Appendix J:
Needs – Pavement

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Kentucky's Long-Range Transportation Vision

INTRODUCTION

This technical memo summarizes the Kentucky Transportation Cabinet's (KYTC) spending needs between 2022-2045 for pavement asset management on state-owned roads, including both the Rural Secondary (RS) system and the remainder of the state-owned system. The technical memo has three primary sections including this Introduction. The Methodology section describes the data used in the needs assessment, assumptions, and data processing steps. The Results section presents the needs by category and by year of expected expenditure. All dollar amounts are in 2022 U.S. dollars (USDs) unless otherwise specified.

METHODOLOGY

Overview

The methodology has two primary components, one for pavement preservation needs for RS routes and one for pavement asset management needs for the rest of the state-owned system. Pavement preservation needs for the RS system are derived from 15 years of historical spending converted into 2022 USDs. Historical spending is multiplied by the share of spending in fiscal year (FY) 2021 that contributed toward pavement preservation as opposed to maintenance or administrative costs. Trends are extrapolated from this historical pavement preservation spending. Twenty-four-year spending needs are the sum of the extrapolated amounts.

Pavement asset management needs for the state-owned non-RS system are derived from a simplified pavement condition forecasting model that was developed for this analysis. KYTC's Pavement Management System (PMS) was not used for this needs analysis because PMS was receiving major updates. The pavement condition forecasting model allows for different spending amounts to be tested to identify the minimum annual spending that will achieve no more than 8% of lane-miles in poor condition in 2045 as defined by the state definition of "poor," which is used for KYTC's pavement management decisions, rather than by the federal definition of "poor."[1] Twenty-four-year spending needs are the amount of spending that the model predicts will be needed to achieve this condition target.

Data Sources

Table 1 lists the data sources used in the analysis. Different data is used to estimate spending needs for RS pavement and for non-RS state-owned pavement.

Fifteen years of historical spending for CB01 (emergency funds) and CB06 (regular rural and secondary system funding) provide the basis for estimating needs for the RS system. CB01 includes master agreements while CB06 includes projects that go through the letting process. While CB01 includes some maintenance activity in addition to pavement preservation, the vast majority of CB06 is for pavement preservation.[2] Activity-level spending for fiscal year (FY) 2021 allows for preservation work to be separated from other activity types. The simplified pavement condition

[1] Meeting with Chad Shive, November 1, 2021. Email from Chad Shive on April 4, 2022.
[2] Meeting with Craig Caudill, November 16, 2021.

forecasting model that is used to calculate pavement preservation needs for the state-owned non-RS uses the number of lane-miles of each road by condition and annual spending budgets as its primary user-provided inputs. Pavement treatment unit costs, treatment effects, and forecasted 10-year budgets for the primary treatment categories are used in the model to forecast the amount of treatments that a given budget can "buy" and to estimate those treatments' effects.

Table 1: Primary Data Sources

Description	Source	Purpose in Methodology
Historical spending for CB01 and CB06 from fiscal years (FY) 2007 to 2021	Kentucky Transportation Cabinet, Office of Budget and Fiscal Management, December 7, 2021	Derive trends in spending for pavement on the RS system
Activity-level FY2021 spending for CB01 and CB06	Kentucky Transportation Cabinet, Office of Budget and Fiscal Management, December 8, 2021	Identify share of CB01 and CB06 spending that is for pavement preservation
2021 inventory of current KYTC lane-miles on state-owned non-RS system by condition	Kentucky Transportation Cabinet, Pavement Management Branch [3]	Lane-miles by condition is a model input. This applies for non-RS roads
Unit costs for KYTC pavement treatments and associated weights for each treatment	Kentucky Transportation Cabinet, Pavement Management Branch [4]	These are used to calculate average unit costs for preventive maintenance, preservation / thin overlays, and rehabilitation and replacement. This applies for non-RS roads
Treatment effects for preventive maintenance, preservation / thin overlays, and rehabilitation and replacement	Kentucky Transportation Cabinet, Pavement Management Branch [5]	These are used in the model to adjust pavement condition as treatments are applied. This applies for non-RS roads
Estimated 10-year budgets for preventive maintenance, preservation, thin overlays, and rehabilitation	Kentucky Transportation Cabinet, Pavement Management Branch [6]	These are used to set initial spending for each treatment category in the model. This applies for non-RS roads
Multiplier to convert historical amounts to 2021 USDs based on Consumer Price Index (CPI)	U.S. Bureau of Labor Statistics[7]	Convert historical spending to 2022 USDs

[3] Email from Chad Shive, April 3, 2022.
[4] Weights derived in phone call with Chad Shive on April 12, 2022.
[5] Email from Chad Shive, April 3, 2022.
[6] Email from Chad Shive, April 3, 2022.
[7] U.S. Bureau of Labor Statistics (n.d.). CPI Inflation Calculator. Retrieved from https://www.bls.gov/data/inflation_calculator.htm.

Assumptions

The following primary assumptions support the needs analysis.

- KYTC's pavement condition target of no more than 8% of lane-miles in "poor" condition will remain constant through 2045.
- The number of lane-miles being maintained will not change enough on either the RS or the state-owned non-RS systems to dramatically change pavement asset management needs.
- Labor, equipment, and material costs for non-RS roads will increase in line with historically derived trends.
- Activity spending shares for CB01 and CB06 will remain similar to what they were in FY 2021.
- Annual spending needs associated with any funding code (e.g., CB01, CB06) will not decrease in constant dollars.

State-Owned Non-Rural Secondary System

Build Simplified Pavement Condition Forecasting Model

An R-based model was built to generate a 24-year forecast of pavement condition at different annual spending levels by applying pavement treatments each year that can be afforded within a given annual treatment budget to update the starting condition of non-RS state-owned pavements. R is a free, open-source, statistical programming language used for the predicative R-based model. The model takes as an input the number of lane-miles within the "good", "fair", and "poor" condition categories and user-defined annual spending budgets. The model advances pavement in age and condition based on pre-determine time-in-condition rules, it applies the treatments that can be afforded by that year's and that spending level's budget, and it upgrades the condition of the number of lane-miles that could be treated before going through the same process for each subsequent year.

The model's primary inputs are the number of lane-miles in "good", "fair", and "poor" condition and the starting budget for each of the three treatment categories (i.e., preventive maintenance, preservation and thin overlays, and rehabilitation and replacement). Treatment categories represent the individual treatments within them through treatment effects and costs that are weighted based on their prevalence on the state-owned non-RS to produce a representative average.

Table 2 shows that the model applies preventive maintenance to "good" condition pavement while it applies the other two treatment categories to "poor" condition pavement. In reality, preservation and thin overlays are sometimes applied to "fair" condition pavements, but often they are applied to pavement that has just transitioned from "fair" to "poor" condition, which is why this model applies them to "poor" condition pavement. After each treatment category is applied, the condition of the pavement that the model applies them to is improved for a number of years that depends on the treatment category and is also described as the "effect of application" in the difference in the length of time for which a pavement remains in a given condition before deteriorating reflects differences in the treatment categories' effects.

Table 2: Application Window and Effect of Treatment Categories

Treatment Category	Pavement Condition Where Applied	Effect of Application
Preventive Maintenance	Good	Keep in good condition for 3 years, fair for 5 years
Preservation and Thin Overlays	Poor	Keep in good condition for 4 years, fair for 7 years
Rehabilitation and Replacement	Poor	Keep in good condition for 6 years, fair for 8 years

The model derives treatment cost categories by producing a weighted unit cost average for treatments in that category. Unit costs for each treatment along with the weights used in deriving the average are provided in Table 3. The individual treatment weights were provided by KYTC and represent the prevalence of the treatment.

Table 3: Treatment Costs and Weights

Treatment Categories	Treatment	Unit Cost ($ per Lane-Mile)	Network to Which Treatment Is Applied	Individual Treatment Weights within Treatment Category
Preventive Maintenance	Chip Seal	$26,000	MP	15%
	Microsurfacing	$42,000	All	85%
Preservation and Thin Overlays	Cape Seal	$48,000	All	11%
	Thin overlay	$75,000	MP	71%
	Thin overlay	$220,000	Interstates and Parkways	7%
	Diamond Grind and Repair	$350,000	MP	4%
	Diamond Grind and Repair	$350,000	Interstates and Parkways	7%
Rehabilitation and Replacement	Intermediate Overlay	$375,000	Interstates and Parkways	25%
	Thick Overlay	$500,000	Interstates	10%
	Structural Overlay	$1,100,000	Interstates	15%
	Rehabilitation	$500,000	MP	25%
	Replace	$2,200,000	Interstates and Parkways	15%
	Replace	$1,350,000	MP	10%

Table 4 provides the resulting unit costs for the treatment categories.

Table 4: Unit Costs of Treatment Categories

Treatment Category	Weighted Average ($ per Lane-Mile)
Preventive Maintenance	$39,600
Preservation and Thin Overlays	$111,929
Rehabilitation and Replacement	$773,750

The model applies a user-defined spending budget to the state-owned non-RS pavements. It then distributes the budget among treatment categories to match the "initial spending shares" shown in Table 5. These initial spending shares are based on the treatment categories' forecasted 10-year budgets. When the user inputs an annual spending amount, the spending is split among the treatment categories in accordance with the initial spending shares. These category-level amounts may be reallocated to any year in the 24-year modeling period if there is inadequate pavement in that condition to treat. Specifically, if the initial category-level spending in any given year would treat more lane-miles with preventive maintenance treatments than would transition from "good" condition to "fair" condition, then the excess spending is reallocated to preservation and thin overlays for that year.

Table 5: Starting Budget by Treatment Categories

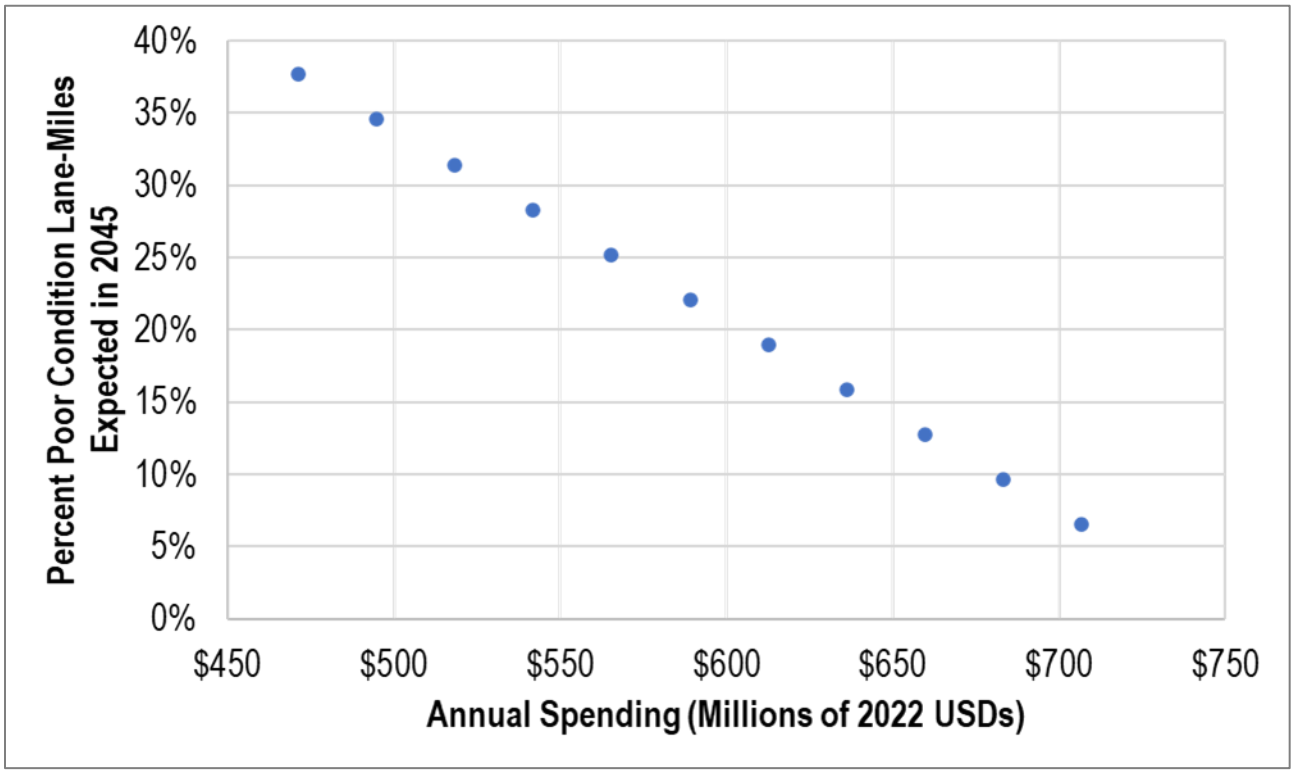
Treatment Category	KYTC Work Types	10-Year Budget (Millions)	Initial Budget Shares
Preventive Maintenance	Preventive Maintenance	$345	7.3%
Preservation and Thin Overlays	Preservation	$284	6.0%
	Thin Overlays	$2,653	56.3%
Rehabilitation and Replacement	Rehabilitation	$1,430	30.3%

After applying the annual spending to the input system, aging pavement, and the treatment categories that the budget can afford for each year, the model summarizes the number of lane-miles of pavement that are in the good, fair, and poor condition categories in 2045. The model is run for multiple annual spending levels to determine the lowest spending level that meets the performance target of no more than 8% of lane-miles being in poor condition in 2045.

Derive Performance Curve

A scatter plot is created based on the forecasted share of the non-RS state-owned system in "poor" condition in 2045 under the different annual spending levels. Using linear regression, a line is fit to the points described by this scatter plot to produce a "performance curve",[8] which is shown in Figure 1. The curve is used to derive the minimum annual spending that will achieve the performance target of no more than 8% of lane-miles being in "poor" condition. This annual spending amount is the annual pavement asset management needs for the state-owned non-RS system.

Figure 1: Relationship between Spending and Expected Share of Lane-Miles in "Poor" Condition in 2045



[8] Even though the relationship is linear, the line is referred to as a "performance curve" for consistency with other needs categories where the relationship between spending and performance was non-linear.

Rural Secondary System

Pavement preservation needs for the RS system are derived from historical spending. The first step is to convert fiscal year (FY) spending to approximate calendar year (CY) spending using the following equation. This equation accounts for the fact that six months of the fiscal year overlap with the current calendar year and six months overlap with the next calendar year.[9]

$$CY\ spending = FY\ spend\ same\ year \times {}^{1}/_{2} + FY\ spend\ next\ year \times {}^{1}/_{2}$$

Where,

- $CY\ spending$ is calendar year spending for a given year between 2008 and 2020.
- $FY\ spend\ next\ year$ is the fiscal year spending for the next year (e.g., FY 2009 if calculating for CY 2008).
- $FY\ spend\ same\ year$ is the fiscal year spending for the same year (e.g., FY 2008 if calculating for CY 2008).

The next step is to multiply the spending for each resulting calendar year (CY 2008-2022) for CB01 and CB06 by the share of activities that are related to pavement preservation. The share of spending associated with pavement preservation as opposed to maintenance or administration was identified for CB01 and CB06 FY 2021 spending using activity names. The sum of the share of activities that are relevant for pavement preservation was multiplied by historical CB01 and CB06 for each calendar year to exclude spending that is not associated with pavement preservation.[10] Subsequently, 50.3% of CB01 and 98.7% of CB06 were associated with pavement preservation. Table 6 and Table 7 below lists the activity codes that were included for pavement preservation need or were excluded from these needs from CB01 and BC06 respectively.

Table 6: CB01 Activity Breakdown FY 2021 (2021 USDs)

Activity Name	Total	Share	Include in Needs or Exclude
Field Survey	$5,799	0.08%	Exclude
Roadway Plans-Preliminary-Off	$7,059	0.10%	Exclude
Construction Engineering	$1,515,495	21.27%	Include
Traffic Enforcement	$68,736	0.96%	Exclude
State Force Construction	$911,130	12.79%	Include
Construction Contracts	$1,160,897	16.29%	Include
Insp-Asphalt Plants & Paving M	$600	0.01%	Exclude
Insp-Miscellaneous Materials	$468	0.01%	Exclude

[9] Commonwealth of Kentucky (2017). How the Budget is Made. Retrieved from https://transparency.ky.gov/transparency/Pages/How-the-Budget-is-Made.aspx#:~:text=Kentucky's%20fiscal%20year%20begins%20July,funds%20during%20a%20fiscal%20year..

[10] Activities associated with pavement preservation were identified in a meeting with Craig Caudill on March 9, 2022.

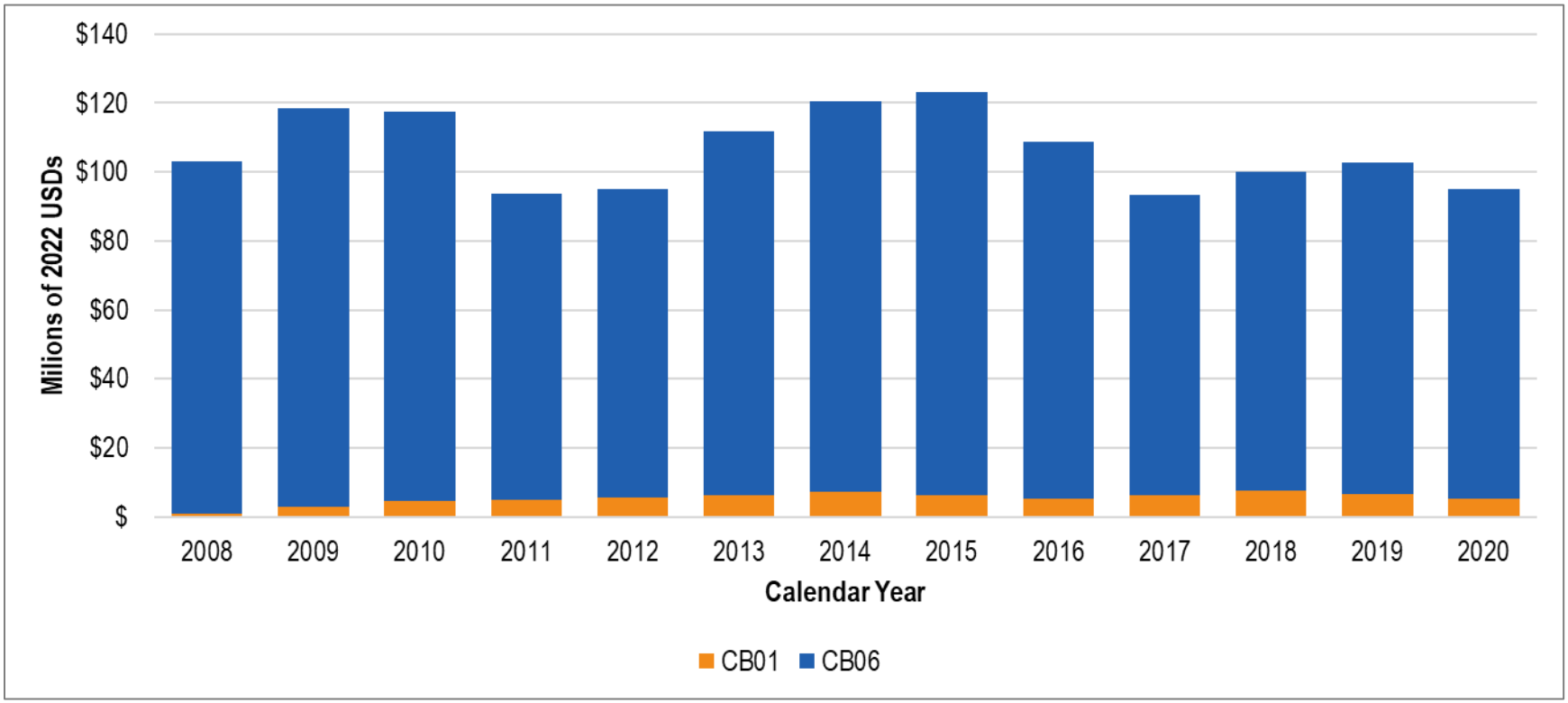
Activity Name	Total	Share	Include in Needs or Exclude
Asphalt Mix Design	$344	0.00%	Exclude
Asphalt Mix Design Approval	$882	0.01%	Exclude
Pay Local Government	$3,418,601	47.98%	Exclude
Federal Non-Participating Leave Costs	$35,721	0.50%	Exclude
Total	**$7,125,732**	**100%**	**NA**

Table 7: CB06 Activity Breakdown FY 2021 (2021 USDs)

Activity Name	Total	Share	Include in Needs or Exclude
Design Contracts-Consultant	$6,675	0.01%	Exclude
Bridges-Construction Engr	$2,880	0.01%	Exclude
Construction Engineering	$2,266,239	4.79%	Exclude
State Force Construction	$301,899	0.64%	Exclude
Construction Contracts	$27,686,819	58.56%	Exclude
Samplings & Testing-Aggregate	$7,357	0.02%	Exclude
Insp-Asphalt Plants & Paving M	$8,991	0.02%	Exclude
Insp-Miscellaneous Materials	$92,482	0.20%	Exclude
Liquid Asphalt Testing Unit	$8,650	0.02%	Include
Testing Of Asphalt Mixtures	$36,380	0.08%	Include
Asphalt Mix Design	$31,138	0.07%	Include
Project Document & Materials Certification	$9,010	0.02%	Exclude
Inspection Of Concrete Plants	$773	0.00%	Exclude
Asphalt Mix Design Approval	$3,470	0.01%	Exclude
Legal Activity on Project	$1,067	0.00%	Exclude
Pay Local Government	$16,422,068	34.74%	Exclude
Administrative Costs	$307,304	0.65%	Exclude
Federal Non-Participating Leave Costs	$84,912	0.18%	Exclude
Total	**$47,278,113**	**100%**	**NA**

Next, a multiplier is applied to the resulting annual spending amounts to account for inflation derived from the U.S. Bureau of Labor Statistics' Consumer Price Index (CPI) Inflation Calculator. This step converts historical spending from year-of-expenditure dollars to constant 2022 USDs.[11] Figure 2 shows the historical spending for CB01 and CB06 after making the adjustments for calendar years, preservation spending share, and inflation described above.

Figure 2: Historical Spending for RS System Pavement Preservation (2022 USDs)



Trends are linearly extrapolated from the resulting historical spending. Since it is assumed that constant-dollar spending will not decrease for either CB01 or CB06, if either of these show decreasing spending, then the average of CY 2008 to 2020 spending is substituted for the extrapolated value. CB06 showed a decreasing trend after accounting for inflation, so the average spending was substituted. An additional $3 million per year was also

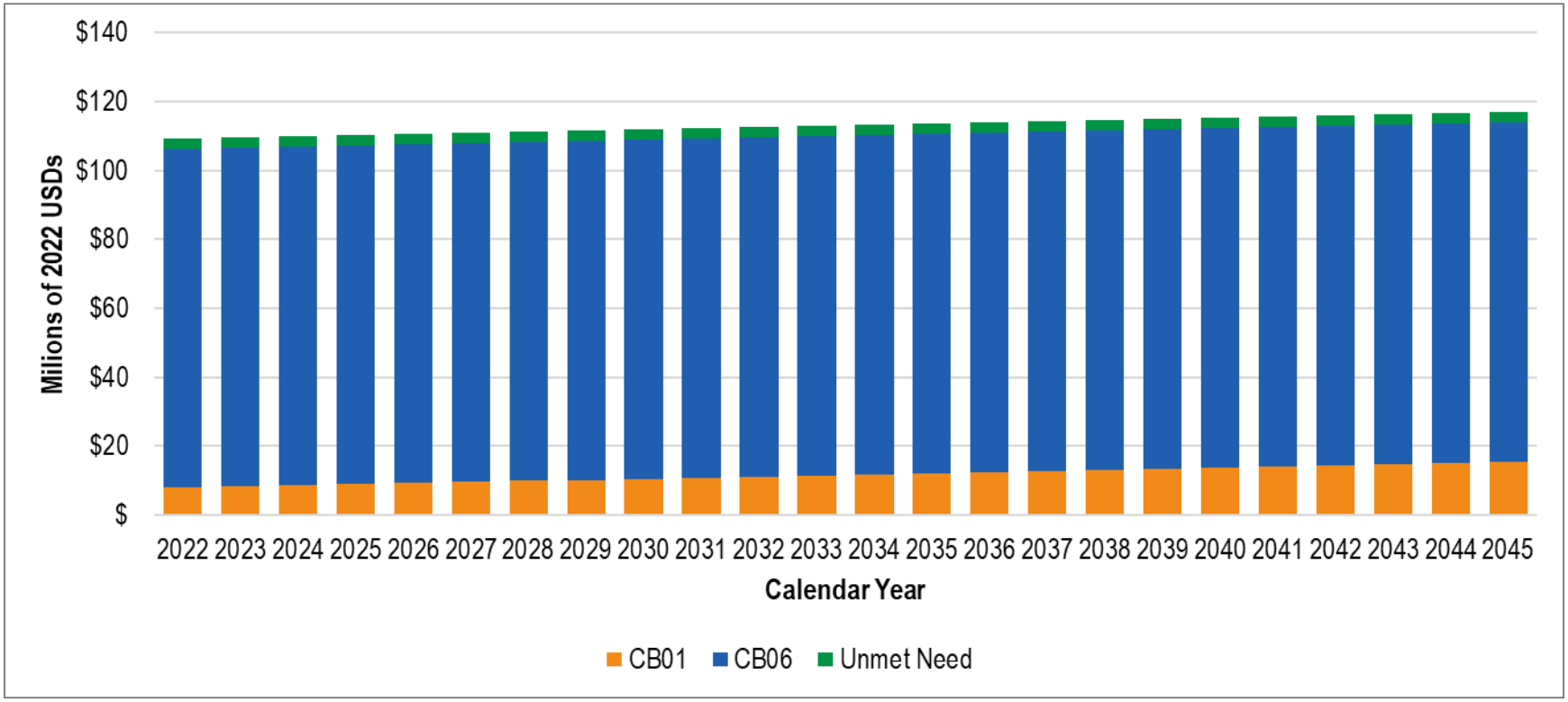
[11] U.S. Bureau of Labor Statistics (n.d.). CPI Inflation Calculator. Retrieved from https://www.bls.gov/data/inflation_calculator.htm.

added to account for needs that have not historically been met by funding ("unmet needs").[12] Total pavement preservation spending needs for the RS system are the sum of the resulting annual spending between CY 2022 and 2045.

RESULTS

Twenty-four-year pavement asset management spending needs for the state-owned system total $18.01 billion (of which $2.71 billion is for RS system and $15.30 billion is for the state-owned non-RS system). This equates to annual needs for $750.62 million (of which $113.11 million is for RS system and $637.51 million is for the state-owned non-RS system). Figure 3 shows the annual spending needs for pavement preservation on the RS system. Spending needs for the state-owned non-RS system are approximately uniform over time.

Figure 3: Annual Spending Needs for RS Pavement Preservation (2022 USDs)



[12] Meeting with Craig Caudill on March 9, 2022.