2021 Pavement System Preservation Report

Maryland Department Of Transportation
State Highway Administration

Prepared by the Pavement and Geotechnical Division of the Office of Materials Technology

MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

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Executive Summary

This report documents the condition of the Maryland Department of Transportation State Highway Administration's (MDOT SHA) pavement network as it was collected in 2021. The MDOT SHA Pavement Management Section is responsible for the management of all pavement-related data throughout the network. This data includes ride quality, rut depth, friction, cracking, construction accomplishments and history, material and construction costs, digital right of way imagery, and truck weight data. Pavement condition data are reported by calendar year. Paving accomplishments and expenditures are reported by fiscal year.

MDOT SHA will not be responsible for the conclusions and any statements made by other entities using the information presented in this report.

For MDOT SHA maintained roadways, the Remaining Service Life (RSL) values (where zero years represents unacceptable condition, and 50 years represents ideal condition) and lane-mile-years (LMY) of construction benefit are shown as follows in Table 1**.**

Table 1: RSL and Lane-Mile-Years Summary[1]

Condition Indicator	Fiscal Year					
	2016	2017	2018	2019	2020	2021
Overall RSL (years)	19	17	17	17	17	17
LMY accomplished based on paving date (All Funds)	20,215	22,663	20,684	16,942	17,834	13,000
LMY accomplished based on expenditures (Fund 77)	14,279	17,471	14,898	14,942	13,912	11,595
LMY Target (Fund 77)	19,663	22,986	17,444	15,410	12,040	8,063

RSL values are categorized into six groups in increments of 10, also labeled A-F as shown below.

Table 2: RSL Categories

RSL Category	RSL Range
Excellent (A)	40 to 50 years
Very Good (B)	30 to <40 years
Good (C)	20 to <30 years
Fair (D)	10 to <20 years
Mediocre (E)	<10 years
Poor (F)	0 years

[1] RSL and LMY summary values are based on one-mile-long roadway segments from all MDOT SHA maintained roadways.

Condition

Statewide, the pavement condition of MDOT SHA's roadways remained steady from 2017. This is based on 100% of NHS and 59% of non-NHS data processed for CY 2021. For each roadway segment, the overall condition is dependent on the worst (controlling) of ride quality, cracking, rutting, and friction. For example, if a roadway segment has poor cracking, good ride quality, good rutting, and good friction, the overall condition is still considered poor since cracking is poor. While **cracking** controls the overall condition **31%** of the time, **friction** now controls the overall condition **36%** of the time, dropping 4% from the condition measured in **2020**. This does not imply that High Dynamic Friction Value (HDFV) mixes should routinely be used. Instead, alternative treatments such as High Friction Surface Treatment (HFST) and Surface Abrasion that result in a higher post-treatment skid number should be considered for lower RSL sections. Ride quality continues to be very good and continues to be the least likely to control the overall condition. It should be noted that the new friction methodology implemented in July 2020 (outlined in the friction section) resulted in friction being a dominating controlling measure.

Lane-Mile-Year Accomplishments

Statewide, MDOT SHA **exceeded** its **FY 2021** LMY goal of **8,063** through Fund 77 alone by **44%**. The goal was exceeded by an **additional 17%** because of paving performed through other funds. MDOT SHA accomplished a total of **13,000 LMY** under all funds and **11,595 LMY** under Fund 77. This was achieved largely due to majority of the Districts accomplishing their preventive maintenance and minor rehabilitation LMY targets. The cost of each preventive maintenance treatment option varies. Patch-only projects tend to have higher unit costs, and crack seal projects typically have lower unit costs.

Recommended Practices

We recommend that we (OMT and the districts) continue our focus on cracking, and at the same time increase focus on friction. To do this, it is recommended to continue the recent trend of selecting more preventive maintenance projects to preserve roads in good structural condition to keep them in good condition, by using cost-effective treatments such as crack sealing and micro surfacing. In 2021, OMT successfully collaborated with the Districts and OOTS to develop statewide friction contracts for High Friction Surface treatment (HFST) and Surface Abrasion. We recommend that continued collaboration between OMT and Districts / OOTS is imperative to proactively address friction needs across our network. This will enable MDOT SHA to improve its pavement condition by focusing on roads that have low friction numbers but are in otherwise good condition.

OMT recommends that approximately 25% to 30% of the Fund 77 construction budget be allocated to preventive maintenance, and 65% to 70% of the construction budget to rehabilitation. About 5% of the budget is set aside for line striping and other expenditures.

The funding levels for FY 2022 were restored to that of pre-FY 2021 fiscal years. While the funding for FY 2023 was restored somewhat to pre-pandemic levels, it is expected that conditions will generally remain steady over the next 1-2 years despite the gap between the reasonably available funding and the objective funding needed to maintain state of good repair long-term. However, it is anticipated that the conditions will deteriorate from 2024 and forward if the gap in funding continues. Therefore, a higher level of partnership across our offices (OMT and the Districts) is critical to succeed in meeting our goals.

2021 Paving Accomplishments

Lane-Mile-Year Accomplishments

MDOT SHA maintains a total of **17,361 lane miles of roadways** as of January 1, 2022. Figure 1 shows the lane-mile-years (LMY) of construction benefit from fiscal years **2013** to **2021**. In **FY 2021**, a total of **13,000 LMY** of pavement performance extension were invested into MDOT SHA's highway system, of which **11,595 LMY** came from Fund 77. MDOT SHA **exceeded** the Fund 77 goal of **8,063 LMY**. The target was based on a **Fund 77 construction budget** of **$154 million**. **Fund 77 construction expenditures** were approximately **$143 million**.

The activity type definitions follow those provided in Appendix B: Pavement Fix Definitions.

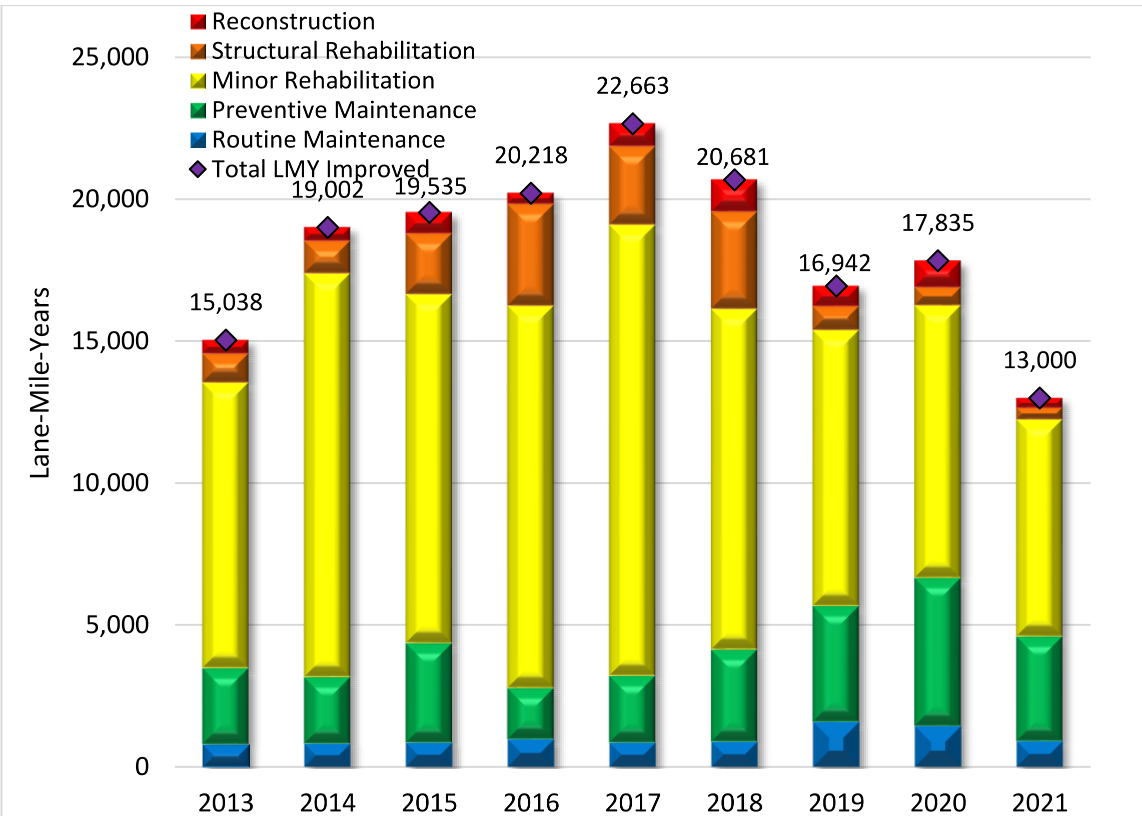


Figure 1: MDOT SHA Lane-Mile-Years Improved through All Funds by Fiscal Year

Figure 2 shows the lane-mile-years of construction benefit improved by treatment type and total MDOT SHA lane miles by District through all funds for fiscal year **2021**. In relation to the total lane miles, **District 1** achieved the highest benefit at around **123%** of its total lane miles while **District 3** was the lowest among the Districts at **49%**.

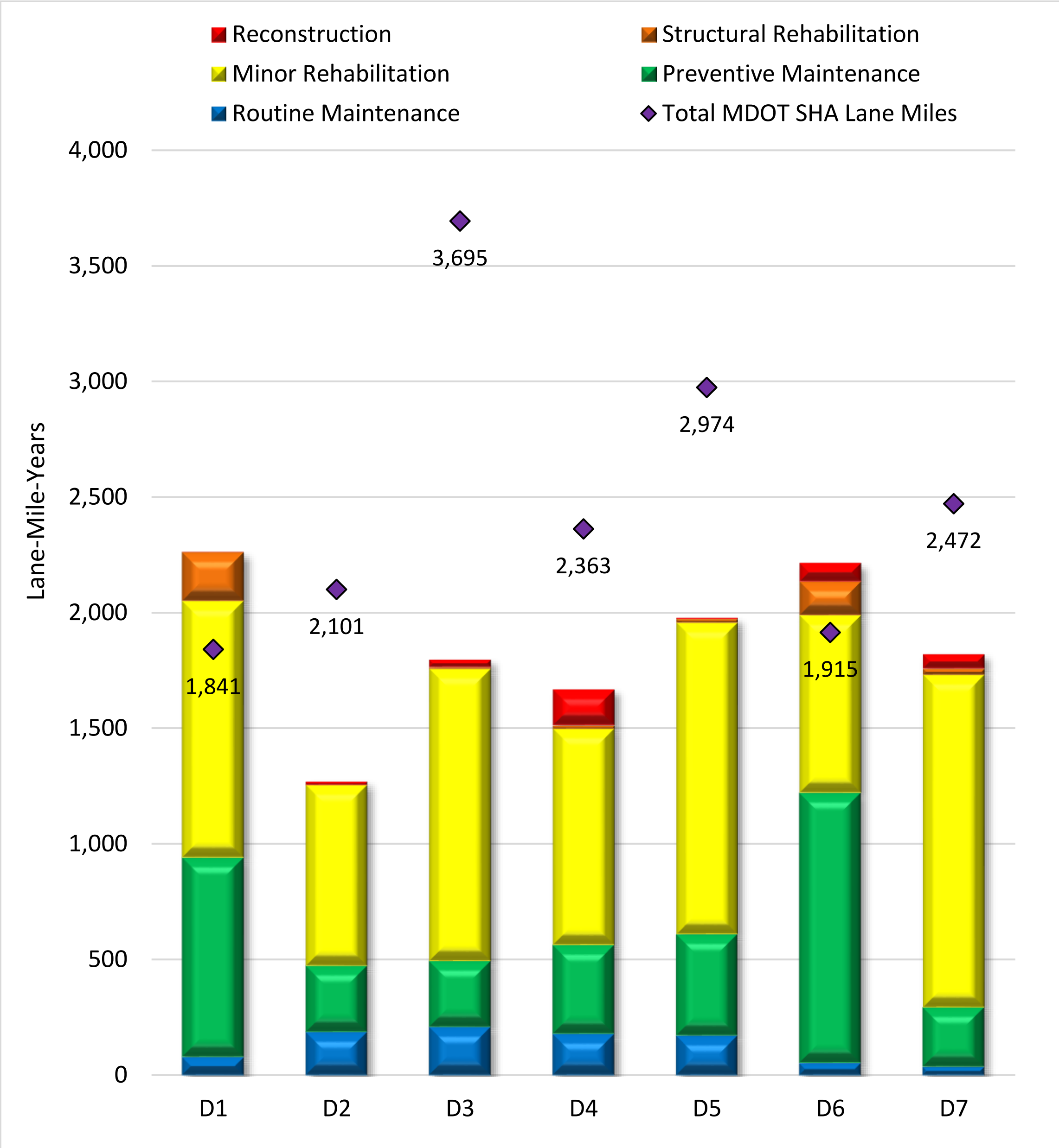


Figure 2: Fiscal Year 2021 Lane-Mile-Years Improved by District through All Funds

Mileage Accomplishments

Figure 3 shows the lane miles treated over the past nine years. In **FY 2021**, a total of **2,248 lane miles** of pavement were treated on MDOT SHA's highway system. **534 lane miles** were treated through rehabilitation, reconstruction or new construction. **810 lane miles** were treated through Preventive Maintenance, and **904 lane miles** were treated through routine maintenance treatments. The activity type definitions follow those provided in Appendix B: Pavement Fix Definitions. Resurfacing includes any paving treatment in a project which affects the entire surface area of a roadway. MDOT SHA improved **13%** of the network lane mileage in **FY 2021**, compared to **18%** in FY **2020**.

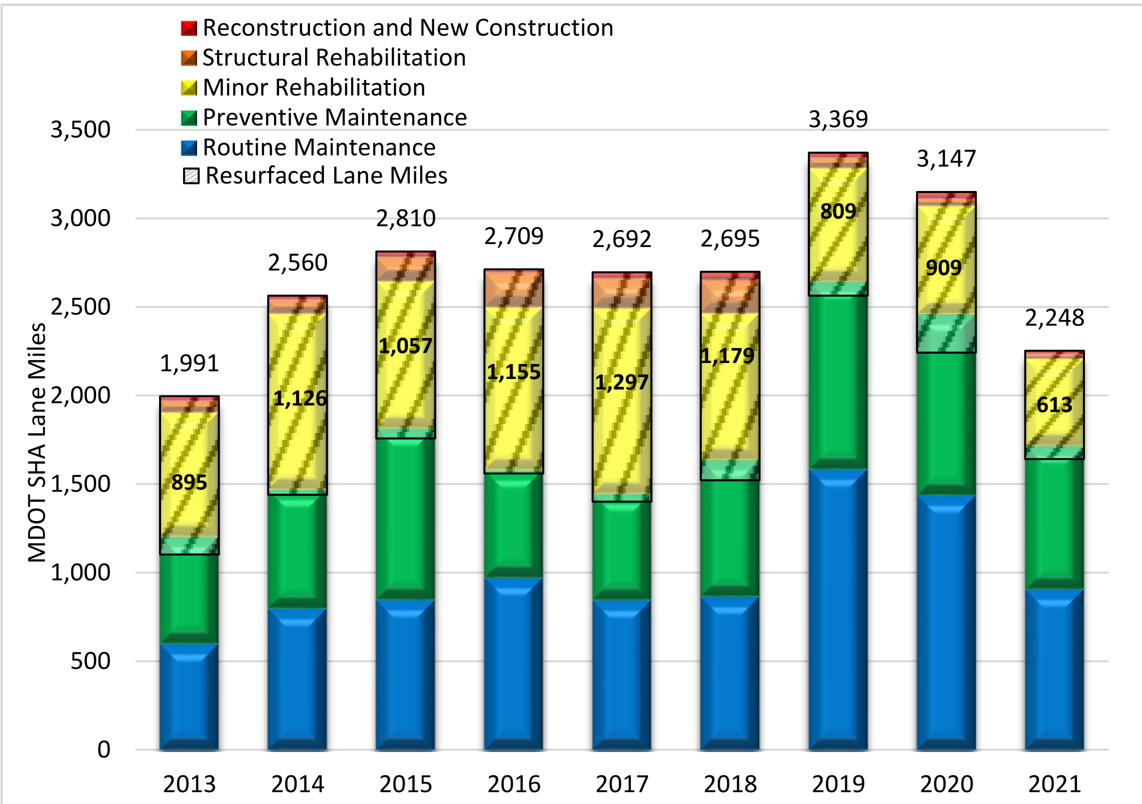


Figure 3: MDOT SHA Lane Miles Improved through All Funds by Fiscal Year

Figure 4 shows the lane miles improved by District through all funds for **FY 2021**. **District 6** recorded the highest percentage of lane miles improved among all Districts at **20% of its total lane miles**, while **District 7** recorded the lowest at **7% of its total lane miles**. **District 1** resurfaced the highest percentage of its total lane miles in **FY 2021** at about **7%**, while **District 3 and District 4** resurfaced the lowest percentage of its total lane miles among all Districts at **3%**.

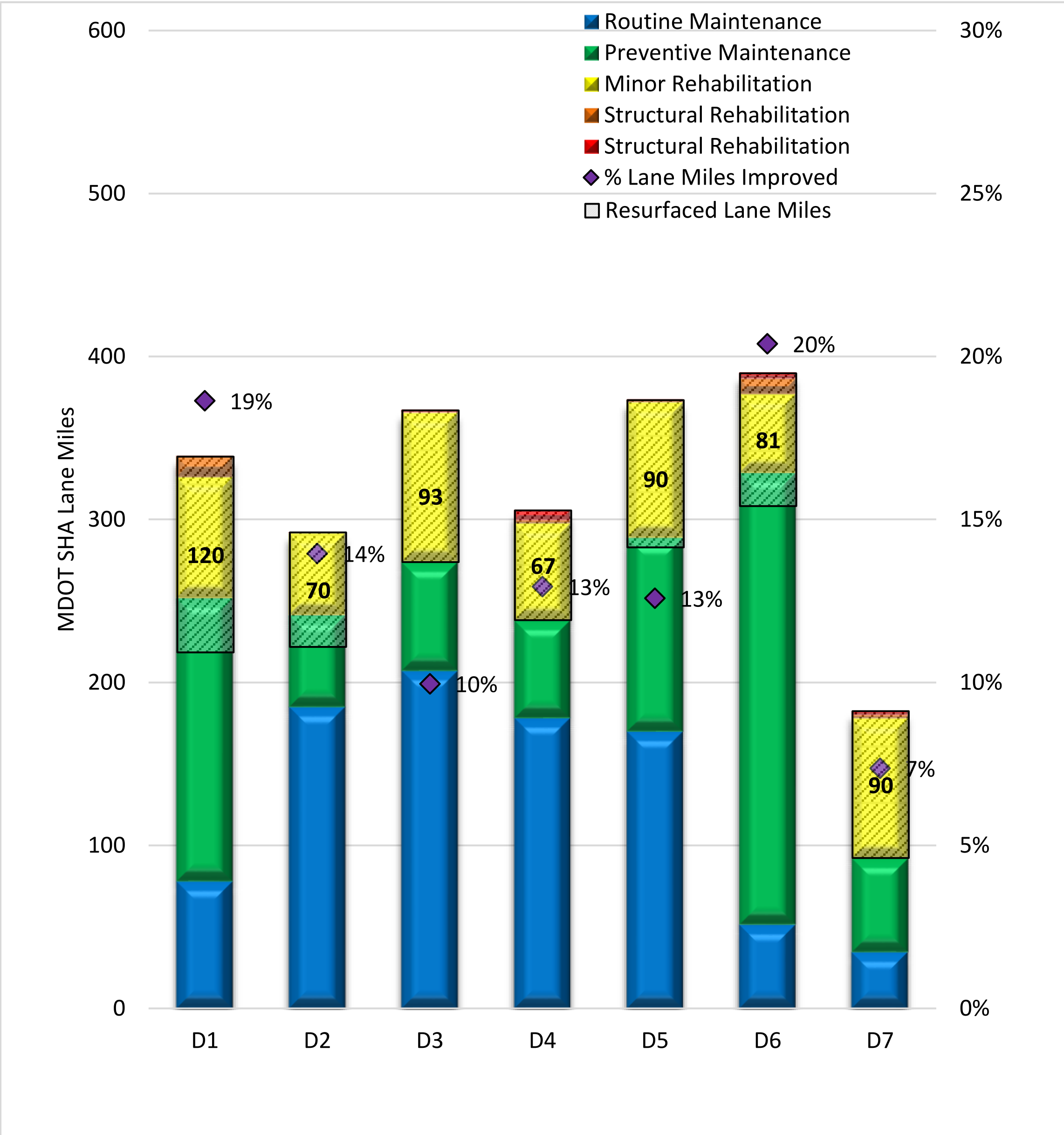


Figure 4: Fiscal Year 2021 Lane miles Improved by District through All Funds

Asphalt Tonnage Produced

Approximately **1.43 million Tons of asphalt (both hot mix and warm mix)** were produced in Calendar Year **2021** and **1.11 million Tons of asphalt** were produced in calendar year **2020** for MDOT SHA projects[2].

Paving Cost Facts

Hot Mix Asphalt costs in **2021** were lower than **2020**. The unit costs displayed in Figure 5 are calculated based on the average bid price of surface mixes, weighted by quantity bid.

Figure 5: Typical HMA Surface Price

Based on local Maryland data**, from January 2013 to December 2021 the cost of liquid asphalt in MD decreased by 3%**[3], dropping from **$553/liquid-ton** to **$538/liquid-ton** (peaking in **September 2014** at **$624/liquid-ton**).

[2] Source: MDOT SHA Office of Materials Technology (Asphalt Technology Division)
[3] Source: MDOT SHA Office of Construction

The average cost per lane-mile-year of Fund 77 projects in **FY 2021** was approximately **$12,329**. Additionally, the percentage of Fund 77 construction expenditures on paving-related items was **57%**. The average statewide $/Lane-Mile-Year ($/LMY) spent over the past several years (**2018-2021**) as displayed in Figure 6, shows that the average $ spent per lane mile year has generally **decreased since 2018** and remained steady at around **$12,000/LMY since 2020**.

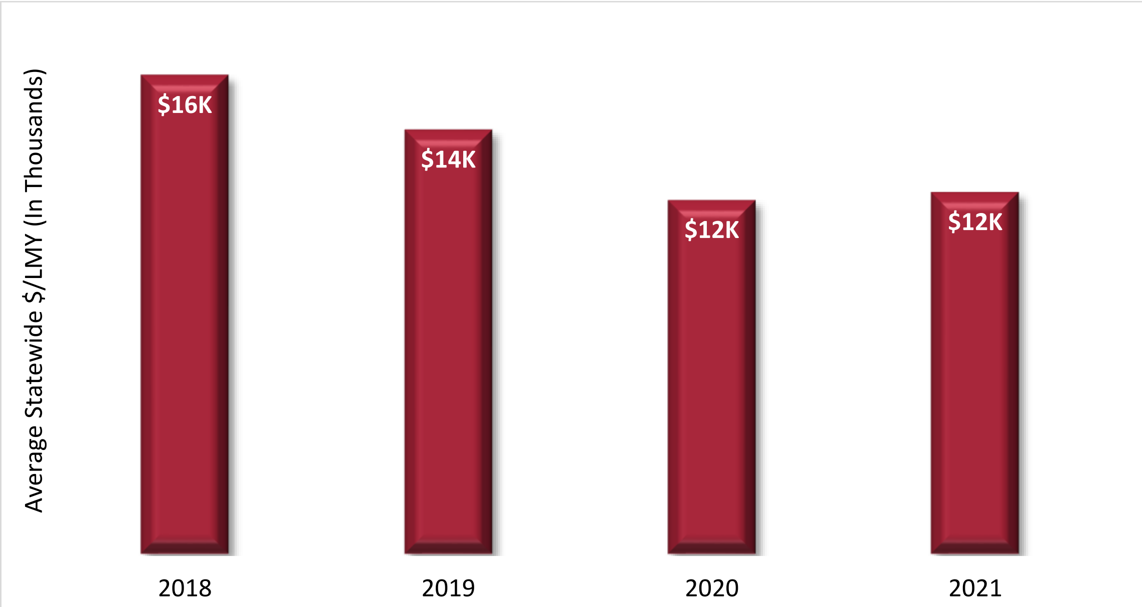


Figure 6: Average Statewide $/LMY Spent (Fund 77)

The data presented in Figure 7 shows that Fund 77 paving projects in **District 6** had the lowest unit costs in **FY 2021** with an average approximate cost-benefit ratio of **$7,200/lane-mile-year**, while projects in **District 4** had the highest unit costs at around **$19,300/lane-mile-year**.

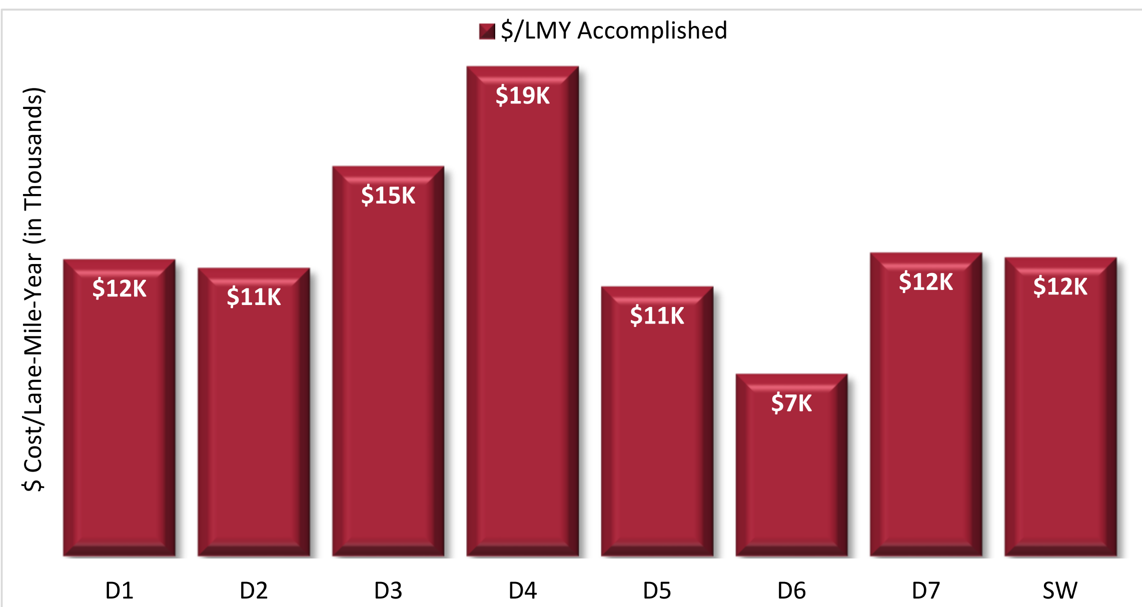


Figure 7: FY 2021 Average Cost per Lane-Mile-Year by District (Fund 77)

Figure 8 presents the percentage of the Fund 77 lane-mile-year Targets for **FY 2021** that were accomplished by District. All **Districts performed well to exceed** the overall LMY targets in **FY 2021**.

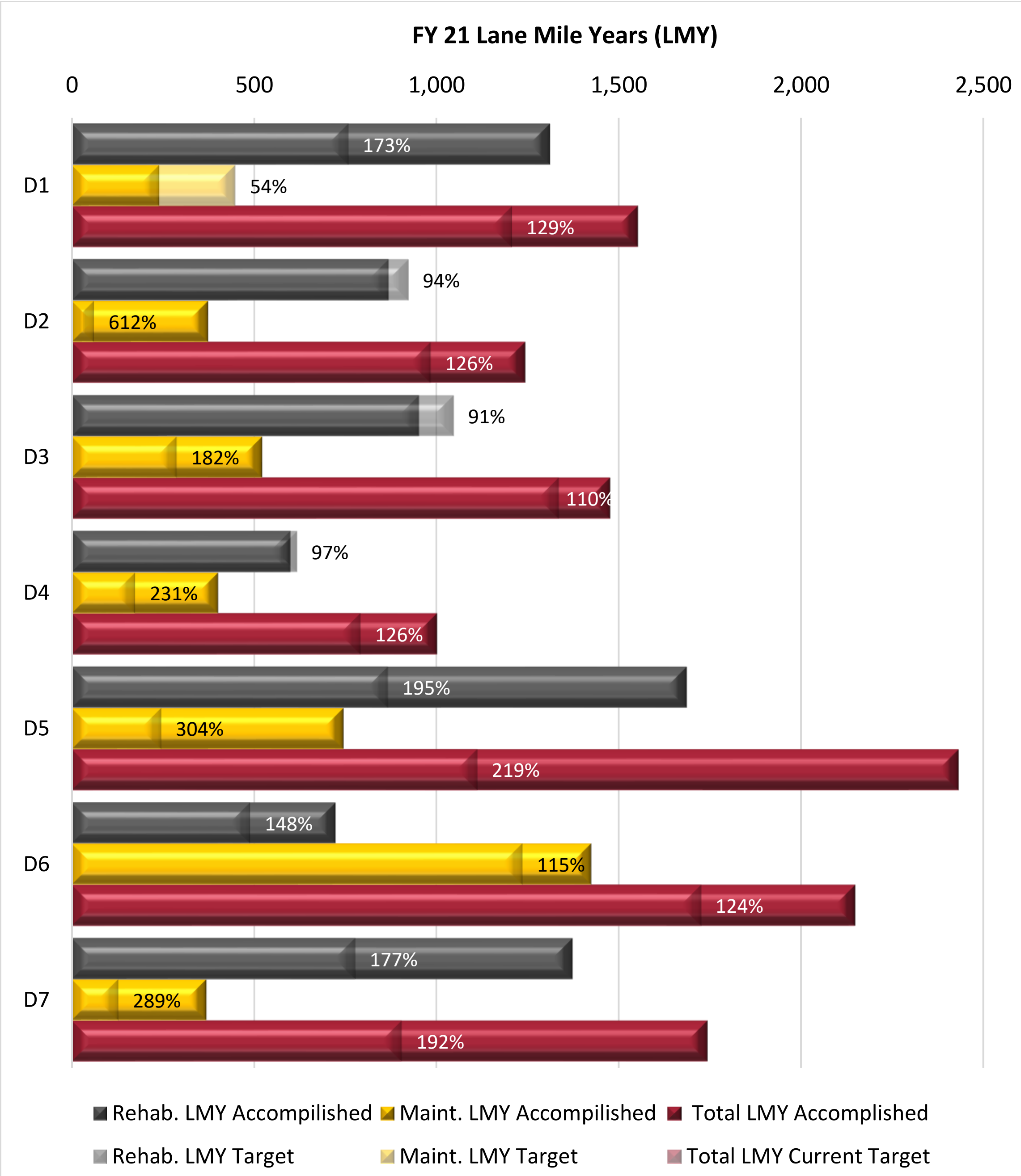


Figure 8: FY 2021 Percentage of Fund 77 Lane-Mile-Year Targets Accomplished

Figure 9 shows the Fund 77 paving expenditures for **FY 2021** by District. The data indicates that only **District 1 slightly exceeded** the Fund 77 allocated budget for **FY 2021** while **District 3 spent about 16% less** and **District 4 spent approximately 13% less** than the original allocation.

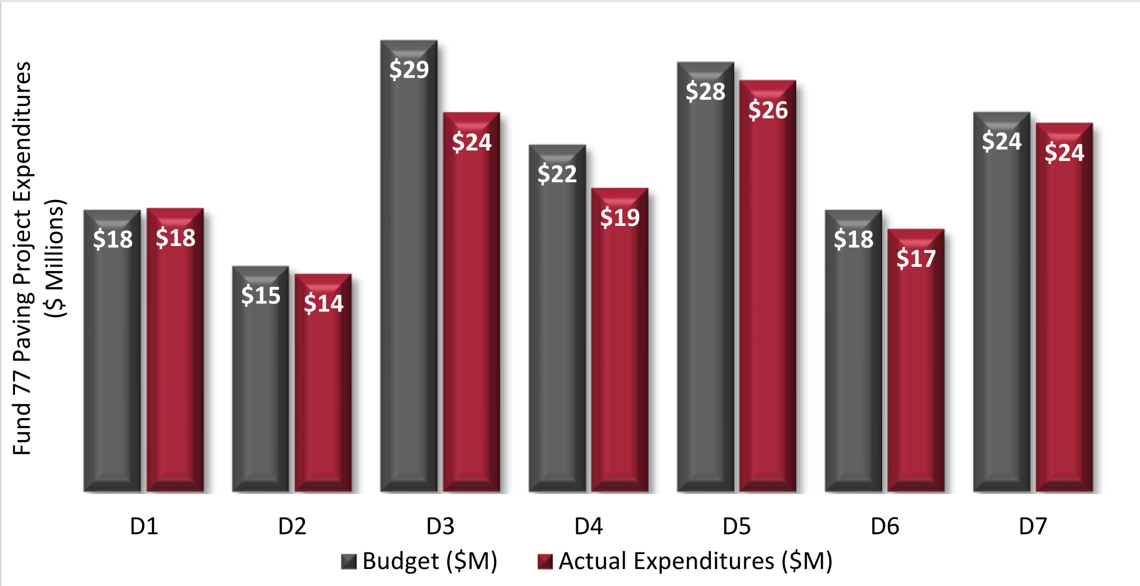


Figure 9: FY 2021 Fund 77 Construction Expenditures

Figure 10 presents the ratio of Expenditures/Budget and LMY Accomplished/Target across all Districts, which is a more objective comparison of individual District performance in **2021**. The chart shows that all seven Districts exceeded the **FY 21** LMY targets. **District 6** led the way by accomplishing **66%** of its total LMY by spending about **20%** of its budget through preventive maintenance projects. The optimization LMY targets for the Districts were fairly conservative based on the information and costs known at the time that selected committed projects in the Districts' work plans were made available to PAGD.

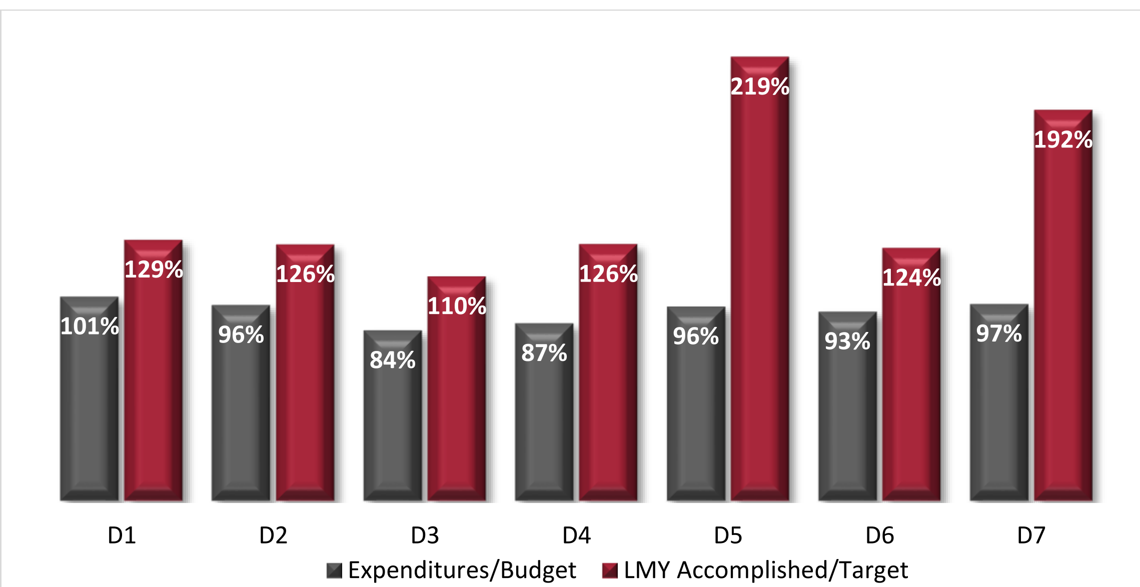


Figure 10. FY 2021 Fund 77 Performance Comparison across Districts.

Figure 11 shows the Fund 77 budget and expenditures by treatment activity for **FY 2021**. This chart shows that the expenditures for Preventive Maintenance was **16.1% higher** than the budget. For Rehabilitation/Reconstruction, the expenditures were **27.1% lower** than the respective budget. The total expenditures in the other treatment activities **exceeded the budget by 209.8%**.

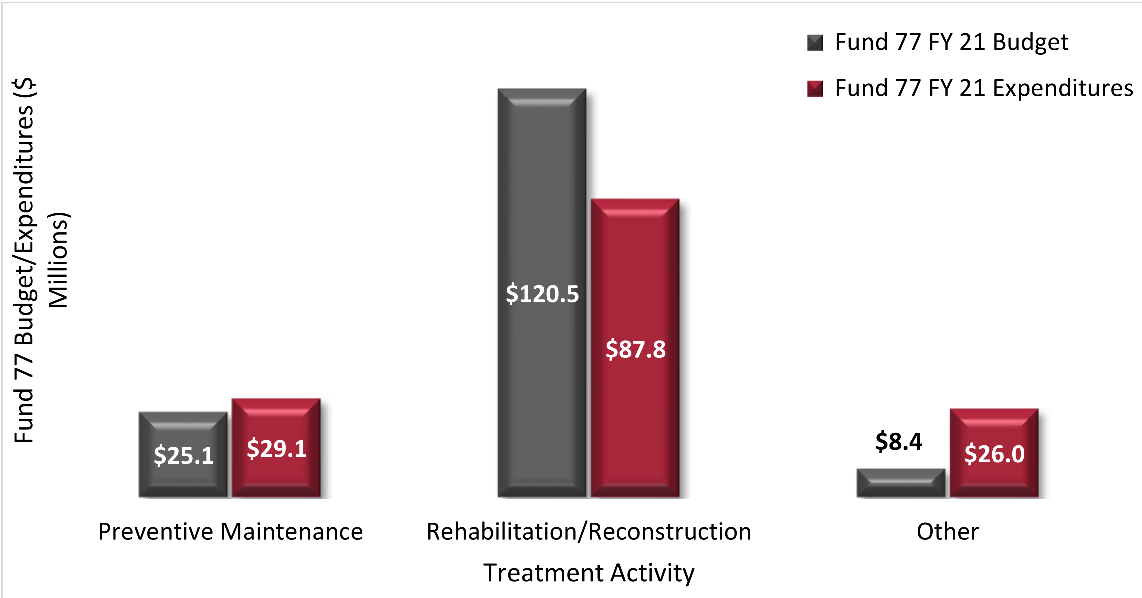


Figure 11: FY 2021 Budget and Expenditures by Treatment Activity

Figure 12 shows the LMY grouped by treatment activity for **FY 2021**. This chart shows that MDOT SHA achieved **137%** of the Statewide LMY target for Rehabilitation/Reconstruction and **158%** of the Statewide LMY target for preventive maintenance.

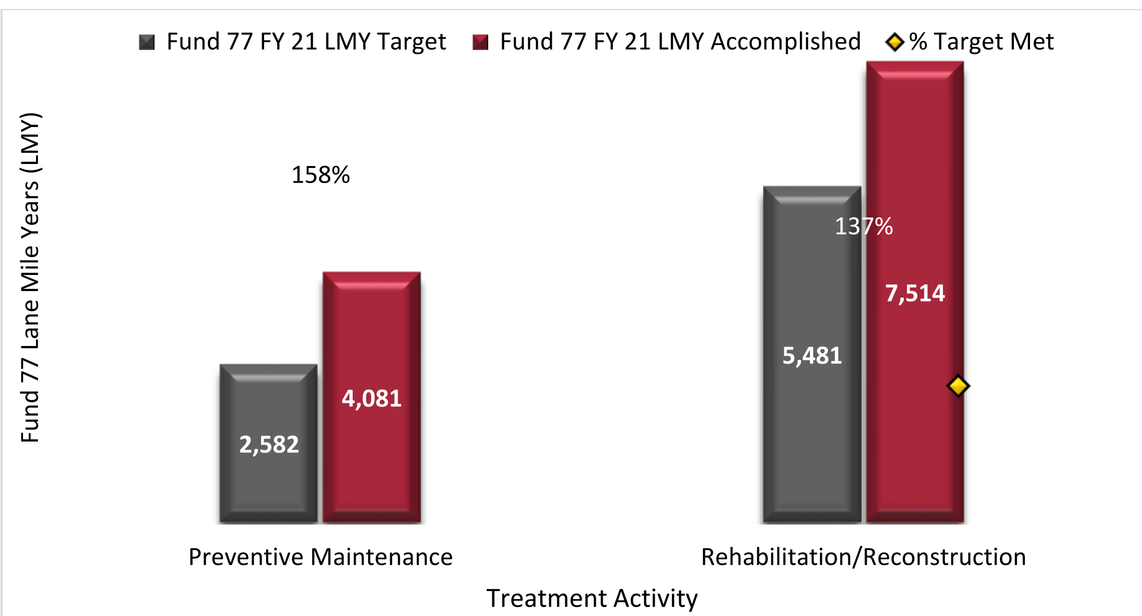


Figure 12: FY 2021 LMY by Treatment Activity

Health of the Network

The health of the MDOT SHA network is monitored through five pavement performance parameters: ride quality, friction, rutting, structural and functional cracking.

Remaining Service Life (RSL)

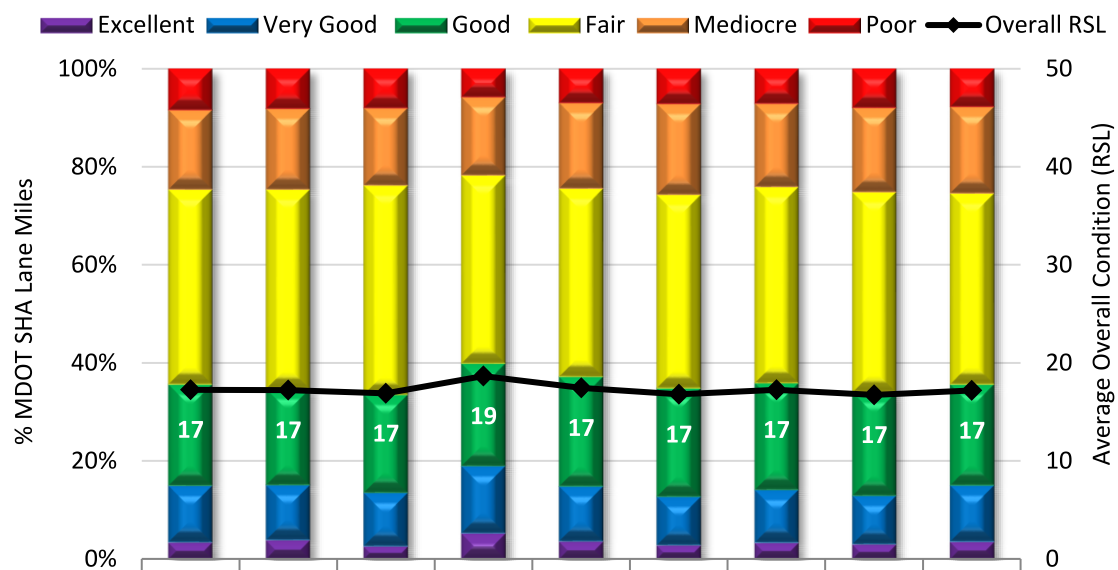
In a network-level analysis, it is essential to know whether present and/or planned program actions (reactive maintenance, pavement preservation, rehabilitation, reconstruction) will produce net improvements in the overall condition of the network as measured by average RSL. RSL is defined as the time until a condition threshold limit is reached.

The overall RSL is the limiting (worst) among five performance metrics (ride quality, rutting, structural cracking, functional cracking, and friction) for each measured portion of the roadway network. Sections with zero years of RSL are considered Poor.

Overall Condition

In July 2020, OMT-PAGD implemented a new methodology to characterize roadway friction based on Friction Demand for Fund 77. The purpose of the change is to better identify and address roadway sections where skid resistance is more important. This new methodology will much more accurately identify the roadway segments that need to be addressed under Fund 77, to act in a preventive manner to ultimately reduce the number of wet accidents. In contrast, Fund 76 will continue to be used in a reactive manner to address locations where wet accidents have been higher than average. Please see the friction section for more details on the new method to calculate Skid RSL.

On average, the MDOT SHA pavement network has **17** years of overall RSL in CY **2021**. Figure 13 indicates that **92%** of the SHA pavement network is in acceptable (not "Poor") overall pavement condition in **2021**, **with no change** from the condition measured in **2020**. The Overall Condition of **17** years RSL is consistent with several of the previous years.



	2013	2014	2015	2016	2017	2018	2019	2020	2021
Poor	8.4%	8.2%	8.0%	5.8%	7.0%	7.2%	7.2%	8.0%	7.8%
Mediocre	16.3%	16.5%	15.8%	16.0%	17.5%	18.5%	17.0%	17.3%	17.7%
Fair	39.7%	40.6%	42.6%	38.3%	38.3%	39.5%	39.9%	40.8%	38.9%
Good	20.7%	19.7%	20.0%	20.9%	22.4%	22.1%	21.9%	21.1%	20.7%
Very Good	11.6%	11.2%	10.9%	13.8%	11.2%	9.9%	10.8%	9.9%	11.5%
Excellent	3.4%	3.8%	2.6%	5.2%	3.6%	2.8%	3.3%	3.0%	3.5%
Overall RSL	17	17	17	19	17	17	17	17	17

Figure 13: % of MDOT SHA Lane Miles by overall RSL performance (2013-2021)

Figure 14 shows the distribution of controlling performance measure for **FY 2019-2021** Statewide. This shows that in FY **2021**, **friction** now controls the condition of about **36%** of the total lane miles in the MDOT SHA pavement network in **2021**, followed by cracking at **31%** of the total lane miles. Ride quality historically controls the condition of the lowest percentage of lane miles among all performance measures ranging between 9 - 10% of the total lane miles from **FY 2019 - 2021**.

Friction now controls a higher percentage of lane miles due to a change in Skid RSL calculation methodology that resulted in a **decrease of 5 years** in statewide Skid RSL and a **11%** increase in controlling lane miles when compared to the original method to calculate Skid RSL. For more details on the new methodology, please see the friction section.

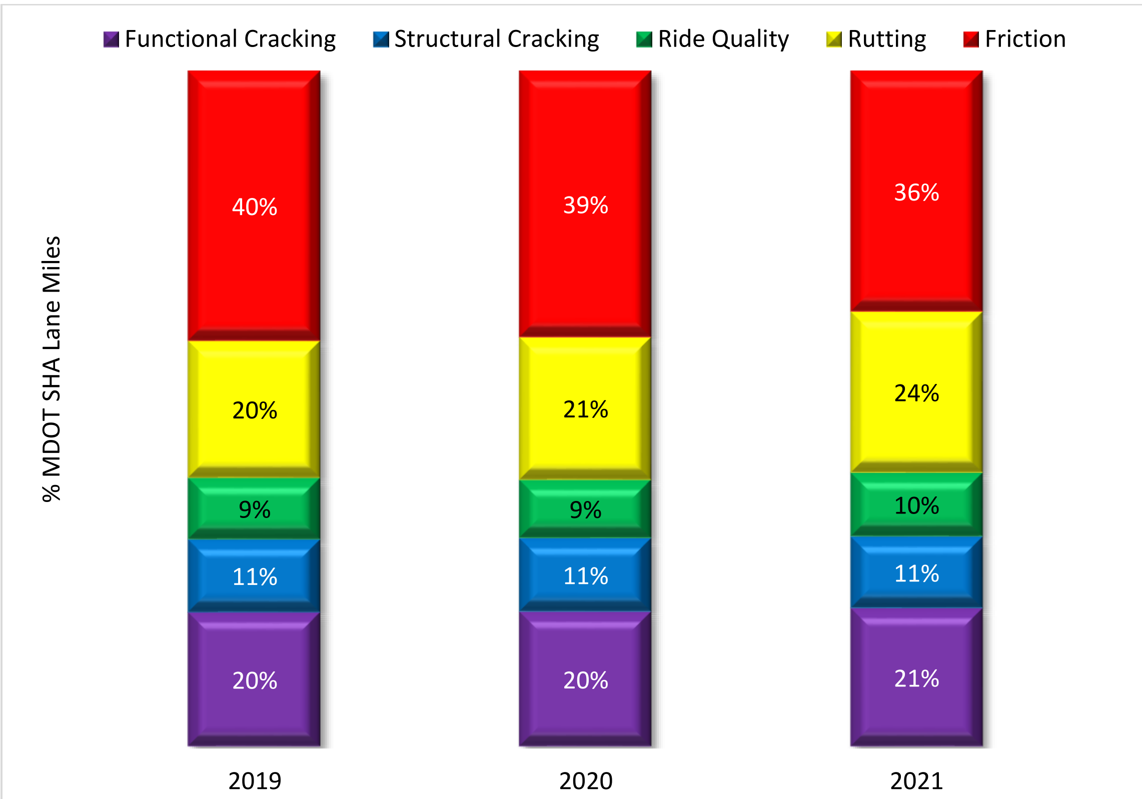


Figure 14: Statewide Distribution of Controlling Performance Measures for 2019 - 2021

Overall RSL By District

The overall condition measured by District has had a similar distribution pattern in recent years. The data presented in Figure 15 below show that **District 1 and District 6** are in good condition relative to the Statewide condition in **2021**. **District 2, District 4, and District 7** have condition values close to the overall state average of **17**. The Overall RSL for **District 3 and District 5** were below the overall state average of **17**. Figure 16 represents the average overall RSL and MDOT SHA lane-mile distribution Statewide and by District, in terms of six RSL categories ranging from Excellent (A) through Poor (F). In comparison to the statistics reported in the **2020** System Preservation Report, the Overall RSL for **CY 2019-2021** have remained steady, due to the methodology for treatment selection (focusing on pavement preservation in addition to pavement rehabilitation) and funding levels remaining consistent. For more details on the new method to calculate Skid RSL, see the friction section.

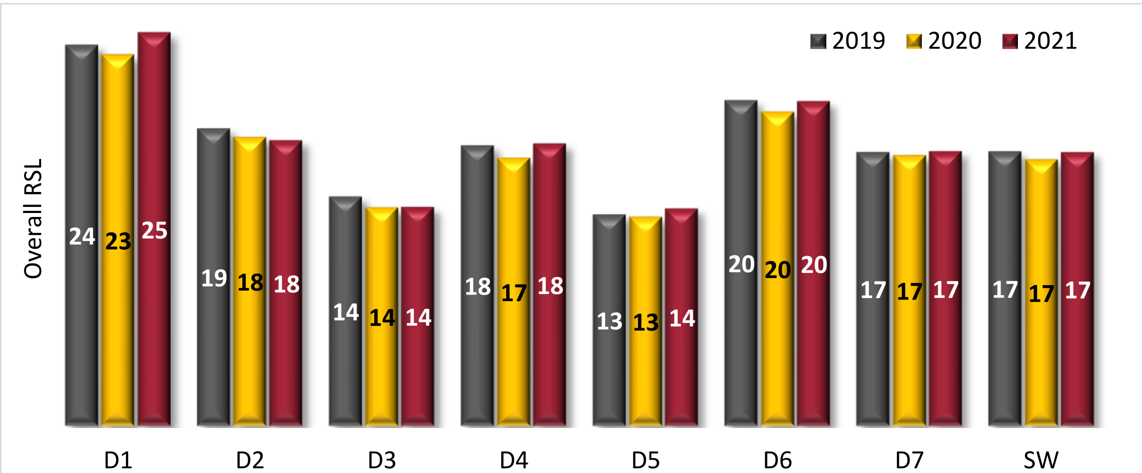


Figure 15: 2019-2021 Average Overall RSL by District

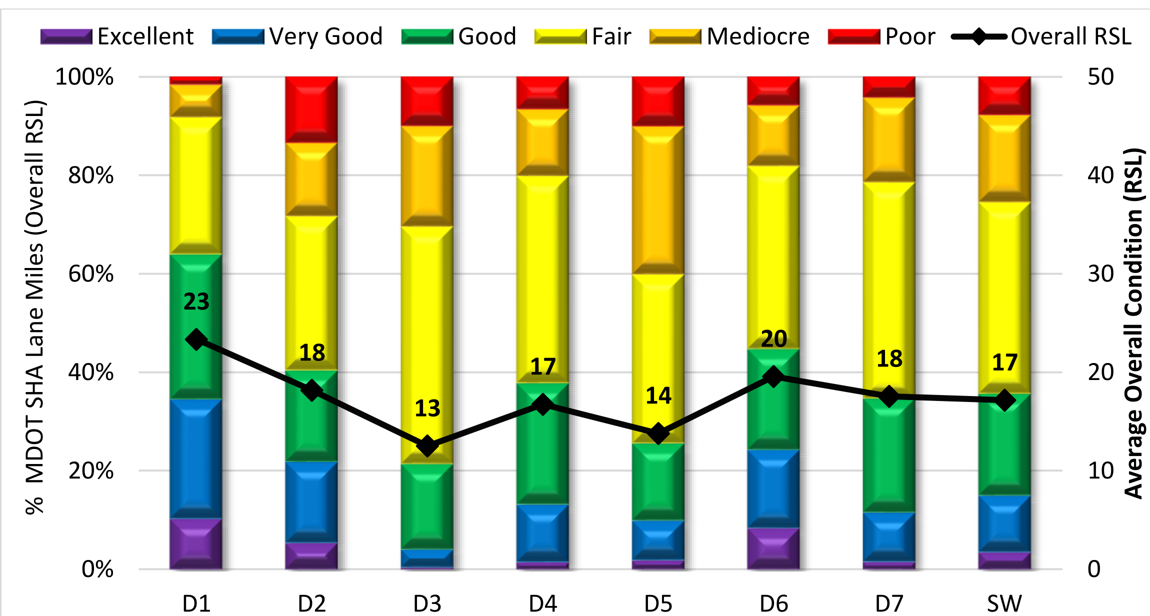


Figure 16: 2021 Overall RSL Distribution by District

Pavement Age

Most roadways in the MDOT SHA pavement network are reaching an age that would require major rehabilitation or reconstruction if sufficient pavement preservation is not performed. As the network continues to age, demands on system preservation continually increase. Approximately **73%** of the roadways in the MDOT SHA pavement were initially constructed at least 40 years ago. The following information, along with Figure 17 presents some of the issues related to MDOT SHA aging roadway network.

- **13%** of MD's existing network was originally constructed prior to 1930.
- **37%** of MD's existing network was originally constructed between 1950 and 1970.
- The average pavement age since original construction is **57 years**.

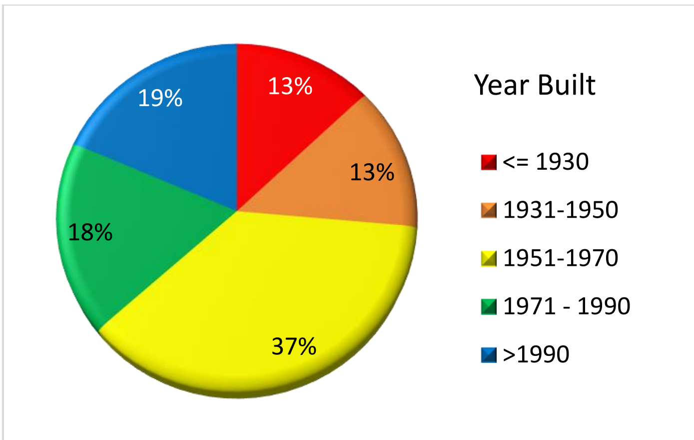


Figure 17: MDOT SHA Lane Miles by Year Originally Built

As of **June 30, 2021**, the average age of the pavement surface owned by MDOT SHA is **10 years**. Figure 18 shows the distribution of MDOT SHA lane miles in terms of the pavement age excluding spot repairs like pothole patching, crack sealing, etc.

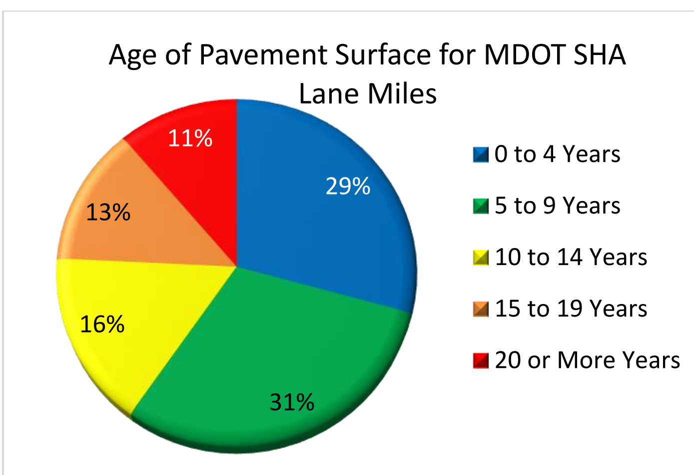


Figure 18: MDOT SHA Lane Miles by Age of Pavement Surface

MDOT SHA Pavement Inventory by District

MDOT SHA is responsible for a total of **17,361 lane miles** (5,715 centerline miles) of mainline and ramp roadways, based on MDOT SHA Data Services Division's 2021 Annual Highway Mileage Report. The breakdown of different types of roadways in the MDOT SHA network is as follows:

- Mainline Lane Mileage: **14,950** lane miles
- Ramps, Auxiliary Lanes, Spurs, Service Roads: **2,411** lane miles

In CY 2021, MDOT SHA collected **4,243** directional miles of friction data, and **6,284** directional miles of ride quality, rutting and cracking condition data on its pavement network in **CY 2021**. The latest available data was used to backfill the remainder of the MDOT SHA network.

The MDOT SHA pavement network includes asphalt concrete pavements (flexible pavements) comprising 63% of the network and Portland cement concrete (PCC) pavements (rigid pavements) comprising 1% of the network. The remaining 36% of the MDOT SHA pavement network is comprised of asphalt concrete surfaces over PCC pavement (composite pavements).

Figure 19 shows the most recent MDOT SHA pavement inventory by District, in terms of total lane miles, vehicle miles traveled (VMT) and paved area in square yards. The total paved area shown below is comprised of all travel lanes, shoulders, MDOT SHA facilities and Park-and-Ride lots. MDOT SHA's statewide inventory can be summarized as follows:

- 17,361 lane miles
- 104,920,000 VMT
- 161,494,649 square yards of paved area

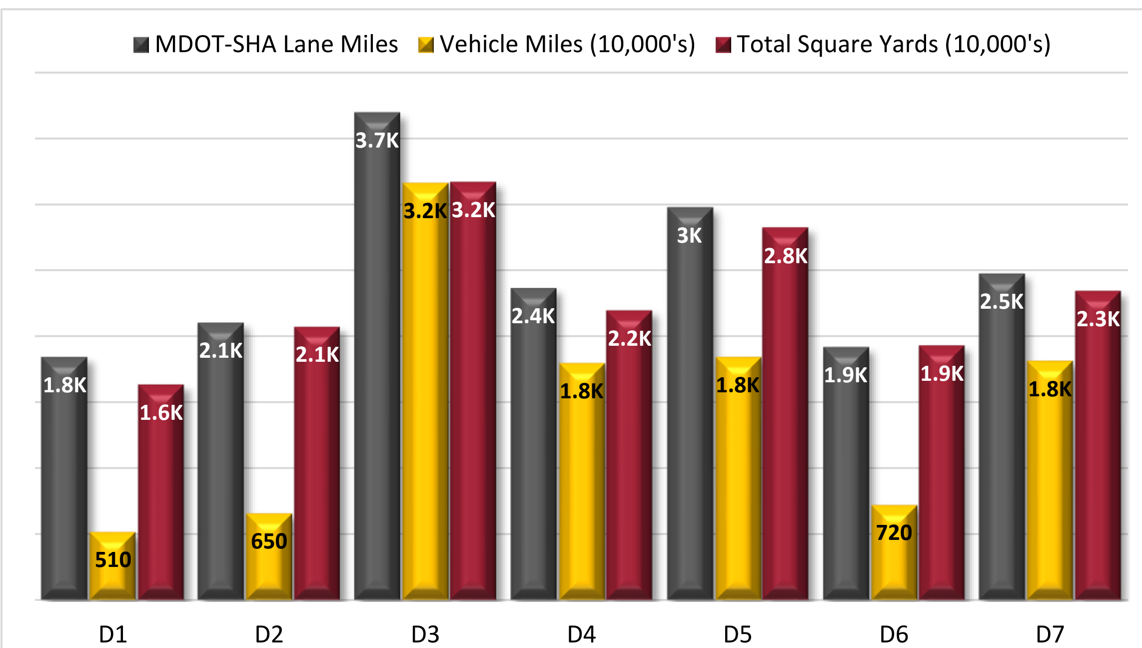


Figure 19: MDOT SHA Lane Miles, Vehicle Miles, and Total Square Yards by District

Pavement System Preservation Plan

The primary goal of the Fund 77 program is to maintain the pavement condition of our roadway network. The Fund 77 program provides a significant majority of the lane-miles improved on the pavement network and is the most important program in terms of influencing pavement condition. Due to the COVID-19 pandemic, the funding levels for FY 2021 were significantly lower than that of the previous fiscal years. While the funding for FY 2022 was restored to pre-pandemic levels, it is still much lower than what is needed to meet the State of Good Repair. Therefore, OMT and the districts should continue to partner to meet our business plan goal of achieving a state of good repair (RSL = 20).

It is essential that MDOT SHA be provided the appropriate amount of funding to support a pavement system preservation program focused on maintaining a roadway network in good condition for the traveling public. A needs assessment is performed every year to justify the annual construction funding allocation as revenue and budget forecasts are subject to fluctuation.

MDOT SHA has ongoing efforts to place a more concentrated focus on preservation treatments as part of the pavement system preservation plan. A broad range of different rehabilitation and preservation strategies are required to make the best use of the funds available, including patching, crack sealing, micro surfacing, thin overlays and other similar techniques. Districts and OOTS, in collaboration with OMT developed and advertised statewide friction contracts for High Friction Surface Treatment (HFST), Surface Abrasion and Diamond Grinding. These contracts will enable MDOT SHA to proactively address friction needs across the network and improve the overall network condition by focusing on roads that have low friction numbers but are in otherwise good condition.

Each year, the Pavement Management section conducts an optimization to identify a list of projects and suggests treatments that will provide the best return on investment within the Fund 77 program. This list is used to establish goals for each district. This analysis is helpful in a preservation-oriented optimization as the underlying principle is to focus on individual condition measures and select the treatment which provides the best overall improvement.

Once the targets are approved by the Deputy Administrator’s Office, each District is asked to select candidate project locations that best meets the optimized targets. The Districts develop a fiscal year preservation program from their list of candidate project locations by working with the design section of the Pavement and Geotechnical Division (PAGD). The Districts are encouraged to select candidate project locations from the optimization suggested projects report as the suggested project locations are expected to provide the best return (benefit) on their investment. Ultimately, the end goal is that the District fiscal year pavement improvement program should meet the District target values for budget and benefit.

Fund 77 budget priorities are assigned so that each maintenance shop gets minimum funding. MDOT SHA uses a combination of total lane miles and Vehicle Miles Traveled (VMT) based on the most recent inventory data to determine the appropriate construction budget allocation for each maintenance shop.

The following charts (Figure 20 and Figure 21) are the results from the Fund 77 optimization for the **FY 2020** through **FY 2023** pavement system preservation plan. Figure 20 shows the total construction budget levels[4] for the Fund 77 program and Figure 21 shows the benefit (lane-mile-year) targets by District and fiscal year.

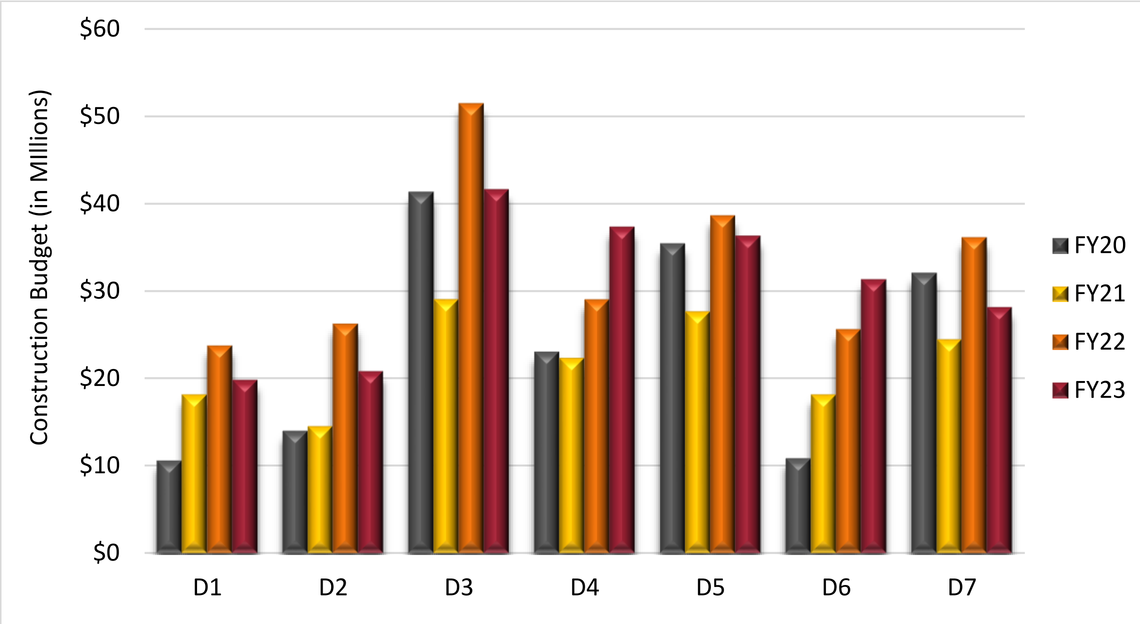


Figure 20: District Construction Budget Allocation Targets

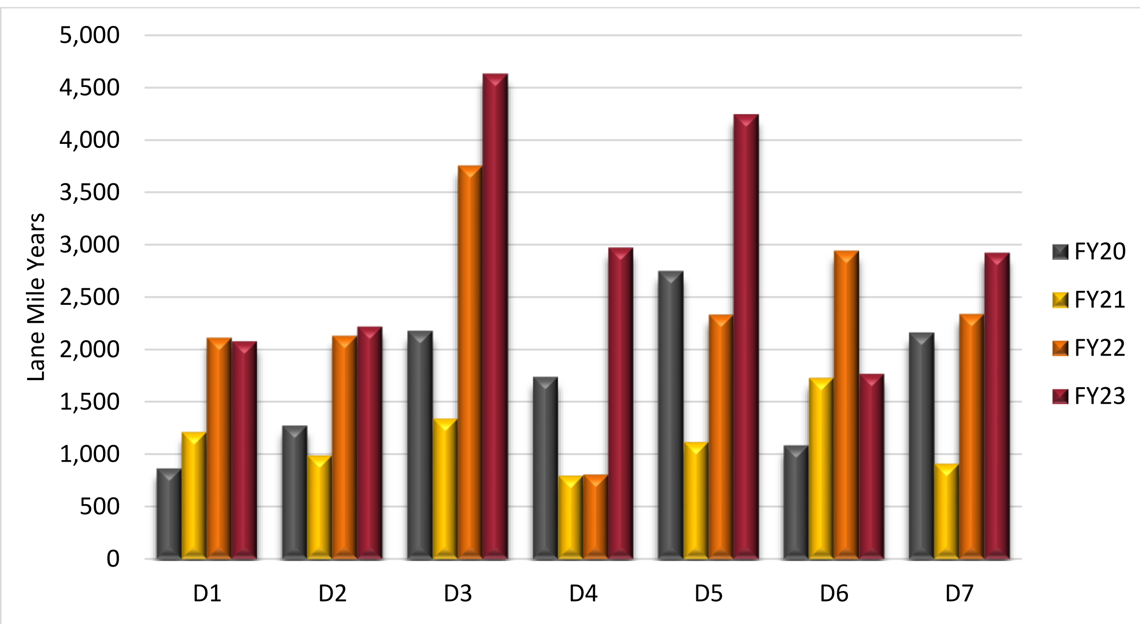


Figure 21: District LMY Allocation Targets

[4] Budgets based on update provided in December 2021. Budgets are based on programmed construction dollars, and are different than cash flows that carry construction projects across multiple fiscal years.

PAGD performed the FY 22 optimization in March 2021 and the FY 23 optimization analysis based on the budgets provided by the Deputy Administrator's office in January 2022. Figure 22 shows the suggested construction budget levels in $ millions and expected benefit in lane-mile-years for the two main types of improvement strategies (i.e. Maintenance and Rehabilitation) that can be used to extend the life of MDOT SHA pavements. These are the anticipated allocation forecasts per the Consolidated Transportation Program (CTP) as of December 2021.

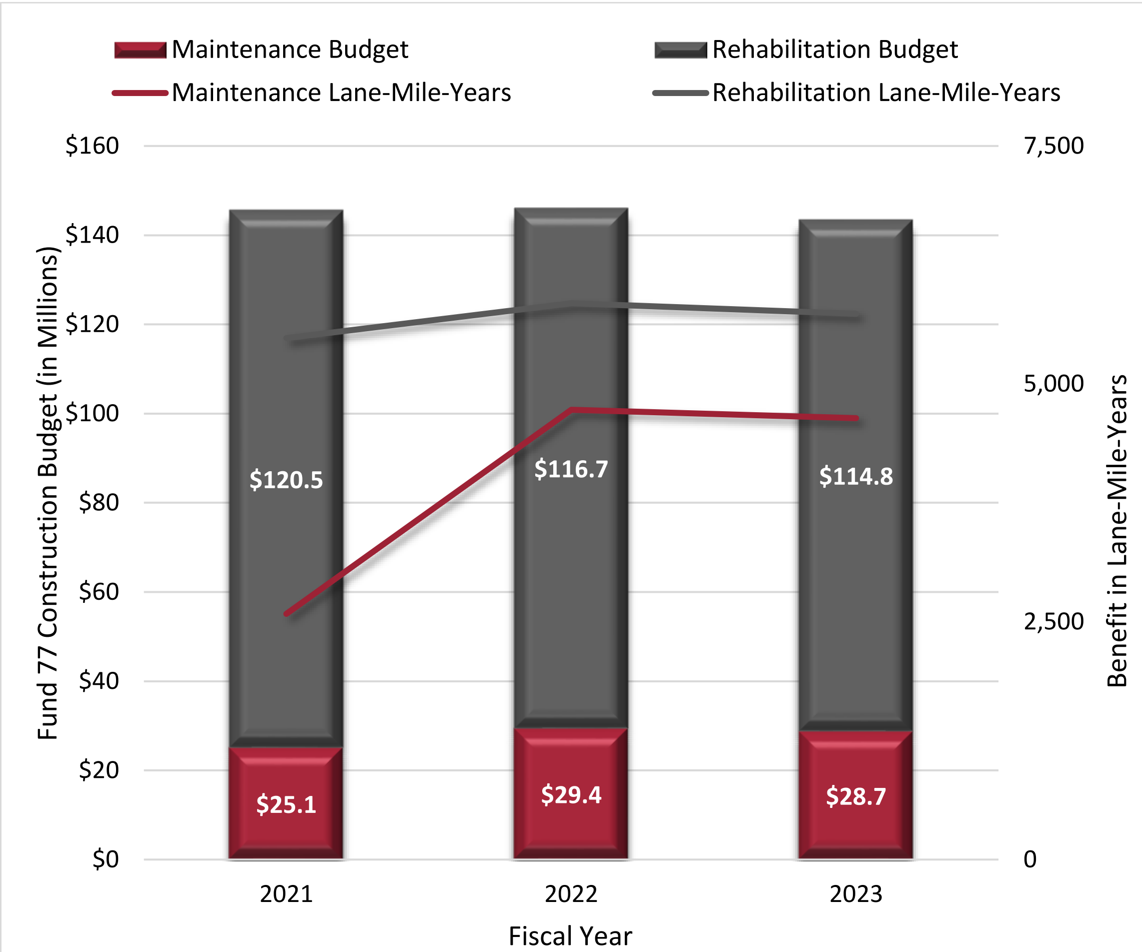


Figure 22: Fund 77 Treatment LMY Targets by Fiscal Year

To meet objectives, Fund 77 needs about **$400 million each year** overall, with construction remaining steady **at $350 million each year** through **2031** (based on a need of **$340 million in 2022 dollars** and inflating at **4.2% per year**). This budget includes items such as overhead, District Engineer (DE) funds, pavement markings, ADA and traffic barrier, and other phases, in addition to pavement construction. This assumes a system preservation approach with an appropriate mix of rehabilitation and preventive maintenance treatments. Figure 23 shows unfunded needs in cumulative lane miles of Fund 77 paving projects to maintain a pavement RSL of 20 years through **FY 2031** and the average unit cost for rehabilitation and preventive maintenance.

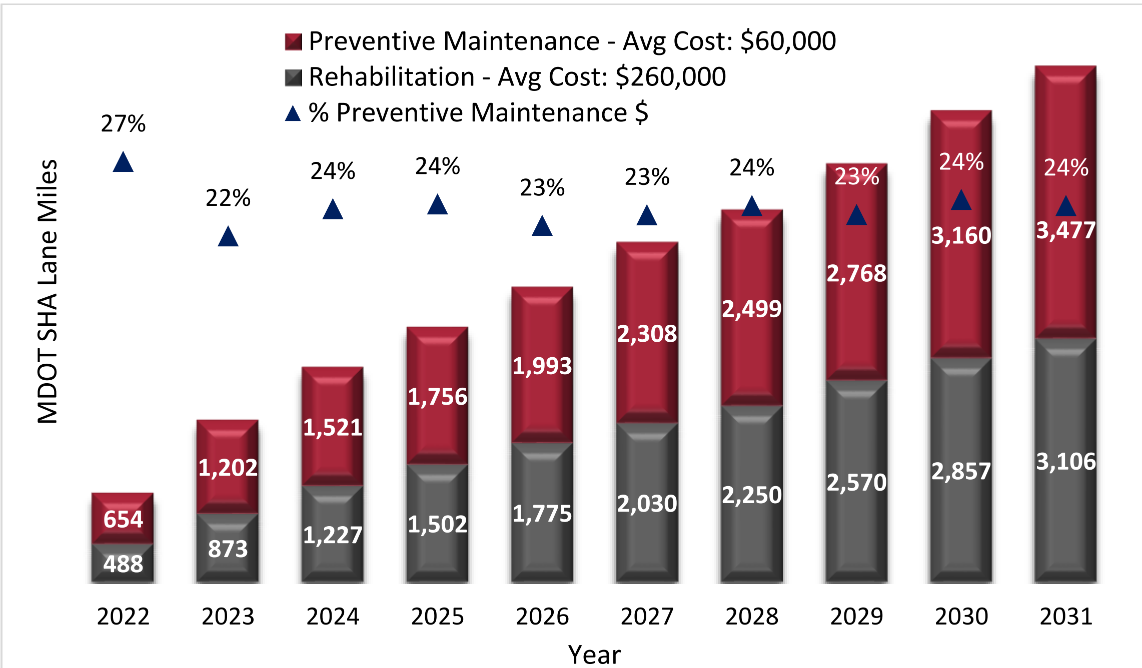


Figure 23: Unfunded Needs to Maintain Goals through 2031

Federal Pavement Performance Measures

On May 20, 2017, the Federal Highway Administration (FHWA) finalized the MAP-21/Fast Act rule which established new pavement performance measures for the National Highway System (NHS), separated by Interstate and Non-Interstate systems. Figure 24 presents the overall conditions (considering ride quality, cracking, and rutting/faulting) in terms of this rule in calendar year 2021 for the roadway network in all jurisdictions (including County and Baltimore City). The condition distributions were computed from the official Highway Performance Monitoring System (HPMS) dataset using the same methodology as specified in 23 CFR § 490.313 - Calculation of performance management measures.

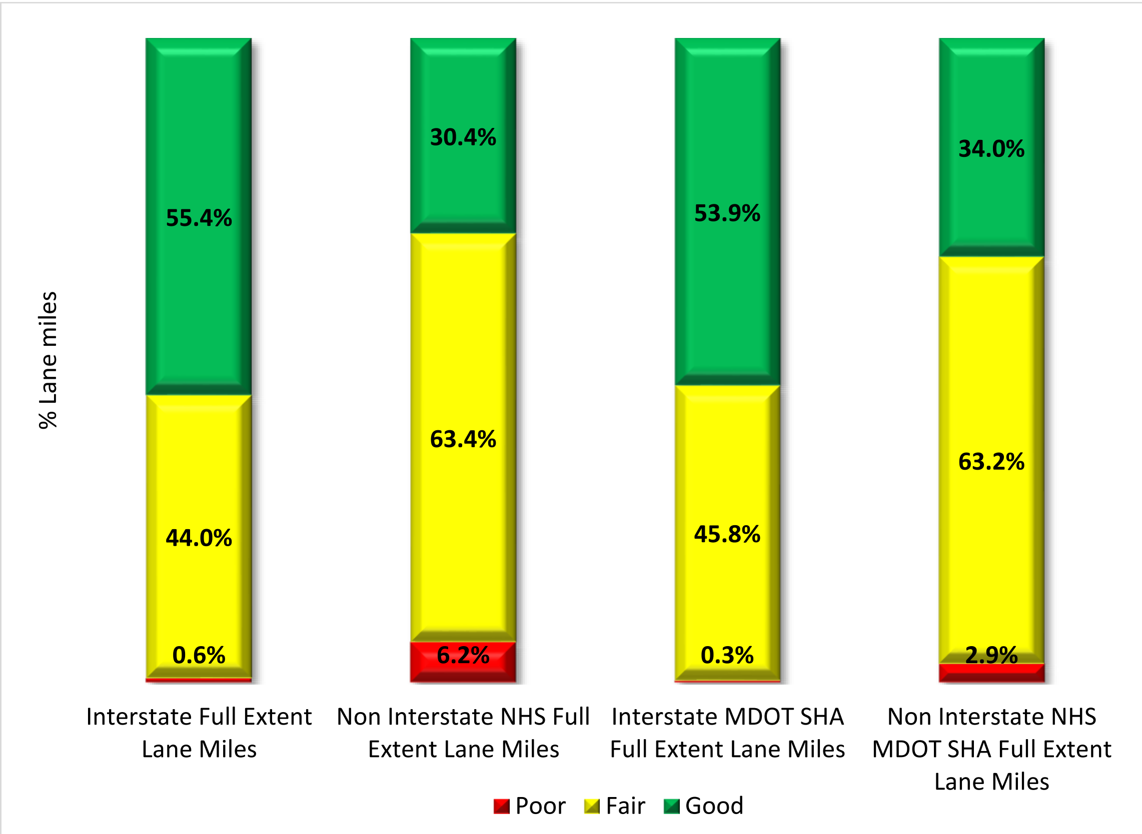


Figure 24: MAP-21/Fast Act Ratings

MDOT SHA has adopted a pavement performance measure system different than the MAP-21/Fast Act performance measures. MDOT SHA's performance measure system includes the following components: 1) all roadways owned by MDOT SHA, 2) friction measurements, 3) six categories for overall condition, and 4) performance measures are adjusted based on roadway functional class and site category. Alternatively, the MAP-21/Fast Act ratings: 1) only include interstate and non-interstate NHS roadways, 2) do not include friction, 3) utilize three categories for overall condition, and 4) do not consider functional class.

Appendix A: Data Collection and Processing

Accomplishments

Paving accomplishments are gathered through the efforts of our Pavement Management Section of the Pavement and Geotechnical Division.

A paving project is considered completed and accomplished when the final surface is placed on the roadway.

The process to update paving accomplishment information is conducted through comprehensive review and investigation of as-built construction activities and treatments within the Pavement Management Section, in partnership with construction staff. Considerable effort is made to track down the completion of roadway work, but it is expected that the information collected does not necessarily include 100% of the accomplishments to date.

Before 2004, only the number of lane miles resurfaced was captured as an accomplishment for MDOT SHA. In 2004, our Pavement Management Section began collecting Fund 77 preventive maintenance accomplishments, and in 2006, began collecting operational maintenance accomplishments to assist in our improved focus on system preservation techniques.

The various rehabilitation, preservation and maintenance terms are in Appendix B: Pavement Fix Definitions.

Performance Condition

The performance of MDOT SHA's pavement network is monitored annually. Each year, pavement ride quality, cracking, rutting, and friction conditions are measured in the outer-most through lane in each direction of travel for the majority of mainline roadways in Maryland.

Figure 25: Automatic Road Analyzer (ARAN)

A video record of the pavement surface and right of way is also captured every year.This information (with the exception of friction data) is collected at highway speeds using Automatic Road Analyzer (ARAN) testing devices, pictured in Figure 25. Friction condition is tested with the Pavement Friction Tester (PFT), exhibited in Figure 26. All equipment is owned and operated by MDOT SHA. Due to change of friction data collection procedure in 2017 and its deviation from the standard ASTM procedure (ASTM E274), a large portion of 2018 network friction data did not follow the historic trends and thus did not pass the PAGD data quality control check. As a result, and to address the change in friction values resulted from change of procedure, adjustment formulas were developed for friction numbers collected from sections in each functional class and median type (divided versus undivided) using the past four years of friction data and were applied to 2018 friction data. That is, measured friction data within each class were adjusted using historic trends to match the expected 2018 values.

In July 2020, OMT adopted a new methodology to convert speed adjusted skid number to RSL. The purpose of the change is to better identify and address roadway sections where skid resistance is more important. This new methodology will much more accurately identify the roadway segments that need to be addressed under

Fund 77, to act in a preventive manner to ultimately reduce the number of wet accidents. In contrast, Fund 76 will continue to be used in a reactive manner to address locations where wet accidents have been higher than average. More details are provided in the friction section.

MDOT SHA acquired its first ARAN vehicle in 1995. It acquired a second-generation vehicle in 2008.

In 2016, MDOT SHA acquired two new ARAN vehicles, using third generation technology. These devices employ the use of new measurement technology which uses a line laser instead of a point laser to measure the longitudinal roadway profile in each wheel-path, resulting in enhanced filtering and slightly smoother results. A Laser Crack Measurement System and new software algorithms are used to measure cracking with better accuracy and fewer false positives than before. Pavement rutting values are calculated from transverse profiles extracted from 3-Dimensional pavement images.

Changes in ARAN technology resulted in some changes in how the data collection systems function, and the accuracy of the data captured. The net result of using multiple sets of technology over the past several years has created some variability in the condition results.

MDOT SHA adjusted data collection procedures and data processing and analysis functions to address these changes in the ARAN data collection systems. The challenge was being able to utilize historical data combined with new data that was collected with different systems and two different levels of quality. Therefore, in many cases, previously reported data is updated so that it is as comparable to current data as can be.

Higher quality data are expected as advanced technologies are utilized. Through enhanced data quality control and quality assurance procedures, data quality has steadily improved. Irregularities in historic data condition trends will be gradually stabilized with these continuous efforts.

Ride Quality

Pavement ride quality is determined by measuring the pavement longitudinal surface profile in both the left and right wheel paths. The pavement profiles are used to generate a ride quality indicator known as the International Roughness Index (IRI). Ride quality data is provided for each 4/1000th mile pavement segment and is summarized into 1/10th mile sections.

Table 3 presents a complete list of highway functional classes and what they represent.

Table 3: Highway Functional Classes

Functional Class	Description
1	Rural Principal Arterial - Interstate
2	Rural Principal Arterial - Other Freeways
3	Rural Principal Arterial - Other
6	Rural Minor Arterial
7	Rural Major Collector
8	Rural Minor Collector
9	Rural Local
11	Urban Principal Arterial - Interstate
12	Urban Principal Arterial - Other Freeways
14	Urban Principal Arterial - Other
16	Urban Minor Arterial
17	Urban Major Collector
18	Urban Minor Collector
19	Urban Local

The IRI values that correspond 0, 20, and 50 RSL bins by functional class are shown in Table 4. Intermediate values are calculated using linear interpolation.

Table 4: Average IRI RSL values by Functional Class

Functional Class	Average IRI (in/mi)		
	RSL=0	RSL=20	RSL=50
1	170	108	45
2	180	115	50
6	250	153	55
7	265	163	60
8	280	175	70
9	325	198	70
11	170	108	45
12	180	115	50
14	250	153	55
16	265	163	60
17	280	175	70
18	280	175	70
19	325	198	70

Cracking

Cracking condition is determined based on the quantity of longitudinal and transverse cracks existing in the pavement surface. Cracking Density is the parameter adopted to indicate a pavement's cracking condition. For example, a cracking density of 0 represents a crack-free pavement and cracking density of 10 indicates 0.01 linear feet of cracking per square foot of pavement surface.

Unlike ride and friction, cracking data cannot be directly produced from a performance device. The ARAN collects pavement surface images that are post-processed in-house by staff utilizing computer analysis tool within Vision software to obtain the raw cracking data.

Vision Software includes a module that utilizes image analysis and pattern recognition techniques to detect cracks. Samples selected from regular intervals are manually traced, then compared with the fully automated detection results. The remaining fully automated results are then calibrated based on the comparison with the selected manually traced results. Calibrated cracking measurements from all pavement images began being used in 2013.

Functional cracks include all transverse, unsealed cracks, and any longitudinal unsealed cracks outside of the wheel path zones. Sealant that is present in the functional zone is ignored, as it is assumed that the sealant has essentially treated the underlying functional crack.

Structural cracks include all sealed and unsealed longitudinal cracks within the wheel paths. MDOT SHA recognizes wheel paths to be 40” wide each and separated by a 32” center zone.

The total quantity of structural and functional cracks in terms of linear feet is then converted to structural and functional crack densities (SCD and FCD respectively).

Table 5 provides the functional cracking density values that correspond 0, 20, and 50 RSL bins by functional class.

Table 5: Functional Cracking Density RSL values by Functional Class

Functional Class	FC Density		
	RSL=0	RSL=20	RSL=50
1	25	7	0
2	35	8	0
6	35	8	0
7	35	8	0
8	45	8	0
9	45	8	0
11	50	9	0
12	25	7	0
14	35	8	0
16	35	8	0
17	35	8	0
18	45	8	0
19	45	8	0

Table 6 provides the structural cracking density values that correspond 0, 20, and 50 RSL bins by functional class.

Table 6: Structural Cracking RSL values by Functional Class

Functional Class	SC Density		
	RSL=0	RSL=20	RSL=50
1	15	3	0
2	35	4	0
6	35	4	0
7	35	4	0
8	35	6	0
9	35	6	0
11	40	7	0
12	15	3	0
14	35	4	0
16	35	4	0
17	35	4	0
18	35	6	0
19	35	6	0

Rutting

Rutting is determined by measuring the transverse surface profile every 2/1000th feet. Twenty-six points are used across 8 feet from the old ARAN, and 400 points across 12 feet from the ARAN purchased in 2008. The maximum rut depth in the left and right wheel path is recorded and categorized based on the average rutting depth.

Table 7 provides the average rut depth values that correspond 0, 20, and 50 RSL bins by functional class.

Table 7: Rutting RSL values by Functional Class

Functional Class	Average Rut Depth (in)		
	RSL=0	RSL=20	RSL=50
1	0.30	0.19	0.07
2	0.35	0.21	0.07
6	0.40	0.24	0.07
7	0.45	0.26	0.07
8	0.50	0.29	0.07
9	0.50	0.29	0.07
11	0.30	0.19	0.07
12	0.35	0.21	0.07
14	0.40	0.24	0.07
16	0.45	0.26	0.07
17	0.50	0.29	0.07
18	0.50	0.29	0.07
19	0.50	0.29	0.07

Friction

Figure 26: Pavement Friction Tester (PFT)

Friction condition is determined by measuring the ability of a wheel to brake under wet conditions at 40 miles per hour using a standard ribbed tire. An indicator known as the Speed Adjusted Skid Number expresses the results of this test. The original method of converting SN to RSL was based strictly on roadway functional class, regardless of the friction site category. This was considered this to be an "okay" method as it was the best that could be done at the time based on available information. The new conversion is based on friction Site Category, which is dependent on friction demand. There are three Site Categories, where Site Category 1 is for the highest demand, in areas such as at traffic lights and pedestrian crossings. The lowest demand is Site Category 3, in areas without any geometrical constraints that influence friction demand. The Site Categories (1-3) are defined in Table 8 in the following page.

Table 8. Friction Site Category Definitions.

Site Category	Site Description
1	0.1 miles within approach to Railroad Crossings, Roundabouts, Traffic Lights, Pedestrian Crossings, Stop and Give Way Controlled Intersections, and the prevailing speed is ≥ 55 mph, **OR** Curves with radius ≤ 750 ft and speed limit ≥ 35 mph, all speeds, **OR** Downhill gradients > 10% and > 0.03 miles long, all speeds, **OR** Freeway/Highway off-ramps, speed limit ≥ 55 mph
2	0.1 miles within approach to Railroad Crossings, Roundabouts, Traffic Lights, Pedestrian Crossings, Stop and Give Way Controlled Intersections, and the prevailing speed is ≥ 35 mph and < 55 mph, **OR** 0.1 miles within approach to all other intersections ≥ 35 mph, **OR** Downhill gradients 5 to 10% and > 0.03 miles long and speed limit ≥ 35 mph, **OR** Undivided Highways without other geometric constraints which influence frictional demand, the travelling speed is at least 55 mph and average rutting > 1/4", **OR** Curves with radius > 750 ft and ≤ 1,500 ft and speed limit ≥ 35 mph. **OR** Freeway/highway off ramps, speed limit < 55 mph
3	All other situations

Table 9 provides the Speed Adjusted Skid Number values that correspond 0, 25, and 50 RSL bins by site category.

Table 9: Friction RSL values by Site Category

Site Category	Speed Adjusted Skid No.		
	RSL=0	RSL=25	RSL=50
1	45	55	65
2	35	45	55
3	30	40	50

Using a skid number = 45 for example, the RSL for a principal arterial was 35 years using the old methodology, where 0 years is poor, and 50 years is excellent. This was the case regardless of the friction demand. With the new methodology, the corresponding RSL for Site Category 1 is 0 years, 25 years for Site Category 2, and 37.5 years for Site Category 3. The net effect of this is that roadway segments with higher friction demand will rise higher on the Fund 77 recommended projects list. Conversely, the segments with little friction demand will appropriately not be a priority.

The change to statewide skid number RSL and overall RSL are minimal except for Site Category 3. The biggest difference lies in the roadway segments that are now classified as being in Site Category 3: those that are now in Site Category 3 generally have a much lower RSL than before. This is appropriate since we should hold Site Category 1 segments to higher standards, and therefore, some segments that were previously in Site Categories 1 and 2, are now in Site Category 3. Table 10 shows the comparison of average RSL using the old and new methodologies:

Table 10: Comparison of 2021 Friction RSL

Average RSL in 2021				
Demand Category	Old Method		New Method	
	Site Category	Avg RSL	Site Category	Avg RSL
High	1,2	7	1	5.4
Medium	3	22.1	2	20.4
Low	4,5	37.9	3	31.7
Overall		27.3		27.4

Appendix B: Pavement Fix Definitions

Table 11: Pavement Fix Definitions

Category	Type of Activity	Increase Capacity	Increase Strength	Reduce Aging	Restore Serviceability	Specific Fixes (Including but not limited to)
Reconstruction	Reconstruction	X	X	X	X	• Full-Depth Reclamation • Reconstruction
Structural Rehabilitation	Major Rehabilitation		X	X	X	• Cold In-Place HMA Recycling (CIR) • Break & Seat and Overlay • Crack & Seat and Overlay • Deep Mill and Thick Overlay • Rubblization & Overlay
Structural Rehabilitation	Structural Overlay		X	X	X	• **Overlay or mill/overlay combination where grade increases more than 1.5"** • Greater than 5% of project area has fatigue distresses needing patching • Any concrete overlay
Pavement Preservation	Minor Rehabilitation			X	X	• **Grade increase due to overlay or mill/overlay thickness is no more than 1.5”**, and the project receives less than 5% patching for structural distress
Pavement Preservation	Preventive Maintenance			X	X	Asphalt-surfaced Pavements: • Cape seal • Chip seal • Crack fill • Crack seal • Diamond grinding • Fog seal • High-friction surface • Hot In-Place Recycling (HIR) • Micro-surfacing • Modified chip seal • Overlay or mill/ overlay using ≤1" asphalt • Patching • Rejuvenators • Sand seal • Sandwich seal • Scrub seal • Slurry seal
Pavement Preservation	Preventive Maintenance			X	X	Concrete-Surface Pavements: • Cross-stitching • Diamond grinding • Diamond grooving • Dowel-bar retrofit • Joint sealing • Slab stabilization • Spall repair
Reactive Maintenance	Routine Maintenance				X	• Crack Fill/Crack Seal • Cleaning of roadside ditches and structures • Pothole patching
Reactive Maintenance	Corrective Maintenance				X	• Pothole repair • Patching of localized pavement deterioration, e.g., edge failures and/or grade separations along the shoulders • Concrete joint replacement or joint sealing • Concrete full-width and depth slab replacement at isolated locations
Reactive Maintenance	Catastrophic Maintenance				X	• Sinkholes • Water-main breaks • Concrete pavement blow-ups • Road washouts • Avalanches • Rockslides

Note: Highlighted areas (Major Rehabilitation, Structural Overlay, Minor Rehabilitation, Preventive Maintenance and Routine Maintenance) are those eligible to be programmatically addressed by Fund 77.