disconnect between the actual and predicted budget needs to maintain the pavement network condition. When asked for confirmation/clarification, ODOT responded that the data depicted in Figure 2 includes historical expenditures through various funding programs that included the following:

pavement preservation, multi-lane major reconstruction, major reconstruction – general system, and major new programs. Conversely, ODOT indicated that Figure 17 only included pavement preservation program activities.

Since the funding of various programs described above are from different sources but result in similar PCR trends, ODOT may have to review the optimization setup, and especially any budget constraints relating to specific funding programs, within the PMS. In addition to funding constraints, when pavement models (i.e. deterioration curves, treatment triggers, treatment resets, unit costs, etc.) are not well calibrated, the PMS can over or under predict future budgetary needs. Given that the PMS is relatively new to ODOT, it is anticipated that additional calibration will take place in the coming years, and it is most common among state DOT and local government agencies that the PMS is continuously being refined and improved into the future.

A key business process to managing a pavement management system is therefore to regularly review and adjust the system's performance models based on new data and information that becomes available to the agency over time. Although ODOT's performance modeling methodology is one of the more sophisticated in the nation, it will require significant effort to regularly review and update. This will likely require ODOT to have a university or consultant assist in-house staff with the process which comes at a cost. In addition, maintaining staff within ODOT who can understand and manage the models will be a challenge as staff turns over.

Considering that ODOT is relatively new to performing optimization-based analyses, ODOT may consider continuing to have a university or consultant assist with the development and management of the modeling process, providing training to assist staff in becoming more proficient. In addition, ODOT should develop clear Standard Operating Procedures (SOPs) for updating and maintaining the TPMs. There will be costs associated with hiring a university or consultant to assist in the management of the models, but the benefits will be significant with improved predictive capabilities, accurate treatment recommendations and knowledge transfer into the department.

Recommendations and Benefits

4. ***Investigate and define the causes of the discrepancy in budget when comparing historical to predicted expenditures***

    - Consider calibration of the PMS modeling and optimization analysis process
    - Ensure ODOT business processes are carefully modeled within the PMS
    - AOS may consider further investigation into the data sources for Figure 2 and Figure 17 to close the loop on the PCR trend results compared to expenditures

    Benefit:

    - More accurate predictions of future funding needs
    - Better project recommendations from the PMS
    - Improved understanding of the PMS modeling process

F. Pavement Condition Forecasting Process

1. Data Collection

ODOT Baseline

As stated previously, ODOT uses an internally developed, manual condition survey methodology as defined in the ODOT PCR Manual. This process is unique to ODOT.

Only four (4) states currently report performing manual condition surveys.[25] Other states have moved to automated condition survey techniques to collect the data used in the analysis of their pavement management systems. Manual condition survey is the process of driving at slow speeds on each road of the network to assess various types of cracking or other pavement deficiencies by visually inspecting the pavement. This may require occasionally stopping the vehicle and walking sample locations of the pavement and taking detailed measurements. Automated data collection is the process of having a specialized vehicle drive the roads at highway speeds and capturing imagery, cracking, rutting, and roughness data using instrumentation attached to the vehicle and storing the information on a data server. The automated process may include a method of automatically determining the cracking and other deficiencies captured with the collection equipment.

ODOT's PCR methodology collects many of the distress types that are common among other more widely used methodologies such as ASTM D6433[26] and the LTPP Distress Identification Manual.[27] However, the methodology ODOT uses to convert these distresses to the calculated PCR value differ from those methodologies. Importantly, ODOT has sponsored third party research that found that completely automating of all typical pavement distresses needed to manage pavement is not possible based on current ODOT distress standards.

ODOT has reviewed the automated approach and found manual collection currently to be more cost effective and allows the use of robust PCR history to obtain accurate distress modeling. ODOT notes that a lack of historical distress data, lack of standard automated distress definitions, limited vendors, and increased collection costs make automated collection less attractive to ODOT at this time.

ODOT PCR Calculations

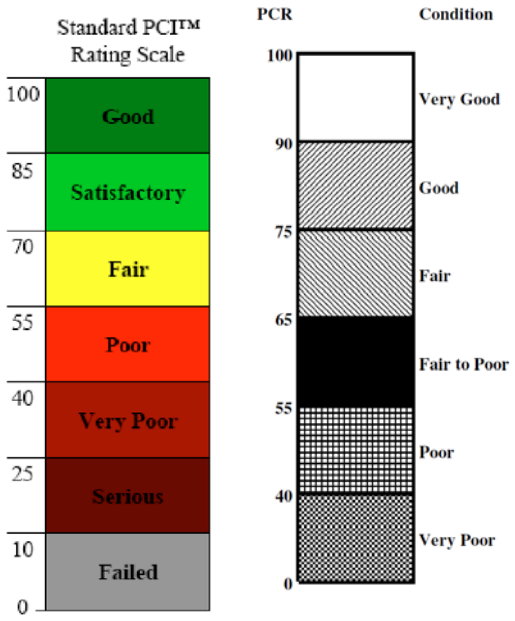
In addition to calculating index values such as PCR, many agencies develop condition categories for reporting. Figure 19 contains a comparison of the ASTM D6433 PCI categories to ODOT's PCR condition categories to show the similarity of ODOT's system to a standard industry example.

[25] Ohio, Wisconsin, Florida, and Nevada

[26] ASTM D6433-18, Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys, ASTM International, West Conshohocken, PA, 2018, www.astm.org

[27] Federal Highway Administration, Distress Identification Manual for the Long-Term Pavement Performance Program, FHWA-HRT-13-092, May 2014, https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/13092/13092.pdf

Figure 19 - Condition Category Comparison (ASTM PCI on left, ODOT PCR on right)



In reviewing ODOT's PCR manual, Kercher finds the identified process of calculating the index appears sound and relates the appropriate distresses, severities, and extents to reasonable deduction values. Accordingly, as long as ODOT can relate the values of PCR to the condition of the pavement in the field, and arrive at good treatment recommendations, Kercher perceives that the current ODOT PCR methodology is serving its intended purpose.

Peer States / Best Practice Findings

Each peer state interviewed for the study indicated that they have different ways to define network health and forecast conditions. Sections B and E of this report cover much of the discussion on condition forecasting.

It is important to note that that no two states are alike in how they collect data and convert pavement data to condition indices such as the PCR. Regardless, PCR is among common industry practices used for summarizing network conditions into a single health score and applying that to the road segment level and the total network condition.

The above statements (variances in how PCR is measured for pavements) stands in contrast to bridges, which use National Bridge Inventory (NBI) values and methodology to report standardized bridge condition measurements.

Analysis

Generally, the peer states described three (3) main approaches to data collection and performance metrics:

1. Self-performed Automated Data Collection

Kentucky[28] and Maryland both manage vans in-house for automated data collection. According to Kentucky's TAMP, KYTC tracks three (3) pavement condition metrics: 1) Remaining Service Interval (RSI), 2) IRI, and 3) Asset Sustainability Ratio (ASR).

Maryland manages many condition metrics including Structural Crack Density (SCD), Functional Crack Density (FCD), IRI, Rutting, Skid, Faulting, and others to assess pavement conditions.

2. Contractor-performed Automated Data Collection

New York, Pennsylvania, and West Virginia each use automated data collection using contracted vendors. While New York and West Virginia both collect all mileage by automated methods on various cycles, New York's approach is mostly focused on major routes.

According to New York's TAMP, NYSDOT tracks Surface Rating, a 10-point scale where 10 is the best condition, and IRI. Additionally, New York's DQMP is detailed in such a way to allow for setting control sites for startup and monthly checks of accuracy and repeatability and has thresholds that determine pass/fail. The system enables the recollection and reprocessing of outliers and provides basis for performing year-over-year comparisons.

3. Manual Data Collection

Wisconsin is seeking the ability to transition to a fully automated system; however, as of the date of the interview, the State's process is currently manual.

Recommendations and Benefits

See Recommendations from Section B of this report.

2. Pavement Deterioration Curve Development

ODOT Baseline

As stated in Section E of this report, ODOT has a sophisticated pavement deterioration modeling process that uses Markov Matrices to predict the change in deduct values for each distress, severity, and extent. The curves were developed by the University of Toledo through a research project and are incorporated into ODOT's PMS. The deterioration curves are based upon ODOT's historical condition data in conjunction with historical project/treatment activity information.

Peer States / Best Practice Findings

Kentucky

KYTC models each of its deteriorating pavement condition variables based on visual evaluation. KYTC has recently worked with a university to develop a process to convert visual distress data to automated distress data for modeling.

Maryland

MDOT SHA has performance models to predict future needs based on past historical data for the various deteriorating indices. Some models are linear while others are exponential; all are used to predict future conditions over time. Models are developed and validated in-house, using onsite consultants.

[28] KYTC replaced its LRMS with a LCMS in recent years and has a project with the University of Louisville to calibrate its automated and historical manual data.

New York State
NYSDOT performs a statistical analysis of its deteriorating pavement indices. The following information is considered in this analysis:

1. Location in the state
2. Current treatment in place
3. Condition of pavement at the time of the treatment

Pennsylvania
PennDOT's current performance modeling practices include modeling IRI and OPI on a scale from 0-100 and using deterministic modeling with typical curve types. All other deterioration indices are based on transition probability matrices, similar to ODOT.

West Virginia
WVDOH uses dTIMS and the deterioration models created by Deighton with input from the Agency. Management of pavement models includes regularly validating deterioration curves, treatment triggers, and treatment costs. Model values are revised as needed.

Wisconsin
WisDOT uses an internally developed PMS, based on using 10 years of distress level data to create the deterioration curves. Central office-based WisDOT personnel work with the regions to improve the model logic to better reflect local knowledge. This review includes examining deterioration curves with validation conducted at the distress level.

Analysis
Each peer state uses historical data analysis to develop models for predicting future pavement conditions. Most have developed deterministic performance models for deteriorating distresses, overall condition scores and federal metrics.

Of interest, PennDOT noted in their TAMP that they are implementing both deterministic and probabilistic models in their pavement management systems, which was discussed during the interview. Wisconsin is currently exploring the use of in-house machine learning and artificial intelligence models for deteriorating pavements. This would be considered a leading-edge capability if successfully implemented.

Recommendations and Benefits
See Recommendations from Section E of this report.

3. Unit Cost Estimation

ODOT Baseline
The consulting team discussed ODOT's process for developing unit costs during the TP and district interviews. This included discussing the unit costs that reside in the ODOT PMS[29].

Unit costs are stored by statewide average for each treatment activity as well as by unit cost averages for each county in Ohio. This supports the ability to account for any variances in rural/urban, single bidder, and other challenges unique to various regions.

TP staff noted that PMS optimization uses county-based unit costs that are updated yearly. Unit costs are calculated as dollars per square yard ($/Square Yard), based on detailed analysis of historical bid

[29] Data Provided by ODOT: OHIO_PMS_ACTIVITY_COST_MATRIX_2019 - Final Results.xlsx

tabulations for similar work activities and within the given county. This information is derived from bid tabulations of various construction pay items that are associated with the treatment activity. In turn, these costs are subdivided by pavement type and a project cost multiplier is applied for ancillary items that may affect project total costs.

In addition to the unit cost calculations described above, ODOT also factors cost inflation projections into future years of the optimization analysis. According to ODOT interviews, the ODOT estimating group projects inflation rates by looking at market trends. These rates are updated yearly prior to running these analyses.[30] Project Costs are a function of the project length, road width, unit cost of the proposed activity(ies) and inflation rate. The inflation rates are stored and managed in the PMS configuration as hard coded values, which requires users with knowledge of the software configuration to update on a regular basis.

Peer States / Best Practice Findings

Kentucky
KYTC collects bid information from every contract awarded on interstate and parkway treatments. This information is used to populate a spreadsheet that in turn, is used to develop unit costs for these treatments.

The rest of the KYTC network is combined and separate unit costs are calculated for those treatments, both statewide and by district. KYTC's performance standard is to update the information annually but this information typically is updated on an "as needed" basis.

Maryland
MDOT SHA collects information on costs continuously throughout the year by project, location, and quantity/size of project. Overall cost matrices are updated annually for all types of asphalt materials and all pavement related project items.

MDOT SHA does not separate costs by districts or functional class and uses these for lifecycle cost analysis and project level pavement design. This information is also used for network level cost modeling for pavement repairs.

New York State
NYSDOT utilizes average unit costs for the pavement related bid items from highway projects stored in the PMS. Costs are distributed by treatment type and broken down by region (functional class is not considered). Cost information was last updated four (4) years ago. NYSDOT indicates that translating project costs back to treatment type has been a challenge.

Pennsylvania
PennDOT uses network-wide unit costs based on averages. However, the PennDOT PMS also can calculate these costs by district and county.

PennDOT indicated having plans to use cost data specific to functional classifications in the future. PennDOT evaluates different treatments in the PMS depending on how they are utilized and when bid history is available.

[30] ODOT Staff Interview Notes, March 2020.

West Virginia
WVDOH tracks costs based on the pavement contracts awarded. Unit costs are updated annually, as needed.

Wisconsin
WisDOT has 18 work types and tracks costs by urban, rural, divided, and undivided roadways. Current practice is to update this information every two (2) years.

WisDOT has pavement improvement types identified in its financial system. This streamlines the translation between PMS work plans and project level assessments.

Analysis

Table 7 summarizes Peer States' unit cost update practices compared to Ohio:

Table 7: Unit Cost Estimation Practices

	Ohio	Kentucky	Maryland	New York	Pennsylvania	West Virginia	Wisconsin
Unit Cost Update Cycle	Annually	Annually	Continuously	Every 4 Years	--	Annually	Every 2 Years
Includes District/Region Breakdown?	Yes	Yes	No	Yes	Yes	--	No
Includes Road Classification Breakdown?	No	Yes	Yes	No	Yes	--	Yes
Use Bid/ Project History?	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Each of the peer states calculate average pavement unit costs using prior construction projects bid history. Most break these costs down further (e.g. by district or functional classification) to account for unique circumstances that affect costs by region or by complexity of the project on certain classifications of roadway.

Of note, Maryland and West Virginia update these costs on at least an annual basis. Maryland has a three (3) year lookback which also removes extraordinary 'outlier' costs and breaks down, by District, specific costs (in order to account for the nuances from region to region).

Comments

Interviews with the 12 ODOT districts identified varying descriptions of how project costs are calculated and used. This was particularly true when comparing specific project locations to the optimization analysis project locations recommended by the Central Office.[31]

Most districts tended to maintain databases of their respective unit costs. Typically, these district-based cost estimates were higher than the cost estimates provided to the districts. Suggested reasons for these cost variations varied but perceived trends were as follows:

[31] ODOT Staff Interview Notes, March 2020.

- Rural districts often only have one bidding contractor for certain types of treatment (e.g., Microsurfacing)
- Urban districts often encounter additional costs related to traffic control and night work

While unit cost factors vary in specific situations, it is important to note that these assumptions have a significant impact in the PMS optimization analysis since the decisional algorithm is based on a calculated cost to benefit analysis. Accordingly, any variation in cost can have significant impact on performance metrics and funding needs in the future.

When unit costs are too high or too low, achieving the project selection goal of 75% match between District and Central Office optimization is affected. This impact potentially can result in making target project recommendation-to-selection goals unachievable.

Recommendations and Benefits

5. ***Perform a yearly survey of the Districts to ensure the costs are accurate prior to running the optimization***

   Benefits:

   - More accurate predictions of future funding needs
   - Better project recommendations from the PMS

6. ***Consider updating the configuration of the dTIMS PMS to put the inflation coefficients in a separate table and calculate the values instead of hard coding them in the analysis variables***

   Benefits:

   - Simplifies management of the program
   - Provide transparency in the process[32]

7. ***Consider more outreach to contractors to improve the competition for certain treatments or allowing for alternative bidding to allow for substitutions in materials when costs are more favorable***

   Benefits:

   - Potentially lower cost and/or better value pavement treatment by promoting competition in the marketplace

4. Treatment Recommendation

ODOT Baseline

ODOT's Office of Program Management provides the districts with pavement treatment recommendations based on the ODOT Office of Pavement Engineering (OPE) developed decision trees and optimization analysis from ODOT's PMS.[33] These decision trees identify specific treatment selection rules such as the following:

- Pavement type

[32] ODOT Enterprise Pavement Management System, Draft Final Report, Deighton, April 2014, Page 279.

[33] Data Provided by ODOT: GenSys Decision Tree-dTIMS Layout 2018-11-02 w changes.pdf, PrioritySys Decision Tree-dTIMS Layout 2019-12-16 w changes.pdf.

- System
- PCR ranges
- Structural deduct values
- Traffic levels
- Specific distress levels that ODOT uses to select specific Treatment Activity Codes.

The initial step in the project selection process is to run the optimization of the statewide budget in PMS, based on the decision tree logic configured in the application. These preliminary project lists are sent to the districts for consideration. As this description suggests, the selection criteria defined in the decision trees are critical to ensuring the right treatment is placed on the right condition road at the right time.

Importantly, the ODOT PMS uses a strategy-based optimization approach that uses incremental benefit cost optimization. This means that multiple possible treatment recommendations can occur for a given set of conditions. However, the resulting statewide analysis considers what combination of options is the most optimal to meet the set of constraints imposed by ODOT in the analysis.

According to the district staff interviewed, five (5) districts use the PMS decision trees to assist in selecting treatments when determining the final list of projects.[34] The remaining seven (7) districts were mostly using localized expert judgment to decide on treatments or keeping a list of deficient roads separate from the analysis process to repair.

The consulting team reviewed the ODOT decision trees developed for the Priority and General road systems but did not review those for the Urban system. This is because the urban system is not run through the PMS optimization as ODOT does not own these assets.[35] (Urban routes are owned by the municipalities and often the recommendation to treat an urban system route is the municipality's responsibility.)

Also as indicated during the TP interviews, while the ODOT PMS is used to analyze pavement treatment needs, the availability of other funding sources and similar project recommendations made outside of the PMS may impact the actual projects selected. Examples of other funding sources that impact project section include safety improvements, expansion and capacity projects and capital improvements, among others.[36]

Since these outside projects can have an effect on the condition of the network and have an outside influence on project selection, they are "hard coded" into the optimization analysis as committed projects. This treatment of projects that are already committed to in some way and being outside the optimization analysis is desirable and considered best practice.

Treatment recommendations as provided in the PMS optimization are also affected by the segmentation rules defined in the PMS analysis. According to ODOT staff interviewed, routes are broken up into homogeneous sections that can range in length from 1/100th of a mile to 14 miles.[37] These segmented

[34] ODOT Staff Interview Notes, March 2020.

[35] Ibid.

[36] Ibid.

[37] Ibid.

sections each receive a treatment recommendation; districts then aggregate the segments manually to create project limits.

According to district interviews, there are certain pavement treatments that are recommended from the PMS but are not always considered most appropriate for the conditions encountered in the field.[38] For instance, some districts noted that Treatment Activity 50 – Overlay may be recommended by the PMS but districts frequently determine that Treatment Activity 60 – Repair and Overlay is needed. This is because districts frequently report that the existing roadway typically needs some sort of repair before condition supports an overlay application.

Microsurfacing also was identified as a treatment not always considered most appropriate on cracked surfaces where they could fail before achieving the target life expectancy. Again, this is not an issue everywhere, but where it is an issue, typical reasons identified as making this treatment inappropriate included the following:

- Conditions were poorer than appropriate
- Material or construction issues
- Weather related conditions

Some districts noted that horse and buggy traffic causes severe damage to pavement surfaces and requires special consideration for treatment selection. Other districts noted that the fracking boom has caused some roads to fail prematurely with the added truck loads, which can cause disproportionate funding needs.

Peer States / Best Practice Findings

Kentucky
KYTC uses decision trees in their PMS network level project selection process. However, the treatments recommended sometimes do not align with project level needs. Typically, this is due to specific information being available at the project level that may not be available at the network level.

Maryland
As is the case with other DOTs interviewed, MDOT SHA indicates that its network level analysis relies solely on the data available to make its preliminary recommendations. However, project level information then is used at the decision tree project selection level to refine the final treatment recommendation.

In essence, the project selection process is viewed as a collaboration between Pavement and Geotechnical Division (PAGD) and districts offices. Network level decision trees can be used to identify the initial set of candidate projects and treatments, but the project level information determines is the final selection.

New York State
Decision trees play a role in the NYSDOT PMS project selection process. NYSDOT consists of 11 regions and a main office. Currently, NYSDOT does not have region-specific decision trees; however, regions are able to request updates to the decision trees based on their input. As part of the process for treatment selection, regions come up with the treatments desired and recommendations are provided to the main office for consideration/review.

[38] Ibid.

Pennsylvania
PennDOT utilizes decision trees but this approach currently is not fully implemented yet.

West Virginia
WVDOH utilizes the decision trees built into the PMS. However, divisions differ in terms of following these recommendations and the process is not always formally documented.

Wisconsin
The WisDOT central office maintains is responsible for pavement management analysis processes. However, pavement design selection occurs in the regional offices but must follow central offices' project selection processes. WisDOT uses a decision tree along with a systematic priority system for project selection.

The WisDOT maintains a facilities development manual which has a defined life cycle cost analysis embedded into the pavement selection and replacement process. This analysis is based on a 50-year analysis period using a discount rate of 5%. The PMS identifies the low-cost alternative in each case and that recommendation is used unless two (2) alternatives are within 5% of each other. In such cases, the field is provided latitude to choose the locally preferred treatment.

Analysis

Each peer state has a formal definition of pavement preservation, applies various preservation treatments under specific conditions, and keeps a detailed list of preservation treatments used. In addition, each peer state has identified limitations or hesitancy to use certain treatments under unique conditions. This is a common practice across the nation.

While all peer states employ a systematic decision-making process that involves decision trees and/or matrices, variation exists in the degree of confidence of the final treatment recommendations provided. Following the initial analysis step in their project selection process, most states deferred to a district/region to provide additional information as part of the final project selection process based on their local expertise. Notably, the best practice approach considers some specific and formal decision tree development for each unique set of conditions by which a treatment is used within a district/region; the resulting network level results would then align as closely as possible to the actual treatment needs.

Comments

The treatment recommendation process used by ODOT is very common among advanced State DOT pavement management practices. The use of homogeneous sectioning is a necessary part of selecting appropriate treatments.

Recommendations and Benefits

8. ***Consider developing a dynamic aggregation process to group smaller segments of the network together into reasonable project limits but limit the maximum length of section to no more than 3 to 5 miles***

   Benefits:

   - Increase the optimization program's ability to identify and fund larger projects
   - Improve road network segmentation to align more closely with reasonable project limits
   - Provide a more realistic project output that aligns more closely with agency business processes
   - Potentially improve project selection results

9. ***Consider calibrating the PMS decision trees to ensure certain treatments are selected for appropriate conditions or allow for alternatives that work best for specific districts***

Benefits:

- Save time in developing project work plans
- Potentially save ODOT money by avoiding project recommendations that are too conservative for current conditions
- Reduce the volume of inappropriate (lighter) treatments being recommended in places where heavier treatments are warranted
- Encourage wider District participation in the Pavement Management System use, setup, and calibration
- Increase buy-in to the PMS and improve Agency confidence in results

10. ***Consider developing a more formal analysis process for Urban System roads so that there is a better understanding of the costs of managing these routes in the context of the overall network***

Benefits:

- Leverage existing ODOT investments in the urban system
- Provide planning and projection data for TAMP

G. Pavement Project and Treatment Selection

1. Guidance to Districts on Managing Pavements

ODOT Baseline

As described, ODOT's pavement management program is decentralized. This is a common organizational structure among state DOTs around the nation.

In effect, ODOT districts select the final projects while the TP develops the budgets. Kercher discussed the ODOT project selection process with TP and district staff during the interviews, each of which had very similar descriptions of the process. These conversations are summarized below:[39]

- The TP performs the PMS budget optimization analyses and distributes the optimized work plan list of activities to the districts and identifies the budgets for each.
- Districts create projects using those fund amounts while also seeking to match 75% of PMS optimization analysis output recommendations for project location and treatment type; however, districts can move a project up or down in time within the analysis time period of six (6) years.[40]
    - ODOT districts strive to complete projects within one (1) year range of the optimized treatment year.

[39] ODOT Staff Interview Notes, March 2020.

[40] Appendix B of the ODOT Transportation Asset Management Plan (TAMP) contains a detailed description of the district workplan process.

- For chipseal/microsurfacing treatments, districts strive to complete this work in the target or earlier.
- The importance of this scheduling is to ensure the recommended treatment type is still warranted and the pavement conditions have not degraded beyond a state that the selected treatment type can appropriately address.

- Districts select the remaining 25% of projects based on various other needs identified outside the PMS optimization. District staff identified the following as common reasons for selecting the projects:[41]
  - The optimization sectioning may result in very small segments or disconnected segments. Districts will use the 25% of project selection flexibility to fill in the gaps to create efficient project limits.
  - Districts typically choose segments in close proximity to the segments selected by the optimization to leverage mobilization costs.
  - County managers may request certain projects to address local priorities/issues.
  - A road has a low PCR, is in poor condition or deficient, but the PMS software does not select it. Based on the feedback provided, such scenarios likely are the result of optimizing project selections under limited funding scenarios that lack constraints that force the funding of deficient segments.
  - Although districts tend to agree with the PMS project recommendations, occasionally the treatment recommendation was considered as inappropriate for the location selected.
  - To address "gap" projects, which typically involve using short-term treatments, aimed at allowing a failing roadway to be used until funding can be allocated for a larger project.

Of note, districts interviewed indicated that the TP provided clear guidance on the project selection process. Respondents state that expectations are well defined, and training was sufficient. Project recommendations are managed in a collaborative manner between the TP and districts. District respondents also indicated that appropriate leeway was provided to make appropriate project selection decisions.

Peer States / Best Practice Findings

Kentucky
KYTC has a centralized decision-making process but districts have opportunities to provide input for limited modification to the project recommendations. This typically occurs in March of each year when there is a request to the districts for project input and needs.

Maryland
MDOT SHA has a decentralized project selection process where districts select projects but the Pavement and Geotechnical Division (PAGD) provides PMS analysis output for consideration.

[41] ODOT Staff Interview Notes, March 2020.

New York State
NYSDOT utilizes a decentralized project selection approach. Regions are allowed to choose the projects and treatment options. Allotments come from the PMS analysis results and the districts are allowed to check their selections against the results. Prioritizations are left up to the central office.

Pennsylvania
PennDOT has a decentralized project selection process in terms of program development. The exception is for projects on the Interstate system, which are handled by the central office.

West Virginia
WVDOH uses a hybrid approach, where projects are recommended to and reviewed by the districts from the PMS analysis results. The districts also recommend projects based upon field knowledge. Federal aid projects are ranked with the use of collected condition data and field knowledge and selected by the central office based on budget constraints.

Wisconsin
WisDOT has a decentralized approach at the project selection level. The state has five (5) regions with multiple offices. Project selection is done at the regional level, although there is a structure in place in which the PMS analysis process provides a foundation for project selection.

Analysis

Like Ohio, most peer states have a decentralized project selection process, with the following nuances:

- Kentucky's process is generally centralized with some input from the districts.
- Pennsylvania's Interstate project selection process is centralized.
- West Virginia considers its process to be both centralized and decentralized, depending on the situation.

Additionally, each peer state identified a similar collaborative project development process between central office and the districts that includes providing initial network-level project plans to the districts. The districts then provide input to determine the project selections.

Overall, ODOT's requirement is that programmed pavement activities match 75 percent of the optimization in district work plans. This practice of setting and enforcing project selection standards is considered a best practice. This is because any time an agency requires the final work plan to be within a reasonable tolerance of the optimization output, there is a better chance that the performance goals being predicted will be achieved.

Kentucky's collaboration efforts between central and district offices in understanding the project selection process and treatments is a best practice in ensuring agency policies are understood while also providing an opportunity to share information and feedback. These practices are supported by providing two (2) training meetings per year with the districts.

Finally, Wisconsin's use of PMS as the starting point for project recommendations and field validations in the project selection process is identified as a best practice.

Comments

ODOT's requirement that districts select at least 75% of the project recommendations from the optimization analysis is a highly progressive policy. This stands in contrast to many decentralized state DOTs that have few project selection control policies in place, often resulting in a gap between agency performance targets and district project selections.

However, many ODOT districts seem to be having no significant issue achieving the 75% target, suggesting that higher match targets are achievable. This likely would be especially true if some of the recommended PMS configuration changes identified in other sections of this report are implemented.

Performing projects recommended by the optimization analysis is critically important over time. This is because every planned project that is selected outside of the recommendations pushes the actual performance metrics away from the predicted values. The impact is to increase the funding required to achieve the goals in the future. Additionally, since ODOT is relying on the pavement management system for 75 percent of its pavement-treatment recommendations, it is imperative that ODOT ensure that the model is "fed" with accurate pavement-condition data. ODOT's pavement data quality management seems to consist of relatively superficial analysis of the quality of the pavement data collected manually by pavement raters.

ODOT may need to revisit the time range that a project can be moved. Six years is a long time and a project selected in year 1 may no longer be viable in year 6. Limiting the timeframe for moving projects around may provide better performance results.

A common issue in PMS optimization analyses with few constraints is that the results tend to be the least costly to achieve the goal. The result can be that some deficient condition roadways are never chosen.

Recommendations and Benefits

11. ***Consider conducting a study to determine the maximum percent match of project selection to PMS project recommendations that can reasonably be achieved***

    Benefit:

    - Ensures the closest possible budget and performance goal target setting possible to the most optimal analysis results

12. ***Consider allowing districts to meet the percent match goal by substituting treatments among a category of treatments, rather than a specific treatment***

    Benefit:

    - Supports the practical efforts of what districts are doing already while supporting compliance with PMS project recommendations

13. ***Consider limiting the timeframe from the optimization analysis results for the percent matching from 6 years to no more than 4 years***

    Benefit:

    - Will provide better performance results and likely save the agency money in better aligning treatments with condition needs

14. ***Consider adding constraints to the optimization analysis to force funds to a more balanced "mix of fixes" approach of projects***

    Benefit:

    - By treating fair and poor roads in addition to good roads should help ODOT control the backlog of unmet project needs and costs

2. Alignment and Application of the TAMP and Pavement Management Strategies

ODOT Baseline

The pavement section of the Ohio TAMP focuses mainly on the procedures that ODOT uses to manage the pavement network using the State's own distresses and metrics. This is in contrast to focusing on the federal metrics directly. The ODOT approach is considered good practice since managing specifically to just the federal metrics, and only on the NHS, can result in strategies that are less than optimal for the network as a whole. Managing only to federal metrics can sometimes result in following so called 'worst first' strategies if the agency puts too much emphasis on the federal "Poor" metrics.

Specifically, the ODOT TAMP uses the PCR to identify performance of the pavement network, which is the same as in ODOT's internal business processes. An example of this is on Page 67 of the TAMP which depicts the average weighted PCR over a ten-year period overlaying percentage of lane mile condition categories.[42] These condition categories are not the same as the federal metrics of Good/Fair/Poor, which are defined by 23 CFR 490 values of percentage of cracking, rutting, IRI, and faulting. This is understandable since, as noted above, it is considered good practice to manage the pavement network according to the State's own metrics while reporting the resulting federal metrics as output.

ODOT identifies the current values and targets for the federal metrics that are in 23 CFR 490.[43] However, the TAMP document does not include any projection of these metrics. Based on ODOT staff interviews and email correspondence, ODOT indicates the FHWA-required 2- and 4-year targets were derived from ODOT subject matter experts and engineering judgment.[44] The targets were not explicitly analyzed as part of the PMS optimization analysis.

Extending the PCR management process is the ODOT concept of Critical Success Factors (CSF). ODOT monitors the Priority and General Systems' CSF values separately. The ODOT TAMP depicts the average weighted PCR of each compared to the CSF Goals: 85 for Priority System and 80 for General System.[45]

According to TP interviews, the goals of 85 and 80 were determined by monitoring statewide conditions and adjusting based on assessments. In addition to PCR, the percentage of deficient lane miles is also monitored by ODOT and targets are set to ensure the optimization does not allow the deficient lane miles to exceed the established targets.[46]

The CSF goals are part of the PMS performance management process and districts are held to these goals through the selection of 75% of the optimized work plan. There are no consequences for districts for not achieving the CSF goals. Additionally, the CSF goals are not managed at the district level; they are managed at the statewide level and can be reported for each district. According to ODOT, districts will be required to redo their annual workplan if they pursue their own agenda and not work toward the state's objective. Reportedly, this has only happened once since the PMS has been established and implemented.

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[42] ODOT TAMP, Page 67.

[43] Ibid, Page 9.

[44] Ibid, Page 12.

[45] Ibid, Page 66.

[46] ODOT Staff Interview Notes, March 2020.

ODOT has not historically tracked the pavement program by NHS designation. NHS is not part of ODOT's business process for managing the pavement network and is not included in the PMS. Since the FHWA requirements are for tracking performance of the NHS, ODOT has to perform data transformations outside the PMS to summarize the data by NHS.

Each district has a TAM Coordinator who is charged with ensuring the TAMP requirements are followed at the district level. According to the TP interviews, the federal metrics are managed at the statewide level but not at the district level.[47]

As shown in Figure 20, ODOT provides a breakdown of the 10-Year NHS Investment Strategy for Pavements that shows planned investments for the Treatment Categories as required by FHWA: Maintenance, Preservation, Rehabilitation, Reconstruction, and New Construction.[48]

Figure 20: ODOT's 10-Year NHS Investment Strategy (in millions) from the ODOT TAMP

Pavements			
	2019	2020–2028 Annual Avg.	10-Year Total
Maintenance	$10.5	$15.5	$150.0
Preservation	$94.9	$70.7	$732.8
Rehabilitation	$515.8	$337.9	$3,558.2
Reconstruction	$88.0	$120.3	$1,168.7
New Construction	$21.1	$15.5	$161.2
Other	$13.0	$24.8	$238.7
Totals	**$743**	**$585**	**$6,010**

According to ODOT staff interviewed and email correspondence, the funding in the planned investment strategy shown in Figure 20 is projected as a 2% increase based on the projects awarded/committed for 2019 and is not based on PMS optimization.[49] The specific process used was initially sourced from the ELLIS database for FY2019 and FY2020, then data was merged to include NHS designation and FHWA Treatment Categories. A multiplier of 62% of funds was applied to account for expenditures assumed on the NHS system, and a 2% factor was used as a growth factor that ODOT management was comfortable assuming as a fund increase above FY2020 levels for FY2021 onward.

The consulting team notes that while ODOT is using its pavement management system to generate workplans for the next year as part of the workplan process, the pavement management system is not being used to project the planned spend by work type over the long term for the 10 year period reported

[47] ODOT Staff Interview Notes, March 2020.

[48] ODOT TAMP, Page 64.

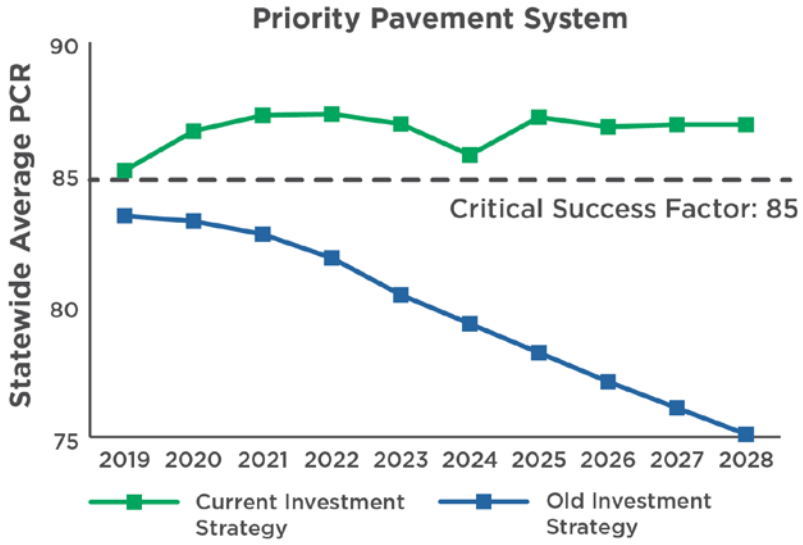
[49] Based on spreadsheet "TAMP Financials Final_20190627.xlsx" received from ODOT.

in the TAMP (see Figure 20). As a result, ODOT may find that as conditions change over time, in future as part of the workplan process, the pavement management system will suggest different proportions of investment for the different work types compared to the fixed proportions in the TAMP that were determined by the 2% projection factor.

The intent of the CFR 515.9(h) and CFR 515.17(d) is that in the future State DOTs should use their management systems to identify short and long term budget needs and that these projections should lead to the STIP and support its efforts to achieve their state of good repair goals. [50] It is recommended that ODOT, since it is already using the pavement management system to support the short term budget needs, also uses the system to project the planned investment by work type in the longer term over the 10 year period of the TAMP rather than using a fixed 2% increase based on the year(s) preceding the TAMP (2018/19). The consulting team further notes that this may require further vetting of deterioration modeling. However, since the pavement management system already appears to be being used to good effect in the short term planning, the logical next step will be to also use it for the longer term 10 years planned investment strategies shown in Figure 20 for the next update to the TAMP.

With regard to the projection of conditions in the TAMP, based on projections from the PMS, ODOT expects to achieve an average weighted statewide PCR of 86 on the Priority System and 85 on the General System by 2028 using the current asset management process. This is shown in Figure 21 and Figure 22. The fact that these projections are based on analyses from the pavement management system is commendable.

Figure 21: Projected Statewide Average Weighted PCR for Priority System from the ODOT TAMP[51]



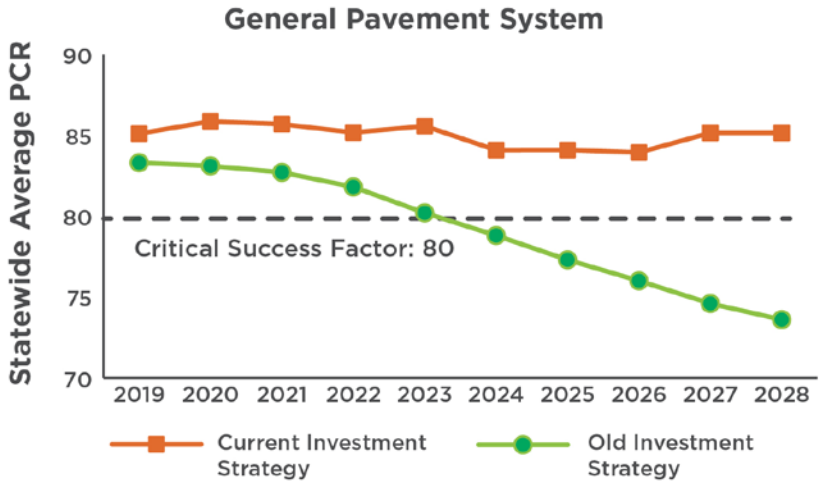
Because ODOT is using the described PMS software, the Agency is using lifecycle cost analysis and projecting pavement network conditions using deterioration modeling for different investment strategies in compliance with CFR 515.17. However, as noted previously, it is recommended that the spending

[50] Also see Answer to Question 32 in TAMP Guidance Questions & Answers (Q&As) https://www.fhwa.dot.gov/asset/guidance/faqs.cfm

[51] Ohio Department of Transportation, Transportation Asset Management Plan (TAMP), June 2019, Section 7.0 Performance Gap Analysis, Page 68.

projections that are associated with the condition projections from the pavement management system be used as the investment plan shown in Figure 20. This will help ensure that condition and spending projections are synchronized.

Figure 22: Projected Statewide Average Weighted PCR for General System from the ODOT TAMP[52]



Peer States / Best Practice Findings

Kentucky
The KYTC TAMP is based on the automated distress collection data and does include a condition report. KYTC's project selection process is more detailed than the process to report TAMP data. However, KYTC does apply the same analysis process for the network that was applied to the TAMP analysis results.

Maryland
MDOT SHA utilizes crosswalks to correlate pavement specific treatments with the TAMP treatment categories. However, the definitions of these treatments are not uniform across the districts.

MDOT SHA does not perform a separate analysis just for the TAMP. The Agency runs its standard analysis for the network and reports the federal metrics as an output. This is considered best practice. Compared to what was reported in the TAMP, in the first year MDOT SHA reported fewer NHS and interstate projects than anticipated.

New York State
NYSDOT performed its standard network analysis and reported federal metrics as output for the TAMP. This is considered best practice. In general, NYSDOT has varying project recommendations by region since the NYC area has unique Maintenance of Traffic (MOT) costs and avoids closing lanes around the City. Of note, NYSDOT allows 2-course mill and overlay at night, which is counted as preservation; many DOTs consider this type of work as rehabilitation.

[52] Ohio Department of Transportation, Transportation Asset Management Plan (TAMP), June 2019, Section 7.0 Performance Gap Analysis, Page 68.

Pennsylvania
The PennDOT TAMP defines how the project selection and performance reporting process will be done in the future. However, the project selection process description in that document effectively is the same as the typical PennDOT processes.

West Virginia
In West Virginia, treatment strategy is the same state-wide but implementation varies by district. Contractor availability and capacity/capability is indicated as driving the various preservation treatment choices.

Wisconsin
The WisDOT TAMP outlines the approach and messaging for preservation strategies when treatments are being recommended in optimized model.

Analysis

With some variation, peer states described running their respective pavement management system analyses using the same processes they would use for their typical state budget analysis and reporting the federal metrics as output for their TAMP. Similarly, each state indicated it is not managing to federal metrics, only reporting them as outputs. The result is that treatment strategies generally can be varied across districts/regions due to the nuances of the regions in each state. For example, in New York, the New York City area has an entirely different set of needs from the Adirondack area of the state, as would be expected.

Further, each peer state indicates that planned work is incorporated into the TAMP analysis process. Interestingly, some states reported not having or using the NHS designation in their PMS. Conversely, PennDOT noted that they have used it for many years while NYSDOT uses NHS as an importance factor component for corridors.

In terms of best practices, Maryland, West Virginia and Wisconsin each use their pavement management systems to project conditions, given specific budget constraints and set targets based on these outcomes. This process is the most objective and data driven approach to setting and managing these targets.

Regarding district outreach, Wisconsin and West Virginia are both considered best practice states because of (1) creating liaisons within the Districts, or (2) developing specific Standard Operating Procedures (SOPs) for managing the program. ODOT, too, could be considered a best practice state in this regard because it has asset management coordinators within the Districts.

Finally, in contrast to ODOT, each Peer state noted that they were using the same budget constraint analysis from their PMS to analyze the 10-year projections for the TAMP. This would be considered best practice.

Recommendations and Benefits

15. ***Consider adding the NHS designation to inventory data in the dTIMS PMS so that reporting on the NHS performance metrics can be easily facilitated for future Consistency and Performance Period reporting to FHWA***

    Benefit:

    - Make tracking and managing the Consistency Determinations and Performance Period reporting required by FHWA easier.

16. ***Use the dTIMS PMS optimization as the process for modeling and predicting the 2- and 4- year federal targets***

    Benefit:

    - Provide consistency/linkage between annual planning efforts and the TAMP.
    - Together with recommendation in 15. above, make Performance Period target setting required by FHWA easier.

3. Management of Pavements Across Districts

ODOT Baseline

The consulting team interviewed all 12 ODOT districts during the information gathering phase of this project. Four (4) group interviews were used to conduct these sessions between March 17-31, 2020, with each group asked the same questions.

The purpose of the interviews was to understand the project selection process districts used and determine if districts clearly understood their directives. In addition, the interview questions were intended to identify if districts had any concerns or major barriers to executing TP directives or if districts had unique issues that made carrying out those directives more difficult.

The overarching findings from the interviews were that the districts performed their duties very similarly, which was perceived as confirmation that districts clearly understood the ODOT business processes and TP directives. However, when asked if meeting the 75% project match goal was difficult, districts had varying responses.[53] Some districts had no issues meeting the 75% goal while others indicated a struggle to achieve this target. Still others noted that it was easier to meet the goal in the first few years but this has gotten harder over time.

These responses could be an indication that conditions are deteriorating, that districts may not be able to match actual project costs to the estimated costs from the PMS, or other localized considerations that affected funding or project selection such as the following:

- Scarcity of contractors to perform certain types of work
- Heavier treatments not being selected by the PMS
- Unable to fund heavier treatments recommended by testing and design recommendations
- Rumble strips, Striping, and Raised Pavement Markers eating into unit costs
- Landslides
- Fracking boom equipment damaging roads
- Horse and buggy traffic damaging roads

One district noted it accesses the PMS to get information for the project selection process. However, most districts do not access the software and rely on the TP to deliver the information in other formats.

ODOT does maintain a robust suite of tools for pavement managers to use in accomplishing the project selection process. These include mapping tools, historical data repositories, and design processes, all of which indicate that ODOT is using a data-driven approach to managing the pavements from network level to project level.

[53] ODOT Staff Interview Notes, March 2020

Peer States / Best Practice Findings

Kentucky
All districts try to follow an optimized pavement strategy with preventive maintenance included in the project selection process. However, there can be issues that are either contractor related, or bidding based, or in some cases personnel knowledge and training may limit the treatments that can be selected in certain districts.

Maryland
Districts use appropriate treatments for their various needs. Some districts might not have the contractors to provide the needed services. For rehabilitation work, there is no issue aligning treatments to needs; however, there are reported cases where preventive maintenance is not used when it could have been appropriate.

New York State
The majority of NYSDOT districts report using appropriate treatments for the pavement conditions encountered. When a recommended treatment is not being utilized, the cause typically is indicated as being due to issues with the project deliverables by the contractor.

Pennsylvania
PennDOT indicates having issues with the time required to program in preservation work crowding out the time needed to plan long-term work. Some districts reportedly are better at planning ahead than others and at making decisions based on available funds and funding streams.

West Virginia
All districts report utilizing the most appropriate treatments to address the unique set of distresses present to achieve the lowest practical life cycle cost on the federal routes. However, this process is perceived as being less consistently followed on the state and county routes.

Wisconsin
WisDOT noted that utilities can cause issues with utilizing certain treatments. WisDOT has had issues with the regions in selecting appropriate treatments in the past but reports achieving major compliance improvements in recent years. WisDOT now has a continuous process improvement framework in place to help avoid future issues.

Analysis

Each state identified that all districts are using the most appropriate treatments; however, some indicated that outside limitations could require alternative treatments. Examples provided included the need to coordinate and schedule around utility projects, treatment life cycles (which can vary by treatment type), contractor availability, etc. These examples were like those identified by ODOT districts and confirm that these are industry-wide issues.

Comments

As previously stated and recommended, ODOT should consider more focused Decision Trees to address district uniqueness. This can be facilitated through an expert panel of ODOT pavement managers to determine those specific issues.

In addition, ODOT should continue to encourage District users to become hands on with the dTIMS PMS software. This will significantly improve District understanding of the output and analysis process.

Recommendations and Benefits

No recommendations

H. Matching Financial Sources to Needs

ODOT Baseline

Funding Approach Overview

ODOT is responsible for allocating funds among highway projects in a way that maximizes its resources. Over a 10-year period between FY2019 and FY2028, ODOT expects to invest nearly $9.7 billion to preserve, improve and replace pavement statewide.[54]

As outlined in the ODOT TAMP, beginning in 2015, the Department's approach to project selection and the associated funding decisions shifted. ODOT adopted a long-term view of the costs required to keep its pavements in service. The focus of this approach is on the increased use of preservation treatments – a move ODOT indicates will reduce the rate of asset deterioration and make more cost-effective use of available funding. The TAMP states:

> "By investing regularly in certain low-cost preservation treatments, the value of these assets is preserved and the cost of maintaining system conditions is reduced, because costly repairs and replacements are needed less frequently. Preserving the condition of the highway system so fewer assets must be replaced is an important objective for the investments included in the TAMP."[55]

Figure 23 illustrates this approach to pavement investments in practice:

Figure 23: Pavement Preservation Strategies

Source: ODOT TAMP

[54] ODOT, "Federally-Compliant Transportation Asset Management Plan," (June 2019)

[55] ODOT, "Federally-Compliant Transportation Asset Management Plan," (June 2019)

In 2017, ODOT established a Funding Council to assist in allocating available funding to ODOT's operating and capital programs, including its pavements programs. According to the Funding Council Charter, membership is comprised of the following:

1. Funding Council "Executive Champions"
    a. Chief of Staff/Assistant Director
    b. Assistant Director, Operations
    c. Assistant Director, Chief Engineer
2. Funding Council Co-Chairs
    a. Two (2) District Deputy Directors
3. Funding Council Voting Members (in addition to Co-Chairs)
    a. Seven (7) District Deputy Directors
4. Funding Council Non-Voting Members
    a. Deputy Director, Division of Planning
    b. Deputy Director, Division of Finance
    c. Executive Financial Advisor
    d. Administrator, Office of Budget, and Forecasting (administrative support)

The mission of the Council is to guide the overall use of ODOT's financial resources by recommending funding allocations for operating and capital programs to the ODOT Governance Board (comprised of the Director, Chief of Staff and Assistant Directors).[56]

The Funding Council's goal is to develop a balanced budget using the agency's Funding Proforma to recommend a fiscally responsible budget approach to make funding allocations. The Funding Council ensures that the optimum level of funding is provided to each program to achieve ODOT's mission, vision, values, goals, and Critical Success Factors. The Council bases its recommendations on a data-driven decision process that focuses on creating steady-state conditions for the Department's assets.[57]

The process of matching ODOT's financial and funding sources to projects begins with the development of its pro forma budget, which includes revenue projections of its various state and federal funding sources (described in detail below). These anticipated funding levels and uses are vetted through ODOT's Funding Council and approved by ODOT's Governance Board. In instances where a delta exists (in other words, when projected funding is less than the investment required for those projects), the use of bonds is considered in order to balance the budget.

To determine whether bonds should, in fact, be issued, ODOT's cash forecasting model analyzes its bond appropriations and determines when associated cash is likely to be used. As a supplement to this model, ODOT's internally developed cash forecasting pipeline analyzes historical data to estimate when funds for various projects are likely to be spent in the future. Based on the results of these analyses, and in consideration of other factors (such as debt service payments and constitutional limits on state bond

[56] ODOT, "Federally-Compliant Transportation Asset Management Plan," (June 2019)

[57] ODOT Funding Council Charter

issuances), ODOT determines when it should issue bonds and for what amount (typically in 18-month cycles).

According to ODOT's current bond policy, "leadership recommends capital program funding levels based on forecasts of revenue and capital program needs as well as from various sources within the Department. Program funding levels include projects that will be funded entirely from a single revenue source or from a combination of state and federal highway revenue and proceeds from the issuance of bonds. The use of a decision model is recommended to determine if it is less costly to currently undertake projects funded by bonds or to defer projects until a later date when the project may cost more due to inflation. By adjusting to present values, the model compares the interest cost on bonds needed to finance the project with the projected inflation cost that results from delaying the project."[58]

The decision model recommended in ODOT's current bond policy is a different tool. It compares whether individual projects should be financed with bonds – and at what point – using a present value calculation that compares the cost of undertaking a project in the near term to the cost of borrowing. Because interest rates are at historically low levels, this decision model has not been in use recently.

Pavement Funding/Financing Sources

ODOT uses a variety of funding and financing sources to make pavement system preservation, major rehabilitation, and reconstruction investments, including state revenue, federal revenue, and bonds. Each of these sources is described below:

- **State revenue** is generated by several sources, with the largest percentage coming from the state motor fuel tax (MFT). The MFT revenue is shared between ODOT, local governments and other state agencies, with each type of entity using it for road and bridge maintenance and construction as prescribed in the Ohio constitution.

  H.B. 62 increased the motor fuel tax rate effective July 1, 2019 – a change expected to generate an additional $865 million per fiscal year during the FY2020-FY2021 biennium, with $476 million allocated to the Highway Operating Fund and $389 million allocated to local governments.[59] According to ODOT Division of Finance leadership, as of March 2020, actual MFT collections are below estimate by approximately $22 million. This is primarily due to decreased levels of fuel consumption statewide (-2.4 percent) attributable to increased vehicle fuel efficiency.[60] The COVID-19 pandemic has further exacerbated this trend, as fewer people are traveling and commuting. In March 2020, ODOT Finance leadership indicated that they have been closely monitoring MFT activity and that, if necessary, the Funding Council would determine what, if any, project funding changes would be made in light of the lower-than-estimated revenues.

  Other sources of State revenue include the fuel use tax, interest income from investments and other miscellaneous sources. As shown in the following figure, total state funding dedicated for pavement projects increased between FY2013 and FY2015 but has decreased each year since, totaling approximately $71 million in FY2020. Over the eight (8) year period, state funding

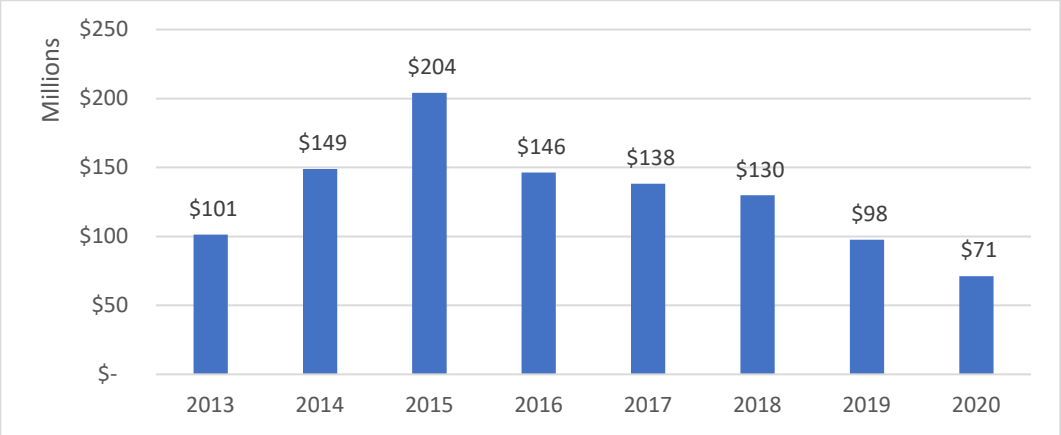
[58] ODOT, "State Highway Capital Improvement Bond and Grant Anticipation Revenue Vehicles Bond Policy (effective April 17, 2015).

[59] Ohio Legislative Services Commission, "Greenbook: LBO Analysis of Enacted Transportation Budget," (September 2019).

[60] Interview with ODOT Division of Finance leadership team (March 17, 2020).

dedicated for pavement projects decreased by a -4.9 percent compound annual growth rate (CAGR).

Figure 24: State Revenue Dedicated to Pavement Projects, FY2013-FY2020

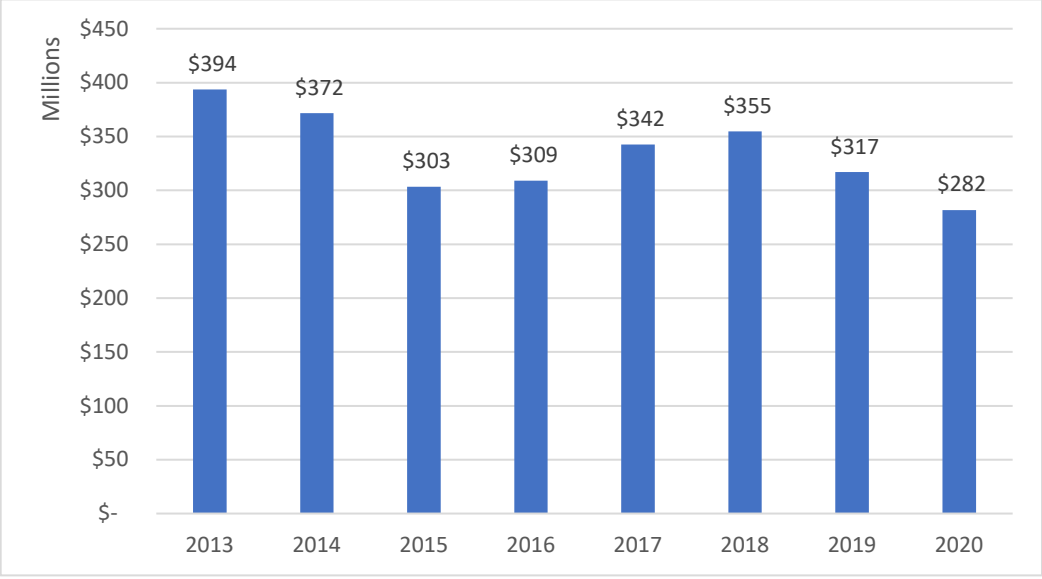


Source: ODOT pavement and bridge project funding data

- **Federal funding** is provided through the Highway Trust Fund, which is financed primarily by the federal fuel tax. Congress is responsible for authorizing federal funding, which is apportioned to projects in accordance with certain requirements. Although federal funding fluctuates annually, the aggregate average level of funding over the last five (5) years has been relatively constant. As of September 2020, current projections anticipate that federal funding will be flat over the next several years.

  As shown in the following figure, federal funding for pavement projects – totaling $282 million in FY2020 – has fluctuated in recent years but has generally trended downward overall, with $282 million in investments in FY2020. Over the eight (8) year period, funding from this source for pavement projects decreased by a CAGR of -4.7 percent.

Figure 25: Federal Revenue Dedicated to Pavement Projects, FY2013-FY2020



Source: ODOT pavement and bridge project funding data

- Two types of **highway bonds** are used by ODOT to finance bridge projects: State Highway Capital Improvement (HCAP) bonds and Grant Anticipation Revenue Vehicle (GARVEE) bonds, both of which are issued by the Treasurer of State's Office. HCAP bonds are used to pay the costs of construction, reconstruction, or improvements of highways throughout the State and are repaid using state resources (primarily state MFT revenue). GARVEE bonds are issued to finance highway construction projects that are eligible for federal funding and are repaid with federal dollars (transportation funds allocated to the State, subject to biennial appropriation).[61] The most recent ODOT bond issuances include the following:[62]

    - In June 2020, the Treasurer's Office issued $68 million in HCAP bonds (General Obligation Highway Capital Improvement Bonds, Series W) on behalf of ODOT. These bonds funded a total of 27 capital road and bridge projects spanning 19 Ohio counties. Such projects include resurfacing and rehabilitation of portions of I-77 in Stark County; rebuilding, resurfacing and widening of structures in the I-70/I-71 "split" in Franklin County; and a major bridge and multi-lane reconstruction and widening of I-75 in Wood and Lucas Counties. In December 2019, the Treasurer's Office issued $180 million in GARVEE bonds (Major New State Infrastructure Bonds, Series 2019-1) on behalf of ODOT. These bonds funded a total of 18 capital road and bridge projects statewide, including the reconstruction and widening of I-75 in Hancock County; replacement of decks on the twin I-480 bridges over the Cuyahoga River Valley; and reconstruction and widening of portions of I-70 in Franklin County. In addition, the current Transportation Budget authorizes the issuance of $57 million in state highway bonds to be deposited into the Highway Capital Improvement Fund to supplement Highway Operating Fund revenues for road and bridge construction.[63]

During the FY2020-FY2021 Biennium, ODOT's bond funding appropriation is just over $264 million; its associated debt service appropriation is just over $684 million.

Table 8: Bond Funding Sources and Debt Service, FY2020-FY2021 Biennium (in millions)

	Total Biennial Appropriation	Debt Service Appropriation
Federal GARVEE Bonds	$133.8	$366.6
State Highway Bonds	$130.0	$317.5
Total Bond Funding	**$263.8**	**$684.1**

Source: ODOT Transportation Budget, FY2020-FY2021

According to ODOT Division of Finance leadership, the vast majority of bond dollars are allocated to long-term pavement (and bridge) projects that tend to be larger and more capital-intensive. However, ODOT has used bond funding in recent years to meet basic preservation needs. As a

[61] The State has also covenanted to use for the payment of debt service, if necessary, other State transportation moneys that have been appropriated to ODOT.

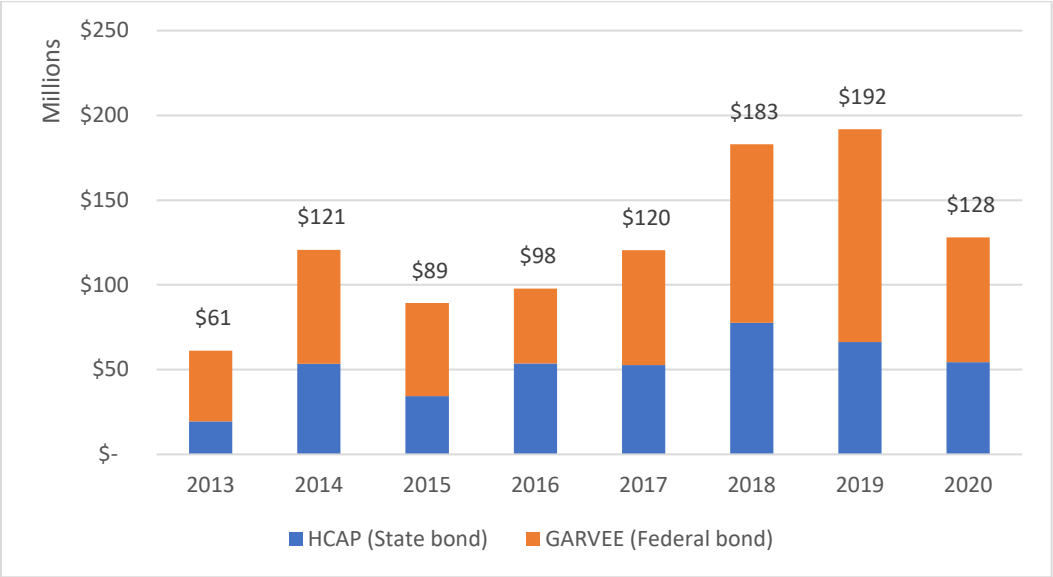
[62] Ohio Transportation Bond Programs, "Recent Transactions"

[63] Ohio Legislative Services Commission, "Greenbook: LBO Analysis of Enacted Transportation Budget," (September 2019).

result of the MFT increase in 2019, ODOT currently, is pushing to transition to a model in which bonding is used primarily for major bridge, multi-lane major rehab, and major new projects.[64] Additionally, the FY2020-FY2021 ODOT Transportation Budget indicates that, as a result of the increase in the MFT, bond revenue will not be relied on at the level it has been in prior years.

As shown in Figure 27, bond financing for pavement projects has fluctuated but generally trended upward between FY2013 and FY2019. Over the course of the eight (8) year period between FY2013 and FY2020, this funding source grew by a CAGR of 11.1 percent.

Figure 26: Bond Financing Dedicated to Pavement Projects, FY2013-FY2020

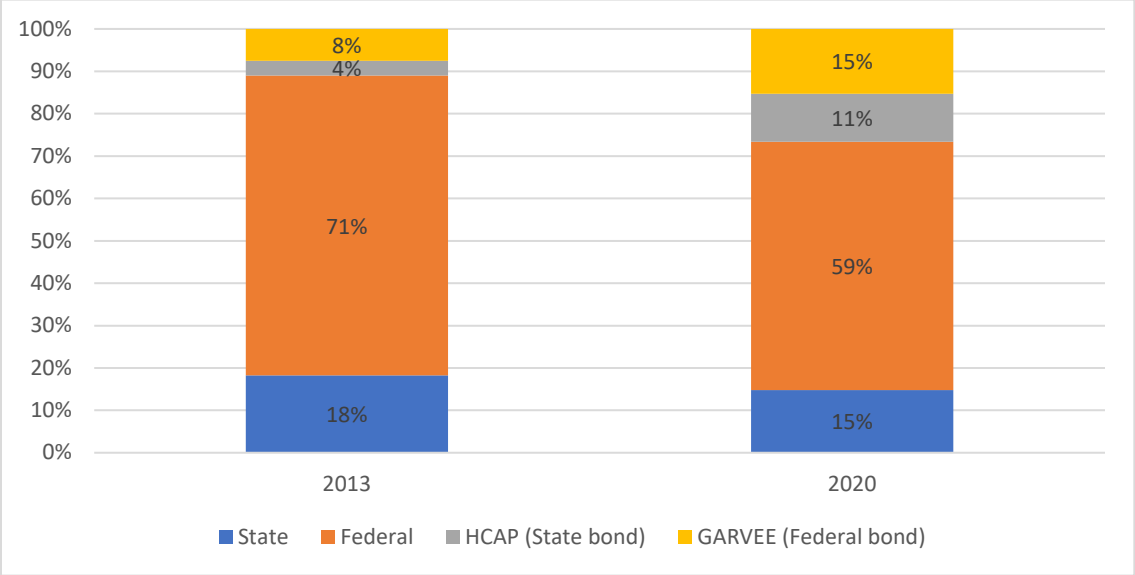


Source: ODOT pavement and bridge project funding data

It is notable that the overall composition of ODOT's pavement project funding sources has changed over time. For example, in FY2013 federal funds attributed approximately 71 percent of the total, state funds were 18 percent and bonds provided 12 percent (8 percent GARVEE and 4 percent HCAP). By FY2020, federal funds accounted for just 59 percent of the total, and there was a slightly reduced reliance on state funds to 15 percent. The overall effect is that the use of bonds to fund pavement projects (referenced above) has increased meaningfully as a share of the total, with HCAP and GARVEE bonds now comprising 26 percent of the total.

[64] Interview with ODOT Division of Finance leadership team (March 17, 2020).

Figure 27: Bond Financing Dedicated to Pavement Projects, FY2013-FY2020



Source: ODOT pavement and bridge project funding data

Analysis

Table 9 identifies and each benchmark state's reliance on various revenue sources to fund projects on state-administered highways in 2018 (the most recent year for which FHWA data is available). At 23 percent of total revenues, Ohio's reliance on highway user revenues is the lowest among peer states, which average 39 percent (when excluding Ohio). While its reliance on bond issuances for capital outlay (27 percent) is the highest among its peers, when combined with bond issuances for debt service, ODOT's reliance on bonds is comparable to Pennsylvania (33 percent) and Wisconsin (30 percent) and lower than West Virginia (43 percent).

Table 9: Sources of Revenues Used by States for State-Administered Highways as a Share of Total Receipts, 2018

	OH	KY	MD	NY	PA	WI	WV
Balance, Beginning of Year, millions (a)	$1,660	$680	$1,443	$1,561	$4,472	$1,076	$114
Highway User Revenues:							
Motor Fuel Taxes	13%	22%	7%	6%	20%	17%	17%
Motor Vehicle and Motor Carrier Taxes	4%	22%	8%	6%	6%	12%	16%
Road and Crossing Tolls (b)	6%	0%	35%	24%	10%	0%	4%
Total	**23%**	**45%**	**50%**	**36%**	**37%**	**29%**	**38%**
Gen. Fund Approps. (c)	10%	1%	10%	12%	9%	4%	1%
Other State Imposts (d)	0%	0%	5%	2%	0%	3%	0%
Miscellaneous	5%	12%	1%	18%	4%	2%	2%
Issue of Bonds:							
For Capital Outlay	27%	8%	10%	18%	9%	6%	43%
For Debt Service (e)	3%	0%	9%	0%	24%	24%	0%
Payments from Other Governments:							
FHWA	30%	34%	15%	14%	17%	25%	16%

	OH	KY	MD	NY	PA	WI	WV
Other Agencies	0%	0%	0%	0%	0%	2%	0%
From Local Governments	2%	0%	0%	0%	0%	4%	0%
Total Receipts	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Amounts shown reflect activities of State highway departments, State park boards, other State agencies and quasi-State toll facilities, including direct work on local roads under State control, and State highway debt service transactions.
Source: FHWA Highway Statistics 2018, Table SF-3 (January 2020)
(a) For Reserves for Current Highway Work (in millions)
(b) ODOT does not collect revenue from tolls. However, this comparison is being used to illustrate a comparison among peer states as a proxy, based on the best available data from the FHWA
(c) Amounts shown represent gross general fund appropriations for highways reduced by the amount of highway-user revenues placed in the State General Fund
(d) Includes sales and use taxes, severance taxes and other State taxes
(e) Including refunding

Table 10 displays each benchmark state's distribution of resources for state-administered highways in 2018 (the most recent year for which FHWA data is available). Relative to most of its peers (with the exception of West Virginia), at 54 percent, Ohio directs a higher percentage of its overall disbursements to capital outlay for roads and bridges, followed closely by Kentucky at 53 percent.

Table 10: Share of Disbursements for State-Administered Highways by Category, 2018

	Cap. Outlay for Roads & Bridges	Maint. & Hwy Svcs.	Admin., Research & Planning	Hwy Law Enforcement & Safety	Interest	Bond Retirement	Total
OH	54%	14%	7%	12%	3%	10%	100%
KY	53%	20%	1%	5%	7%	14%	100%
MD	37%	13%	3%	9%	6%	32%	100%
NY	34%	26%	5%	6%	9%	20%	100%
PA	38%	17%	5%	8%	6%	27%	100%
WI	39%	11%	7%	3%	2%	39%	100%
WV	81%	10%	3%	2%	0%	3%	100%

Source: FHWA Highway Statistics 2018, Table SF-4 (April 2020)

Table 11 displays each benchmark state's change in indebtedness related to its state highway obligations in 2018 (the most recent year for which FHWA data is available). With a 5.2 percent increase in indebtedness, Ohio's experience is similar to Kentucky (also 5.2 percent), New York (6.2 percent) and Wisconsin (4.3 percent).

Table 11: Obligations for State Highways: Change in Indebtedness, 2018 (in thousands)

	Obligations Outstanding, Beginning of Year	Total Obligations Issued (Original & Refunding)	Obligations Retired (By Current Revenues or Sinking Funds)	Obligations Outstanding, End of Year	% Change in Indebtedness
OH	$2,072,115	$516,290	$408,125	$2,180,280	5.2%
KY	$1,604,662	$430,610	$347,887	$1,687,385	5.2%
MD	$2,951,206	$140,000	$145,089	$2,946,117	-0.2%

	Obligations Outstanding, Beginning of Year	Total Obligations Issued (Original & Refunding)	Obligations Retired (By Current Revenues or Sinking Funds)	Obligations Outstanding, End of Year	% Change in Indebtedness
NY	$5,457,158	$1,193,122	$852,406	$5,797,874	6.2%
PA	$5,821,428	$3,464,711	$1,687,048	$7,599,091	30.5%
WI	$2,618,326	$245,310	$132,476	$2,731,160	4.3%
WV	$658,059	$886	$65,091	$593,854	-9.8%

Source: FHWA Highway Statistics 2018, Table SB-2 (April 2020)

Funding Sources and Approaches

While all states levy some form of a gasoline tax, 22 have a variable-rate gas tax that adjusts, to some degree, with inflation or prices without regular legislative action. Among the benchmark states are the following practices:[65]

- **Ohio** and **Wisconsin** have non-variable levels of motor fuel taxes.
- **Kentucky**, **Pennsylvania**, **New York** and **West Virginia** have a gas tax which varies with fuel price.
- **Maryland's** fuel tax varies based on both fuel price and the Consumer Price Index.

While it is common for the motor fuel tax to be the largest source of state revenue for highway programs, in Illinois, the single-largest source is motor vehicle registrations, which support both road and bridge projects.

Some states have adopted creative approaches to preserving highway revenue. For example, **Pennsylvania**'s Motor License Fund (MLF) has had both a decreasing balance and an increase in usage by other state agencies. Fiscal code changes capped the amount of MLF funding diverted to other agencies to preserve a predictable revenue stream to invest into highway and bridge projects.

In response to declining fuel tax revenues associated with increasing vehicle fuel economy and electric car usage, the I-95 Corridor Coalition (a multi-state partnership of transportation agencies and other related organization) conducted a pilot study of a mileage-based tax system in **Pennsylvania** and **Delaware**, where a driver would pay a fee based on miles driven (commonly referred to as vehicle miles traveled or VMT) in lieu of a per-gallon fuel tax. Both **California** and **Oregon** have also conducted pilot programs that tax certain drivers' VMT instead of gasoline purchased. It should be noted that there are administrative challenges in measuring VMT.

Rhode Island has put into place truck-only tolls to help fund a state bridge repair program; **Connecticut** is currently considering a similar proposal.

In 2015, **Indiana** conducted a study to assess its transportation funding needs and potential funding sources.[66] The study indicated that Indiana's transportation funding would decrease over the next 20 years as a result of inflation and increased fuel efficiency. As a result of the study, in April 2017, the

[65] National Conference of State Legislatures, "Variable Rate Gas Taxes," (April 11, 2019).

[66] "Study of Indiana Transportation Infrastructure Funding Mechanisms" (October 2015).

Indiana General Assembly passed House Enrolled Act 1002, also known as "Next Level Indiana." The sources of funding for Next Level Indiana include the following:[67]

- Fuel tax increase on gasoline
- Increase of special fuel tax
- Increase of motor carrier surcharge tax
- Transportation improvement fee for all motor vehicle registrations
- Supplemental registration fee for electric vehicles
- Redirecting a larger portion of the sales tax collected on fuel from the state general fund to dedicated highway funds

1. Financing and Debt

In 2017, the Transportation Research Board published a synthesis of evolving debt finance practices for surface transportation. One area of analysis was how a state decides between whether to issue debt backed by federal funding or state funding for transportation purposes. Among the benchmark states, responses included the following:[68]

Ohio

The bonding decision process is largely driven by project type and funding eligibility. Since funding used on federal (GARVEE) bonds is more restrictive, it limits the use of these fund. ODOT also is restricted by coverage ratios used on debt covenants of past bond issuances; for instance, ODOT has an informal internal policy to limit GARVEE debt service to 20% of federal revenues.

Kentucky

GARVEEs are used for federal projects that have been identified in their biennial highway plan and approved by FHWA and the General Assembly. Road Fund bonds are issued for state funded projects that have been identified in the biennial highway plan and approved by the General Assembly.

Maryland

In the State of Maryland, the use of GARVEEs requires special legislative authorization.

New York

The State of New York does not leverage federal highway/transit apportionments.

Pennsylvania

The choice of bond usage is made through discussions with the Governor's Office of Budget. Primary considerations include how much debt service payments will be, for how long, and is it more beneficial than using current revenues for projects. Pennsylvania does not use GARVEE debt.

[67] INDOT, TAMP

[68] Transportation Research Board of the National Academies of Sciences, Engineering and Medicine, "Evolving Debt Finance Practices for Surface Transportation," (2017).

West Virginia
State of West Virginia bonding usage is determined on a case-by-case basis, based on available funds and need.

Wisconsin
The State of Wisconsin currently does not have the authority to issue debt backed by federal funding for transportation purposes.

Michigan
The decision to bond is made by MDOT's Director in cooperation with the Finance Bureau; additional oversight is provided by the Transportation Commission and legislature.

2. Alternative Financing and Other Innovative Approaches

The FHWA encourages the consideration of public-private partnerships in the development of transportation improvements, noting that "early involvement of the private sector can bring creativity, efficiency and capital to address complex transportation problems facing state (and local) governments"[69]. As of September 2019 (and with the exception of New York), most peer states have either broad or limited enabling statutes:[70]

- Broad enabling statute: **Ohio, Kentucky, Maryland, Pennsylvania, West Virginia**
- Limited enabling statute: **Wisconsin**

Like Ohio, **New York** has used a bundled finance approach to realize efficiencies – but only for state-owned bridges – as part of its New York Works Accelerated Bridge Program. The 112 deficient bridges addressed under the program used both the traditional design-bid-build and newly authorized design-build project delivery methods. In Phase 1A of the program, NYSDOT initially procured six (6) bundles totaling 64 bridges on a design-bid-build basis. In Phase 1B, it used its new design-build contractual authority to let an additional three bundles totaling 32 bridges, for which NYSDOT estimated a 27 percent cost savings over traditional design-bid-build project delivery:[71]

Considered to be a "value capture" strategy by the FHWA's Center for Innovative Finance Support, many states have established commissions or study groups to identify transportation funding gaps and suggest strategies for overcoming them, including nearly all peer states.[72]

- **Ohio**: 21st Century Transportation Priorities Task Force (2009)
- **Kentucky**: Enhancing Kentucky's Transportation Funding Capacity: A Review of Six Innovative Funding Options (2005)
- **Maryland**: Blue Ribbon Commission on Transportation Funding (2011)
- **Pennsylvania**: Transportation Funding Advisory Commission (2011)
- **West Virginia**: Blue Ribbon Commission on Highways (2012)

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[69] FHWA, Public Private Partnerships

[70] Bureau of Transportation Statistics, "Public Private Partnership Legislation by State," (September 2019)

[71] FHWA, "NYSDOT New York Works Accelerated Bridge Program."

[72] FHWA Center for Innovative Finance Support, "State Transportation Revenue Commission."

- **Wisconsin:** The WI Commission on Transportation Finance and Policy (2013)

Recommendations and Benefits

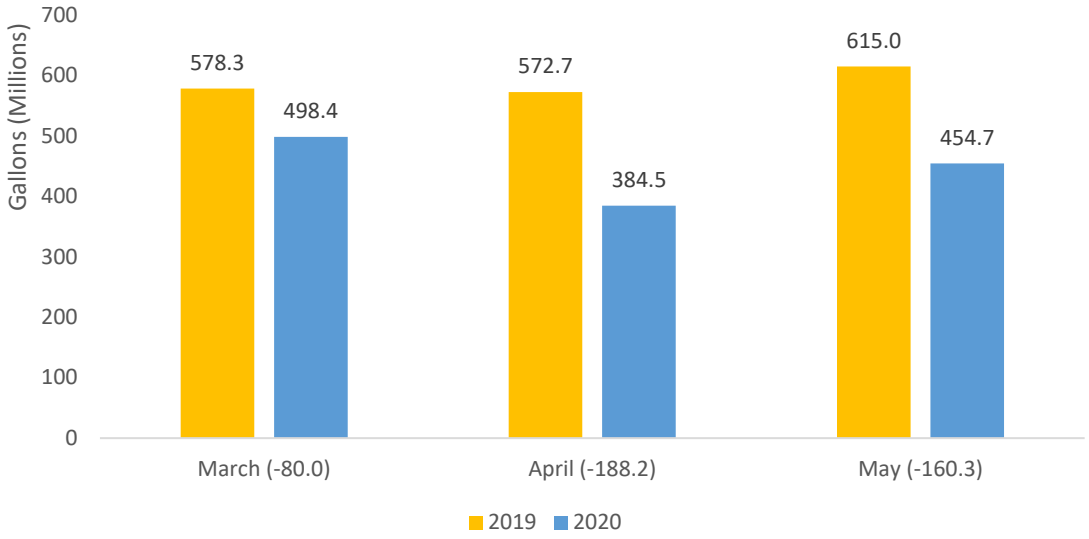
17. Reserve bonding for projects with a long useful life

Benefit:

- Financial best practice is to tie bond length to useful life, issuing bonds only when they can be paid off before the value of the project is depleted

According to ODOT representatives, bonds have been used in recent years to address basic preservation needs. While ODOT indicated it is their intention to move away from this practice in conjunction with the 2019 fuel tax increase, the current economic downturn has resulted in fewer drivers and, therefore, less fuel subject to taxation. For example, in the aggregate, net taxable gallons for the months of March, April and May 2020 were 428.5 million (24.3 percent) lower than during the same months in 2019. The year-over-year variances for these months is displayed in Figure 28.

Figure 28: Net Taxable Gallons of Motor Fuel, March-May 2019 and 2020



Source: Ohio Department of Taxation Motor Fuel Reports, FY2019 and FY2020

While it is commendable that ODOT has strived to move away from bonding for basic preservation in recent years, if the fuel tax increase is, in fact, what enabled the Department to do so, a decline in fuel tax revenues may jeopardize this goal. It is recommended that ODOT maintain its commitment to reserve bonding for projects with a long useful life in alignment with best practices.

18. Require debt affordability studies to gauge when ODOT can afford to take on new debt prior to pursuing new bond issuances

Benefit:

- Ensures that any new debt incurred can be supported and serviced
- Supports strong bond ratings, which reduce the cost of borrowing

Debt affordability studies are data-driven analyses that equip states with the ability to manage debt in a way that aligns with their resources as well as their spending priorities by evaluating the impact of potential issuances on self-imposed debt caps. According to a study by the Pew Charitable Trusts

(Pew), although all states employ some measures to track their debt, 23 states – including Ohio – do not conduct debt affordability studies.[73]

According to Pew's analysis of state debt affordability studies, best-practice states:

- Evaluate their debt affordability using metrics, benchmarks and multi-year projections under several scenarios.
- Define a purpose for the affordability study and include all relevant debt. The purpose should reflect the state's debt issuance structure.
- Require that debt affordability studies be conducted and make clear their purpose, use and who will prepare them. Spell out a timetable so the report is released as the governor is putting together capital and operating budget proposals to submit to the legislature.

An example of a best practice state, North Carolina uses an interesting approach: Its study separately assesses (a) debt supported by general funds and (b) borrowing backed by transportation revenue, and then combines the results of the two evaluations. This allows its legislature to focus in on liabilities of particular purpose (e.g., transportation debt) while also taking a broader view of its long-term obligations.[74]

19. ***Clarify in ODOT's bond policy75 that its GARVEE bond program's capacity is based on future estimated funds***

Benefit:

- Taking the future trend of federal funds into consideration reflects the availability of pledged revenues in the future, conservatively factoring in the risk that anticipated fund growth may not materialize

The availability of future, pledged revenues affects debt repayments. Accordingly, sound financial management strategy suggests the need to consider future federal funds availability when considering whether debt can be supported. Forecasting future federal funds is challenging and might be considered an aggressive approach. However, if the anticipated funds growth does not materialize, or decreases, then that risk will be factored in anyway.

The following provision of ODOT's current bond policy appears to suggest that its GARVEE program's limitation is based on historical federal funds:

- "This stipulation was further changed with the Series 2012-1 bonds such that additional debt service charges could not exceed twenty percent (20%) of the highest annual amount of Obligation Authority distributed during any of the three most recently completed FFY immediately previous to the date of such issuance and delivery."

[73] The Pew Charitable Trusts, "Strategies for Managing State Debt," (June 2017).

[74] North Carolina Department of State Treasurer, "Debt Affordability Study," (February 1, 2020).

[75] Ohio Department of Transportation, "State Highway Capital Improvement Bond and Grant Anticipation Revenue Vehicles Bond Policy (effective April 17,2015).

A separate provision within the same policy seems to conflict, implying instead that capacity is based on future estimated funds:

- "Due to the relative difficulty in forecasting future Federal-aid receipts from year to year, the forecasts prepared by the Division of Finance will base the calculation on ODOT's estimated total annual Federal-aid Highway Obligation Authority."

20. Petition the Ohio legislature to remove the requirement for biennial legislative approval of pledged revenue for GARVEE debt service payments.

Benefit:

- Potentially increase credit ratings, thereby reducing the cost of borrowing

According to the State constitution, the Ohio legislature must approve biennial appropriations of state's FHWA funds – the source of pledged revenue – for GARVEE debt service payments. While this has not historically been an issue in practice, as there has been no delay in appropriation, the requirement itself has been cited as a credit challenge by ratings agencies. In 2018, for example, Moody's Investors Service indicated that the removal of this requirement could lead to an upgrade, and that the failure to provide timely appropriation to allow for payment of debt service could lead to a downgrade.[76] In alignment with this analysis, Fitch Ratings has stated that "In instances where state appropriation policies may affect the distribution of federally received funds, standalone GARVEE ratings are capped below the state rating to reflect appropriation risk."[77]

Such ratings changes have been observed in other states. In May 2020, for example, Fitch Ratings downgraded the New Jersey Transportation Trust Fund Authority (NJTTFA)'s outstanding federal highway reimbursement revenue notes from A- to BBB+ in part due to this issue, stating, "As with other similarly structured GARVEE transactions, the financial resources of the NJTTFA are limited to the discretion of the NJDOT to appropriate revenue to the trustee for debt service, which increases bondholder vulnerability should the HTF experience future gaps or delays in funding…Though it is highly unlikely federal-aid transportation funds would be appropriated for other uses, the legal ability to do so is still factored in to GARVEE ratings."[78]

[76] Moody's Investors Service, "Ohio DOT Fed. Grant Anticipation Program: Update to Credit Analysis," (March 12, 2018).

[77] Fitch Ratings, "Fitch Affirms U.S. Municipal Standalone GARVEE Ratings," (May 28, 2020).

[78] Fitch Ratings, "Fitch Downgrades NJTTFA's Outstanding GARVEE Bonds to 'BBB+'; Outlook Negative," (May 22, 2020).