2022

Condition of Connecticut's Pavement

I-84 EB, Hartford, CT

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1. INTRODUCTION AND BACKGROUND

Purpose of Annual Report

This report on pavements for the Connecticut Department of Transportation represents the calendar year 2022. This report provides executive-level management and outside parties with a summary of Connecticut's pavement conditions. It provides a summary of the current condition of 1,883 lane-miles of interstate, 3,136 lane-miles of state-maintained non-interstate National Highway System (NHS), and 4,809 lane-miles of CTDOT Maintained Non-NHS roads (Totaling 9,826 lane miles and 3,715 centerline miles). Also summarized within this report are CTDOT's paving programs, funding, and projections of future activity resulting from the use of the Connecticut Department of Transportation (CTDOT) Pavement Management System (PMS). Except where otherwise noted, the current information presented in this document, such as pavement condition, inventory of lane-miles of roadway, etc., is derived from calendar year 2021 data. While there are over 35,000 lane miles of municipal roads in Connecticut, the state does not monitor or report on their conditions save for a small portion that is part of the HPMS.

To understand the current condition of the network and project the conditions in the future, CTDOT uses a Pavement Management System (PMS). State pavement engineers analyze pavement-rating data collected annually and then perform analyses and generate reports from this data. The PMS is also used to evaluate the effectiveness of funding priorities and pavement treatments and guide decision-making.

CTDOT Pavement Management System

Data Collection

CTDOT employs two Fugro Roadware Automatic Road Analyzer 9000 (ARAN) vans. The data collected by the vans are processed to identify the presence of different types of pavement distress, including wheel path rutting, cracking, faulting, and surface cross slope. (Faulting applies to concrete pavements only, which make up approximately 0.5% by centerline miles of CTDOT's pavement network.). The ARANs also provide 3-D imaging using a Laser Crack Measurement System (LCMS), which includes two scanning lasers. This offers excellent detail in the measurement of cracking.

Data Analysis

After collecting pavement condition data, the Photolog Unit then reports it out to the Pavement Management Group, who then utilize a Microsoft SQL Server database and a customized version of Deighton Total Infrastructure Management System (dTIMS®) software to analyze, summarize current condition, and predict the future condition of the network. Condition data are summarized by lane miles for federal Highway Performance Monitoring System (HPMS) reporting, and FHWA subsequently uses the reported data to determine the Federal performance measures. Condition data are summarized by centerline miles (road or route miles) for State performance measures.

2. OVERVIEW OF NETWORK MILEAGE

Statistics on the extent and length of Connecticut's roadway network, in both centerline (road) miles and lane miles, are provided in Table 1 below. Although Connecticut is the third smallest state in terms of area, it is ranked 44th for length of network centerline road mileage (*5*).

Table 1 Connecticut Centerline (Roadway) Miles and Lane-Miles* (2021)

Classification	Centerline (Road) Miles	Lane-Miles**
CTDOT Maintained NHS	**1,406**	**5,018**
Interstate	**346**	**1,883**
Non-interstate NHS (state only)	**1,060**	**3,136**
CTDOT Maintained Non-NHS	**2,309**	**4809*** **
Total CTDOT maintained routes and roads (excluding ramps)	**3,715**	**9,827**
Municipal NHS	**56**	**152**
Total Municipal Roads	**17,466**	**~35,300**
Total Municipal and CTDOT Roads	**21,182**	**~45,170**

* All figures have been rounded to the nearest whole mile. These mileages are from CTDOT Bureau of Policy and Planning Public Road Mileage as officially reported to the FHWA on Dec 31, 2021. The exact mileage on the ground, used for inventory, measured with automated equipment, and analyzed with software varies slightly from these reported figures. These totals exclude 110 centerline miles of Federal roads and 295 centerline miles of state park, state forest, and state institution roads.
**Lane miles are defined as centerline (road) miles multiplied by the number of lanes. These miles do not count shoulders as lanes.
***State Routes and Roads Lane Miles includes 249 lane miles of bridges and 464 lane miles of ramps.

Table 2 shows Connecticut's centerline and lane miles within the four CTDOT-designated highway maintenance districts.

Table 2 Approximate Centerline (Road) Miles and Lane-Miles by CTDOT District *

	Centerline (Road) Miles	Lane-Miles
District 1	800	2,500
District 2	1,100	2,700
District 3	700	2,200
District 4	1,100	2,500

Notes:* These mileages are from CTDOT Bureau of Policy and Planning Public Road Mileage
** The mileage amounts have been rounded to the nearest 100 miles.

The average surface age from 2008 through 2021 of the CTDOT-Maintained network can be seen in Figure 1 CTDOT-Maintained Network Average Surface Age Over Time. A simple regression model of age versus time generates a trend line slope of -0.0435. This indicates that CTDOT's network pavement surface is getting younger at a nominal rate, nearly a stable age. The previous year's trend line was a slope of 0.043, again demonstrating that the resurfacing and aging of the network is very nearly at a steady-state level.

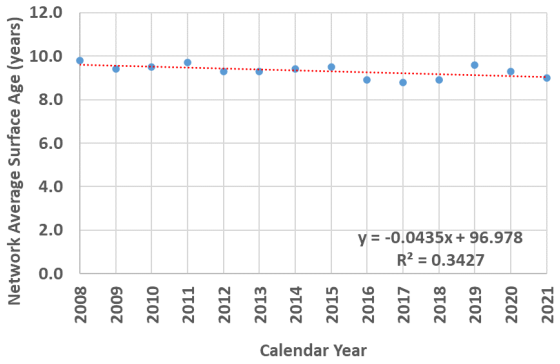

Figure 1 CTDOT-Maintained Network Average Surface Age Over Time (2008-2021)

Distribution of Pavement Surface Type

The distribution of roadway mileage by pavement type in Connecticut for both lane and centerline miles is shown in Figure 2 below. This demonstrates that the predominant pavement surface type is flexible (asphalt concrete), representing approximately 70.7% and 61.4% of centerline and lane miles, respectively. Most of

the remainder of the pavement network is composite pavement, defined as Portland Cement Concrete (PCC) overlaid with bituminous (asphalt concrete) pavement. The amount of PCC (rigid pavement) remaining uncovered in Connecticut is less than 1% of the network by lane miles.

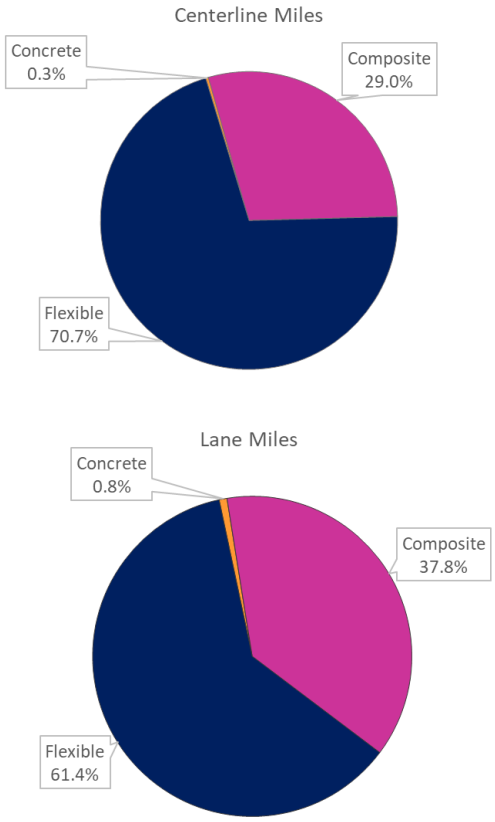

Figure 2 Distribution of CTDOT Pavement Network Surface Type by Centerline and Lane-Miles

Condition of Statewide CTDOT-maintained Roadway Network

CTDOT's internal performance measure for the overall category of CTDOT-maintained roads is the percentage of centerline miles in a state of good repair (SOGR)**.**

FHWA has also adopted SOGR following the FAST Act, and as defined in Code of Federal Regulations 23 CFR 490.313, National Performance Management Measures (April 2017), it must now be included in the Transportation Asset Management Plan (TAMP) developed every four years by the state of Connecticut.

CTDOT currently uses a composite rating system, the Pavement Condition Index (PCI), to express the condition of CTDOT-maintained pavements. A PCI is calculated for each 0.1-mile segment based on five pavement characteristic sub-indices; the overall PCI is a weighted average. The weights for the constituent indices that comprise the overall PCI are:

- ***Index_Roughness*** -10% (based on the International Roughness Index)
- ***Index_Rutting*** -15%
- ***Index_Cracking*** -25%
- ***Index_Disintegration*** -30%, *and*
- ***Index_Drainage*** -20%

The first three indices are related to the FHWA metrics described later for the NHS. The metric ***Index_Disintegration*** is used to quantify general degradation of the pavement surface caused by age, traffic, and weather exposure (similar to the ASTM D6433-designated distress Weathering/ Raveling) – primarily a function of oxidation of the asphalt binder. Still, a whole host of factors can cause this phenomenon which are extremely difficult to model accurately. In the CTDOT PMS, ***Index_Disintegration*** is currently calculated using pavement age as a proxy for measured distresses that are more elusive to measure using automated data collection techniques. Drainage refers to the ability of the roadway's surface to transport rainwater from the pavement structure. CTDOT uses information collected on pavement transverse cross slope and longitudinal grade to compute the ***Index_Drainage*** metric. The PCI and each constituent index are scaled from 1.0 to 9.0, where a pavement without defects would be scored 9.0. A pavement section for which the PCI is calculated at 6.0 or higher is classified as being in an SOGR.

The centerline miles of CTDOT-maintained roads in good, fair, and poor condition are tabulated for all sections at 0.1-mile increments to determine the overall percentage of pavement in good, fair, and poor condition. The results for 2021 conditions are shown in Table 3 below. The percentage of sections on the CTDOT maintained roads in 2021 that are in a SOGR (i.e., PCI ≥ 6 and rating of 'good') is 73.5%. It is worth noting again that these figures are for CTDOT-maintained roads only. Therefore, the condition of the municipal roads is not included in these percentages, nor are conditions for federal roads or state roads (parks, forests, and institutions) that are not maintained by CTDOT. For a side-by-side comparison of the condition of the CTDOT-maintained roads by centerline mile versus lane-mile, see Figure 3. It is also noteworthy that for the past three years, the overall percent of roads considered *Good* has gone up while the overall percent of roads considered *Poor* has gone down, a sign that the current funding levels combined with improvements to construction practices are making incremental improvements to the network.

Table 3 Connecticut Inventory and Conditions (2021) of CTDOT-Maintained Roadways Using the PCI by Centerline Miles (Excludes Towns + Overlapping Routes)

Route Category	*% Good**	*% Fair**	*% Poor**
INTERSTATE	90.5%	9.5%	0.0%
NON INTERSTATE NHS	78.0%	21.1%	0.9%
NHS	82.1%	17.3%	0.6%
NON_NHS	65.9%	31.4%	2.7%
ENTIRE NETWORK	73.5% SOGR	24.8%	1.7%

Notes: *These Good, Fair, and Poor percentages were calculated using CTDOT's Pavement Condition Index.

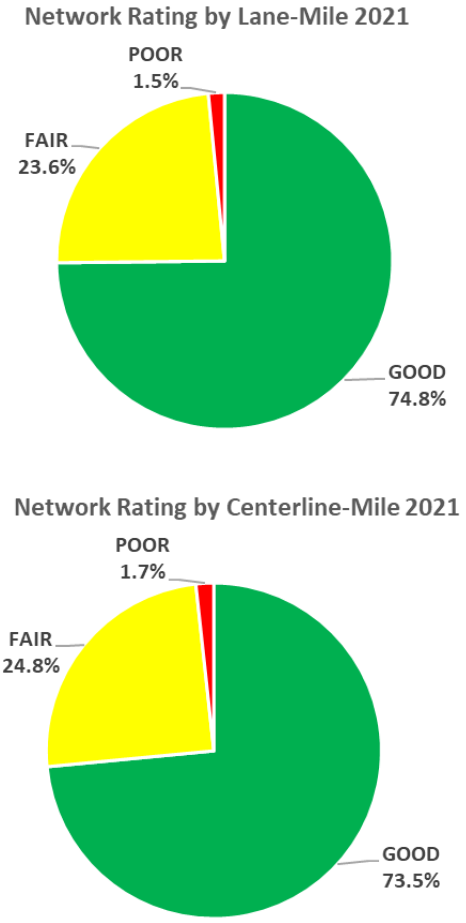

Figure 3 Conditions of CTDOT-Maintained Roadways (2021) Using the PCI, by Lane Mile and Centerline Miles (Excludes Town Roads + Overlapping Routes)

Condition of National Highway System (NHS) in Connecticut

The FHWA defines the National Highway System (NHS) as the Interstate Highway System and other roads important to the nation's economy, defense, and mobility.

For each performance metric (IRI, Rutting, Cracking, and Faulting), FHWA has established thresholds for good, fair, and poor conditions. Conditions are assessed using these criteria for each 1/10-mile-long pavement section. The NHS condition is summarized and reported by lane miles per the requirement of FHWA.

The FHWA performance measures can be transcribed into a good-fair-poor rating as well. An individual section is rated as being in good overall condition if all of the metrics for that section are rated as good. An individual section is rated in poor condition when two or more metrics are rated as poor. For all other combinations, the individual sections are rated as fair. The FHWA prescribes all of the methodology for the NHS rating described above in 23 CFR 490.313.

The resultant overall conditions for the NHS in 2021 are shown in Table 4.

Additional details about the condition of the NHS, broken down into interstate and non-interstate NHS in Connecticut, using the categories delineated by FHWA, are given in Figure 4. Specifically, CTDOT has adopted the FHWA's pavement condition performance measures for the NHS pavements.

Table 4 Overall Connecticut NHS Inventory and Conditions (2021) (Includes State and Town NHS)(CTDOT Asset Fact Sheet, June 2023)

	Lane miles	Good	Fair	Poor
NHS Pavement *	5,162	48.7%	50.1%	1.2%

*Note: "Missing, invalid, or unsolved lane miles are excluded from calculations to determine G, F, and P percentages. Lane miles on the full extent basis coded as bridges in HPMS are also excluded from the calculations but are included in the total lane miles.

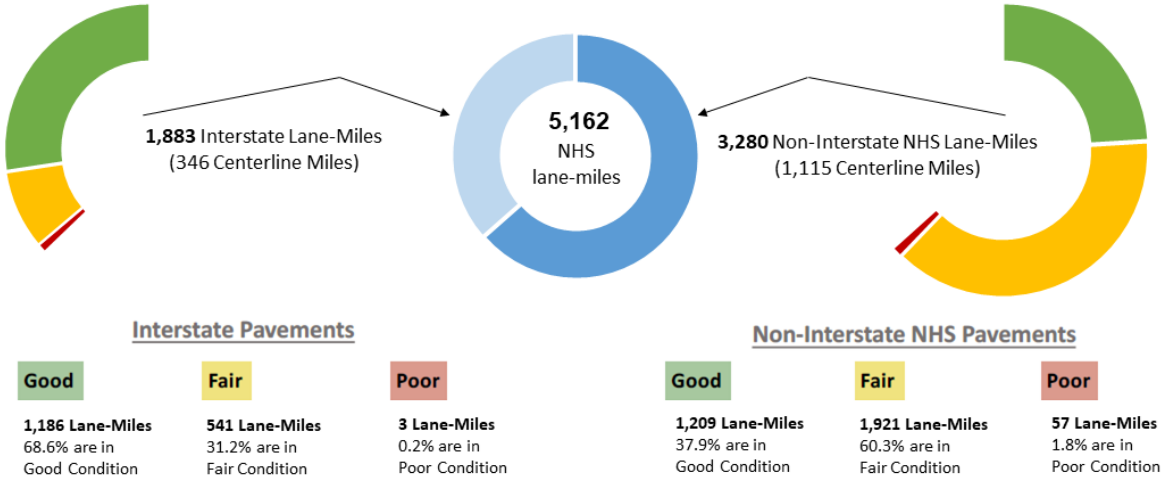

Figure 4 Connecticut NHS Pavement Inventory and Conditions as Required for FHWA Reporting (Based on 2021 HPMS pavement condition data submitted to FHWA June 14, 2022) (See Note, Table 4)

Historical Presentation of Pavement Performance Measures

Before the advent of the TAMP, and even before MAP21 was enacted, CTDOT reported the following two pavement performance measures as representative of the condition of the road network:

- Percent of State Maintained Roads on the NHS with Acceptable or Better Ride Quality ≤170 in/mi
- Percent of the Entire Network of State Maintained Roads with Acceptable or Better Ride Quality ≤170 in/mi

The definition of acceptable or better (≤170 in/mi) is utilized by FHWA for reporting the HPMS ride quality in their Highway Statistics Series reports (*6*).

The above-cited pavement measures are based only on ride quality. Ride quality refers to the pavement's smoothness over a measured section of roadway. If a roadway doesn't have a smooth ride, it is referred to as rough; thus, smoothness and roughness are used interchangeably when referring to measured ride quality.

The roadway characteristic known as the International Roughness Index (IRI), which is obtained from longitudinal profile measurements along the two-wheel paths of a travel lane, is used as a measurement for ride quality and is a well-established indicator of current roadway pavement condition as experienced by road users. In Connecticut, this is obtained with the CTDOT ARAN vehicles. The left and right wheel path IRI values are averaged to determine the IRI metric for the individual roadway segment being considered. The ride quality using IRI is reported as the change of height (inches) per mile of roadway, where a lower measured value indicates a smoother road.

To compute the CTDOT performance measures, the percentage of roadway centerline miles having an IRI of less than or equal to 170 in/mile is calculated. That percentage represents the percentage of state-maintained roads with acceptable or better ride quality.

Figure 5 below shows the condition of the CTDOT maintained network and the NHS elements of the network over the past eleven years *(3)*. Based on IRI alone, the condition of both networks has improved every year since 2012. Note that the PCI is not included in these graphs. In addition, the Ride Quality (IRI) values

reported in this graphic use a 3-year moving average.

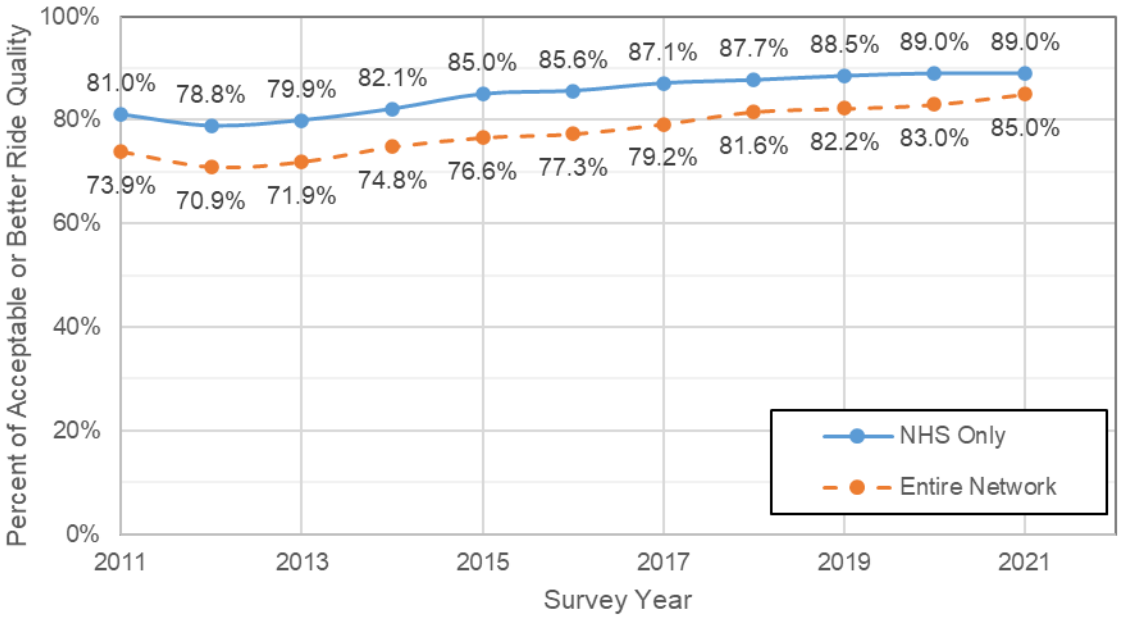

Figure 5 Ride Quality (IRI) Using 3-year Moving Average for the NHS Systems and the Entire CTDOT-maintained Network (3) for Calendar Years 2011 through 2021.

Performance Projections for the Future

As defined in federal regulation 23 CFR 490.313, the FHWA requires states to include targets (as well as the measures discussed previously) for the condition of NHS pavements reported in the TAMP. Connecticut performance targets have been set to be aligned with both the federal requirements and state goals and objectives**. They are based on anticipated funding levels projected to be available** for transportation. The targets help guide Connecticut in allocating resources to projects and programs to make progress toward the goals.

Using the measures of condition defined by FHWA, consistent with state asset management objectives, all State DOTs must also specify their desired "state of good repair" for the 10-year analysis period. The desired SOGR must also support progress toward achieving goals.

As part of the federal rule (23 CFR Part 490), states must also set two- and four-year asset condition performance targets. States must also maintain NHS pavements to meet federally established minimum condition levels. **The federal minimum condition level for pavements is to ensure that no more than five percent of pavement lane miles on the Interstate system are in poor condition**.

Federal Minimum Condition Level for Interstate System Highway Pavements
Maximum of 5% of pavement lane-miles in poor condition

Figure 6 Federal Minimum Condition Level for Interstate Pavements

Table 5 Performance Targets for Connecticut NHS (Percent of Lane-miles Projected to be in Good and Poor Condition)

	2-Year Targets		4-Year Targets	
	Good	Poor	Good	Poor
Interstate Pavements	72%	1.0%	70%	1.3%
Non-Interstate NHS Pavements	37%	2.7%	35%	3.5%

NOTE: Performance targets were also submitted to FHWA by CTDOT via a report called "Transportation Performance Management - State Biennial Performance Report for Performance Period 2022-2025 (New Targets) 2022 Baseline Performance Period Report." (*7*)

3. CTDOT PAVING PROGRAMS

Maintenance Resurfacing Paving Program

The purpose of the Maintenance Resurfacing Program (MRP) is to resurface pavements that are in poor to fair condition due to either functional or structural distresses by using DAS contracts that can be delivered quickly and efficiently. The program is needed to maintain the pavement network in a state of good repair by performing minor rehabilitation on pavements in backlog to prepare them for future pavement preservation cycles or to buy time to deliver a major rehabilitation project.

A substantial number of CTDOT miles of paving is accomplished each year under the MRP. These projects are primarily state-funded using state bond financing. Although this has traditionally been an annual paving program developed approximately 18 months before the actual paving, PMG is currently developing multi-year programs, which involve pavement preservation projects as well (see also next section) and allow for more efficient planning and programming by utilizing models that include Cost-Benefit Analysis.

For calendar year 2022, paving was planned for approximately 551 lane miles on 81 state roads. During the previous calendar year (2021), approximately 495 lane miles were resurfaced. The amount budgeted for these 495 lane miles in 2021 was roughly $69 million.

Table 6 Summary of Planned Maintenance Resurfacing Paving Program[1] (2022)

Treatment Type	Location	Number of state roads	Lane Miles	Approx. Material Quantities (tons)**	Approx. Cost ($million)***
Overlay	District 1	27	155.6	296,250	$23.7
Overlay	District 2	16	124.6	237,500	$19.0
Overlay	District 3	19	112.6	215,000	$17.2
Overlay	District 4	19	157.8	301,250	$24.1
Grand Total		**81**	**550.6**	**1,050,000**	**$84.0**

Notes: [1] This Table is based on the CTDOT Final Resurfacing Program mileages, quantities, and cost are estimated
* Mileage excludes ramps
** An estimated average cost of $80/ton is used to calculate approx. quantities. However, before calculating the quantities, the approximate cost was reduced by 30% to exclude safety improvement costs that are not directly related to paving.
***These are estimated using the 2022 department-established $305,000 per 2-lane mile cost.

Pavement Preservation Program

The purpose of the Pavement Preservation Program (PPP) is to preserve pavements that are in good to fair condition by using thin overlays and sealing strategies that save money over the pavement's life cycle. The program is delivered through construction contracts and is needed to maintain the pavement network in a state of good

repair at the lowest cost and with the lowest impact to the traveling public.

As noted earlier, pavement preservation is the preferred surface treatment program in that every mile of road that is preserved defers the higher cost of rehabilitation. Additionally, using network preservation techniques, it is easier to keep the condition of the roads in an SOGR and lower the highway user costs with smoother pavements. CTDOT has begun prioritizing and implementing preservation projects utilizing a 3-year condition/funding projection. To date, three types of preservation treatments have been employed: asphalt-rubber chip seals, ultra-thin bonded overlays, and mill and fill (overlay). See Table 7 for details on 2022 preservation projects by district.

Table 7 Summary of Planned Pavement Preservation Program (2022)

Treatment Type*	Location	Number of state roads	Centerline Miles	Lane-Miles	Material Quantities (SY)	Approx. Cost ($million)
UTBO	District 1	2	5.86	17.69	137,855	$2.0
	District 2	2	17.09	36.40	393,778	$6.8
	District 3	3	11.3	23.34	275,599	$8.1
	District 4	2	14.98	34.87	333,797	$8.3
ARCS	District 1	3	10.34	18.10	150,707	$2.0
	District 2	3	18.42	36.84	318,514	$3.5
Mill and Overlay	District 1	1	9.13	37.56	529,900	$22.4
	District 3	1	4.38	13.14	375,000	$11.3
GRAND TOTAL		17	91.5	217.94	2,515,150	$64.40

*Notes:*UTBO=Ultra-thin bonded Polymer Modified Asphalt (PMA)overlay*
ARCS=Asphalt-rubber chip seal, expenditures from CTDOT ViewPort

Pavement Rehabilitation and Reconstruction Program

Beginning in CY2024, a new funding stream was established for a new paving program called the Pavement Rehabilitation and Reconstruction Program (PRRP). The purpose of the PRRP is to perform major rehabilitation, up to and including reconstruction, on pavements in poor structural condition using construction contracts. The program is needed to maintain the network in a state of good repair by removing structurally deficient pavements from backlog to prepare them for future pavement preservation cycles.

4. OTHER CTDOT PAVEMENT-RELATED ACTIVITIES

Various strategies are being implemented to improve the performance metrics of MAP-21 pavement, including reducing crack percentage, improving smoothness, and minimizing rutting. These strategies involve using polymer modified asphalt (PMA), repairing and filling existing pavement before paving, applying thin preservation treatments like ultra-thin overlays and rubberized chip seals, and improving pavement smoothness and uniformity through specifications. Furthermore, using material transfer vehicles (MTVs) during paving operations and the requirement for contractors to obtain pavement cores to determine asphalt concrete pavement density have resulted in smoother, denser, and more uniform pavements. These specification improvements are the outcome of years of collaboration with the industry and are expected to produce positive results.

New Technology

Connecticut has a proven track record of being at the forefront of adopting and utilizing automated technology for road inventory and analysis. This has led the CTDOT to acquire and use ARANs for network data collection. The CTDOT has gathered network-level roadway images and data since the early 1970s. Currently, the Pavement Design Unit and the CAP Lab are collaborating on research initiatives to pilot traffic-speed Ground Penetrating RADAR to conduct preliminary engineering forensic investigations.

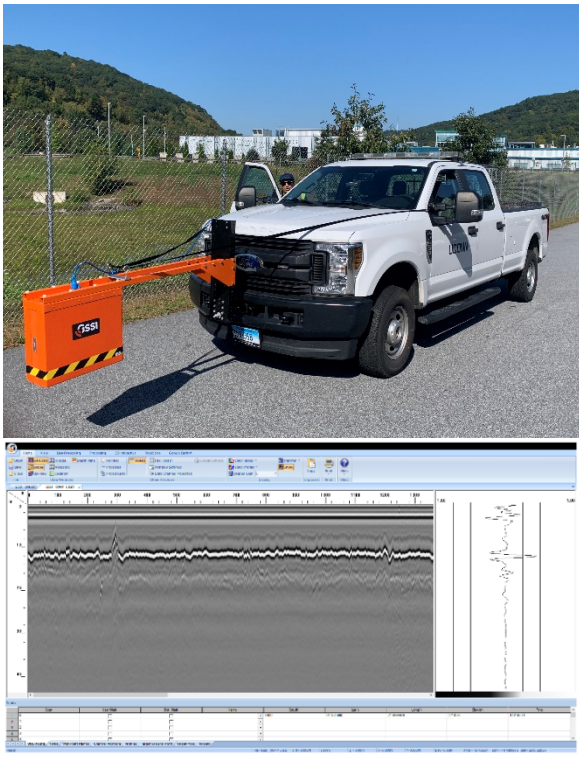

Figure 7 CAP Lab vehicle with the 2.0 GHz Air-Launched RADAR (left), Software output showing radio signal of GPR data (right)Research Initiatives in Pavement Management, Maintenance, and Preservation

Implementation of a new Pavement Management Framework

The Pavement Management Group, with the support of the CAP Lab, is implementing a new framework within the state's pavement management system. This involves using a new rating system and distress-based triggers in the dTIMS™ software package. By doing so, they can forecast pavement conditions more responsively and select treatments more effectively. Additionally, this will simplify the computer models and ensure flexibility for years.

Preparatory Analysis in Advance of Balanced Mix Design Implementation

The pavement materials community has been searching for practical mixture performance tests

that are easy to conduct and correlate with field performance. To achieve this goal, a national initiative called "Balanced Mix Design" (BMD) is being implemented to modernize Quality Assurance specifications.

The CAP Lab, under the CTDOT, has been conducting a long-term study since 2016 on asphalt pavement mixes placed across the state. They are using modern mixture performance tests to evaluate the mixes placed in-service across the state. The researchers are beginning to link field performance and laboratory performance to identify desirable traits. A new iteration of pavement specifications will be implemented in the state within the next 3 to 5 years based on the findings.

Figure 8 Mixture Performance Testing conducted at the CAP Lab in preparation for Balanced Mix Design Implementation. Clock-wise from the top-left corner: Hamburg Wheel Tracker (AASHTO T324), Texas Overlay Test, 100 kN Instron 1331 Load Frame with FastTrack 8800

Implementation of a GIS Database for Forensic Coring in the Transportation Enterprise Database (TED)

CTDOT and the CAP Lab have developed a GIS layer for pavement core data across the state. Each core is catalogued in the CTDOT Enterprise GIS system with photos and other pertinent metadata, tied directly to the Linear Referencing System (LRS). The goal is to minimize coring in the future and for the core data to serve a wider audience within the DOT, saving money and future lane closures.

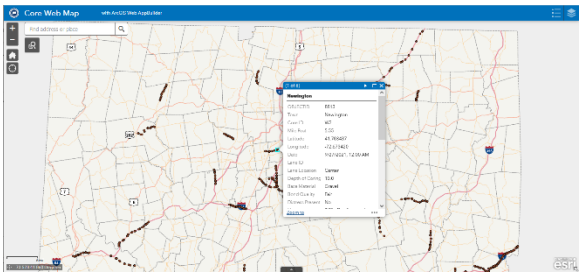

Figure 9 Core Database for State-wide Forensic Pavement Coring in the TED/GIS Interface

Sustainability

The first-annual report identified Warm Mix Asphalt Modification, Recycling, Reclaimed Asphalt Pavement, Reclaimed Asphalt Shingles, and Polymer Modification as materials and methodologies that improve the sustainability of pavements across Connecticut either with longer-lasting materials or diversions of materials that would otherwise be a waste product. Any action taken to improve the *in-situ* performance of pavement can be attributed to improving its sustainability. To that end, the CTDOT/CAP Lab effort to update and enhance the modeling methods for pavement management to optimize project selection and improve the overall performance of the network while extending the service life of pavements where appropriate continues to contribute to the sustainability of the State's roadway network.

5. SUMMARY AND CONCLUSIONS

Connecticut's Department of Transportation (CTDOT) has various rehabilitation and resurfacing programs that aim to increase the useful life of pavements. The ultimate goal is to

maintain a State of Good Repair (SOGR) by utilizing pavement preservation treatments, conducting state-of-the-art condition surveys, and employing forecasting techniques that use deterioration modeling. However, due to high traffic levels and a harsh climate, Connecticut's roadways experience significant wear and tear. As a result, maintaining Connecticut's roads in a SOGR requires a considerable amount of resources.

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