

Appendix K: Needs – Bridge



**Kentucky's Long-Range
Transportation Vision**



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INTRODUCTION

This technical memo summarizes the Kentucky Transportation Cabinet's (KYTC) spending needs between 2022-2045 for bridges. Bridge needs include preservation, rehabilitation, and reconstruction activity on state-owned bridges to meet performance targets. The analysis is consistent with the 2022 Transportation Asset Management Plan (TAMP), which is under development. 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. Unless otherwise specified, all dollar amounts are in 2022 United State Dollars (USDs).

METHODOLOGY

Data Sources

Table 1 lists data sources used to calculate bridge needs and briefly summarizes their purpose. The primary data source is output from six runs of the Bridge Management System (BMS) over a 10-year period starting in 2023. Each of these model runs predicts the share of deck area that will be in good, fair, and poor condition at the end of the 10-year period. This is used to derive a performance curve that shows the relationship between spending and condition change. The analysis also used the bridge condition forecast and associated annual spending from the 2019 TAMP, which served as an anchor point for the relationship between spending and condition change. Using this anchor point allows for the conversion from element-level condition forecasts, used in the six 10-year BMS runs, to the National Bridge Inventory (NBI) condition levels. Finally, the analysis also used KYTC's standard unit costs for preservation, rehabilitation, and replacement activities to adjust the performance curve in a way that accounts for changes in the share of bridges that are in good or fair condition later in the analysis period.

Table 1: Primary Data Sources

Description	Source	Purpose in Methodology
Six 10-year BMS runs with different spending levels (annual target spending levels of \$100, \$170, \$210, \$250, \$290, and \$300 million)	KYTC ¹	Derive relationship between spending and change in share of deck area in poor and good condition
Bridge Condition Forecast from 2019 TAMP	KYTC (2019). Transportation Asset Management Plan. Retrieved from http://www.tamptemplate.org/wp-content/uploads/tamps/048_kentuckytc.pdf .	Shift relationship between spending and change in share of deck area in poor condition to intersect with 2019 TAMP condition forecast to account for element to NBI definition conversion
Activity Costs in BMS (i.e., Preservation, Rehab, Replace)	KYTC ²	Generate and apply multiplier based on comparison of good and fair deck area and related preservation and rehab activities to account for shift of good deck area to fair condition

Assumptions

The following primary assumptions ground the analysis:

- KYTC will continue to select bridge treatments using similar processes and models to what are used in the six 10-year BMS runs through the end of the forecast period.
- There will not be a significant change in state-owned bridge deck area through 2045, and activity types, costs, and effects will remain similar after accounting for inflation.

Processing

The process for estimating KYTC bridge needs begins by using regression to define a relationship between annual spending and change in systemwide poor and good condition shares as derived from the six 10-year BMS runs. Next, this relationship with poor condition is horizontally shifted to anchor it to the change in condition predicted by the analysis for the 2019 TAMP. The reason for this shift is that the six 10-year BMS runs define condition based on bridge elements, whereas the 2019 TAMP defined condition based on NBI definitions, which corresponds more closely with KYTC's condition targets. This adjusted relationship is used to forecast bridge condition with variable annual spending amounts for the next two 10-year periods ("second 10-year period" and "third 10-year period" respectively), which brings the total analysis period to 30 years. The last six

¹ Email from Katherine Caldwell on February 14, 2022.

² Email from Katherine Caldwell on March 23, 2022.

years of the analysis are removed to bound the analysis to the 24-year LRSTP analysis period. The annual spending is varied such that the following conditions are met at the least possible cost:

- Annual spending does not fall below \$50 million in any year.
- Condition of no more than 3% of bridge deck area in poor condition and at least 40% of bridge deck area in good condition in 2045 is met. KYTC's current target for the share of bridge deck area in poor condition is 4.5%, which is expected to decrease to 3% during the 24-year period.

Next, two multipliers are derived from the relative shares of good and fair condition pavement at the end of the second and third 10-year periods, and the unit costs for preservation and rehabilitation work, which are typically applied to good and fair pavements respectively. These multipliers are applied to the annual spending for the second and third 10-year periods to account for the fact that fair deck area share is increasing at the expense of good deck area share over the forecasting period, which will tend to raise treatment costs.

The following subsections detail these analytical steps:

Define Initial Relationship between Annual Spending and Change in Condition

For each of the six BMS runs with different spending levels, the average annual spending in 2022 USDs and the 10-year change in both poor and good condition share are calculated. Two scatter plots are created relating average annual spending in 2022 USDs (x-axis) and change in poor and change in good condition shares (y-axis). The regression models shown in Figure 1 and Figure 2 were fit to this data.

Figure 1: Relationship between Annual Spending and Change in Poor Condition Deck Area Share

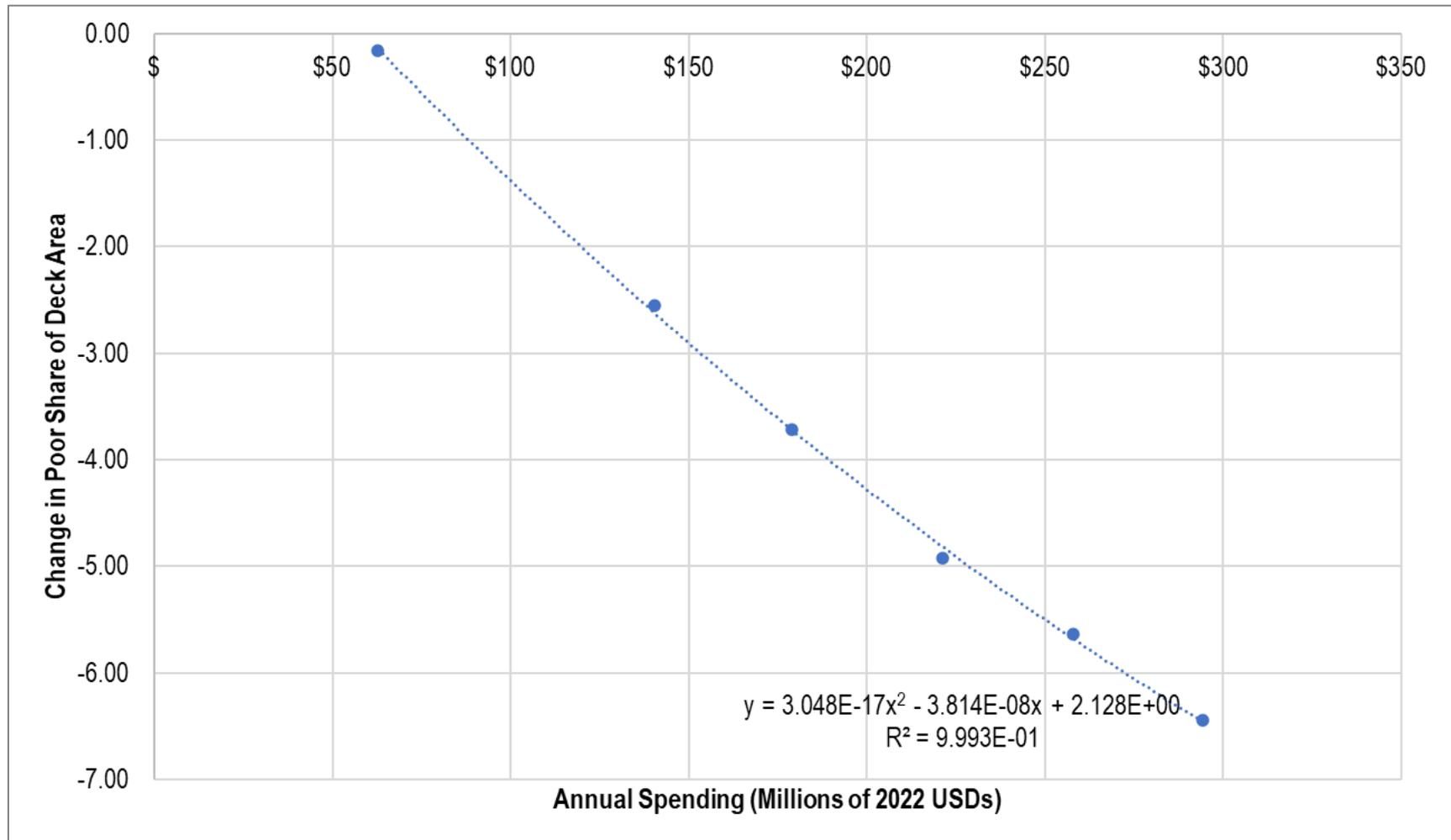
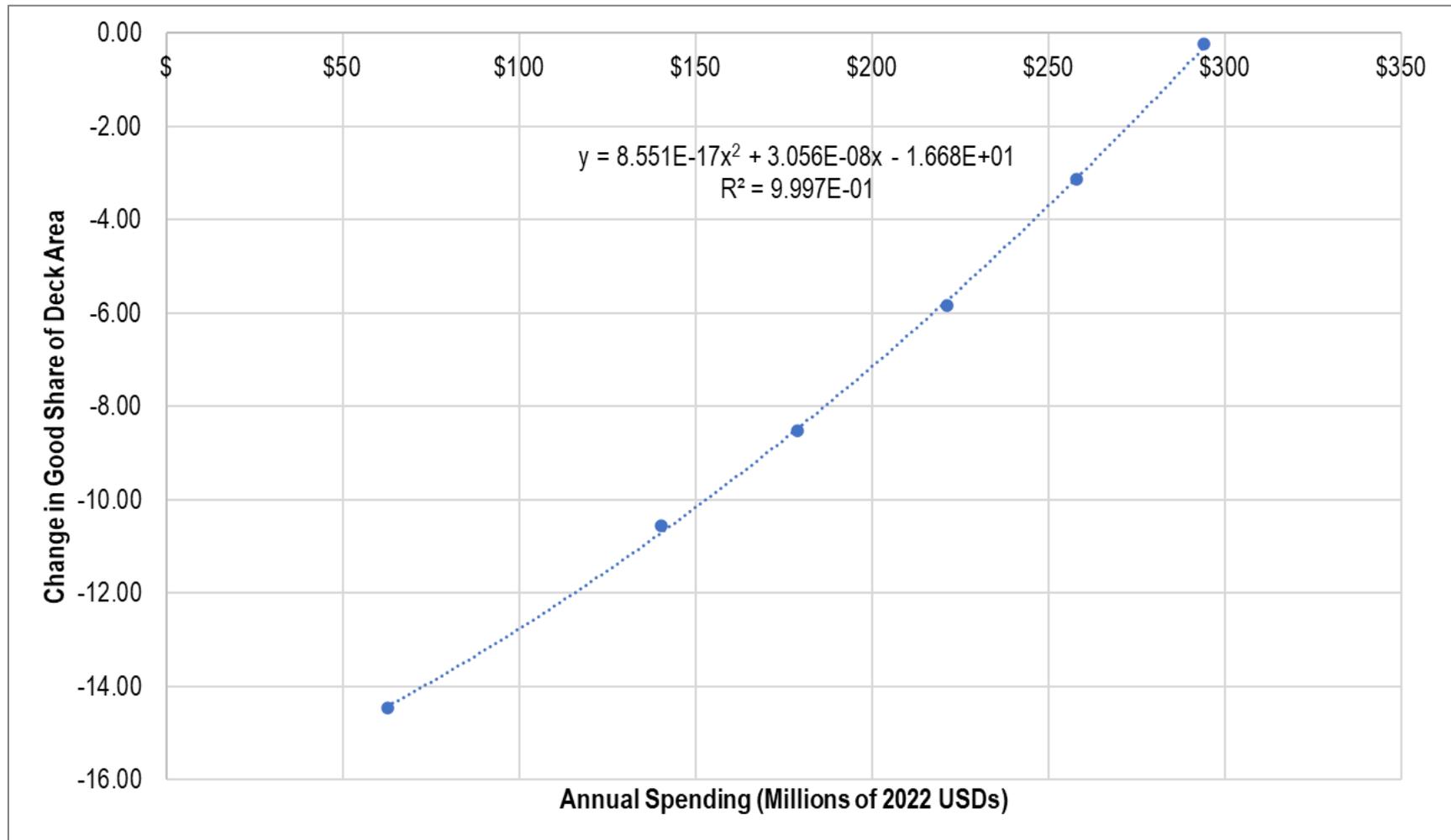


Figure 2: Relationship between Annual Spending and Change in Good Condition Deck Area Share



Convert from Element Condition Definition to National Bridge Inventory Condition Definition

The regression model from the previous subsection describing the relationship between spending and poor condition share was shifted to the right to intercept the 10-year change in condition described by the 2019 TAMP. The 2019 TAMP provides forecasts of bridge condition at different spending levels for Interstates, parkways, and the Maintenance Program (MP) system. These condition forecasts were combined into a single condition forecast for the state-owned system by weighting these three forecasts by the deck area within each. Also, annual spending associated with these estimates was converted to 2022 USDs using multipliers derived from the U.S. Bureau of Labor Statistics' CPI Inflation Calculator. The result is that

the 2019 TAMP model predicts a decrease in poor condition over a 10-year period share of 1% poor condition share with approximately \$201 million in annual spending in 2022 USDs. The regression model describing the relationship between spending and poor condition was shifted by adjusting its intercept so that it intersected with this point.

No adjustment was made for the equation linking annual spending with good condition share since the 2019 TAMP forecast was deemed overly optimistic for change in good condition share.

Forecast Out Years

Change in condition is forecasted in 10-year increments based on the average annual spending over the 10-year period. The modified equation for change in poor condition share and original equation for change in good condition share are used for these forecasts. Actual condition is estimated by adding the change in condition that is forecasted at the end of the 10-year period to the condition of the last year in the previous 10-year forecast period. The model is built on top of the “advanced” strategy TAMP spending scenario between 2023 and 2032. Condition in interim years is interpolated.

Adjust Out Year Spending for Increased Fair Condition Deck Area

A multiplier is developed to apply to spending during the first and second forecast period to account for the growth in “fair” condition deck area, which costs more to maintain than good condition deck area. Table 2 shows the unit costs associated with rehabilitation and preservation, Table 3 shows the start and end condition shares for the first forecast period, and Table 4 shows the start and end condition shares for the second forecast period.

$$Multiplier = \frac{end \% fair \times rehab\ unit\ cost + end \% good \times preservation\ unit\ cost}{start \% fair \times rehab\ unit\ cost + start \% good \times preservation\ unit\ cost}$$

Table 2: Unit Costs

Activities	Associated Condition	Unit Costs (\$/sq ft)
Preservation	Good	\$63
Rehab	Fair	\$225
Replace	Poor	\$612

Table 3: Condition Shares for First Forecast Period

Activities	% Fair	% Good
Start (2023)	41.80%	49.14%
End (2032)	52.92%	42.87%

Table 4: Condition Shares for Second Forecast Period

Activities	% Fair	% Good
Start (2023)	41.80%	49.14%
End (2042)	56.59%	41.76%

The multipliers of 1.17 (“multiplier 1”) and 1.23 (“multiplier 2”) are derived for the first (2033-2042) and second (2043-2045) forecast periods respectively. These multipliers are applied to the annual spending in these time periods to account for the fact that fair condition share is higher relative to “good” condition share compared with the six TAMP model runs from which the relationships between spending and change in condition were derived.

Needs for the first and second forecasts periods are the average annual spending between 2023 and 2032 times a multiplier. The multiplier for each time period is adjusted to derive the lowest cost that meets the conditions shown in Table 5.

Table 5: Source of Spending for Each Modeling Period

Year	Description	Spending Source
2022	Current year	Estimated FY 2022 spending is \$180 million. ³
2023-2032	TAMP forecasting period	“Advanced” strategy TAMP spending scenario.
2033-2042	First forecast period	Average annual 2023-2032 spending times multiplier 1.
2043-2052	Second forecast period	Average annual 2023-2032 spending times multiplier 2.

³ Email from Katherine Caldwell, February 9, 2022.

RESULTS

The bridge needs between 2022 and 2045 total \$6.33 billion, or an average of \$263.8 million per year. This includes the FY 2022 preservation spending, spending associated with the “advanced” strategy developed for the TAMP between 2023 and 2032 and forecasted spending for the entire first forecast period (2033-2042) and the first three years of the second forecast period (2043-2045). Table 6 shows the origin of the needs by portion of the methodology. Figure 3 shows the annual needs, and Figure 4 shows forecasted condition.

Table 6: Bridge Preservation Needs (2022-2045, in Constant 2022 USDs)

Component of Needs	Annual Need (Millions)	24-Year Need (Billions)
Original (no adjustment)	\$237.8	\$5.7
+ effect of model shift to convert element condition to NBI	\$0.0	\$0.0
+ adjustment for increased fair share	\$26.0	\$0.6
= Bridge Needs	\$263.8	\$6.3

Figure 3: Annual Spending Associated with Bridge Needs

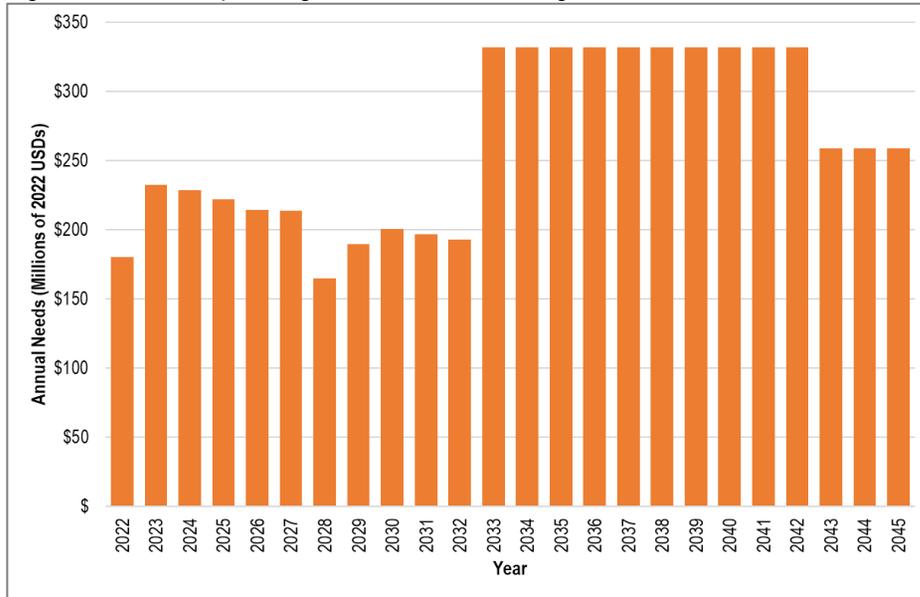


Figure 4: Forecasted Deck Area Condition Associated with Needs

