# Appendix N:
# Needs – Transportation Systems Management and Operations

GET THERE TOGETHER.

Kentucky's Long-Range Transportation Vision

# INTRODUCTION

This technical memo summarizes the Kentucky Transportation Cabinet's (KYTC) spending needs between 2022-2045 for transportation systems management and operations (TSMO). As described by the Federal Highway Administration (FHWA), TSMO is "a set of strategies that focus on operational improvements that can maintain and even restore the performance of the existing transportation system before extra capacity is needed."[1] TSMO needs described in this memo include two primary components: highway safety and intelligent transportation systems (ITS). KYTC's safety programs include among other activities the data-driven identification and implementation of engineering and behavioral countermeasures as well as partnerships with owners of other highway systems to reduce crashes, fatalities, and injuries on Kentucky's roads.[2] ITS integrates "advanced communications technologies into transportation infrastructure and in vehicles" to improve highway safety and mobility. This infrastructure facilitates such functions as vehicle-to-vehicle and vehicle-to-infrastructure communication, real-time data capture and management, road weather management, and dynamic mobility applications (such as dynamic routing).[3] For this memo, ITS includes all roadside electrical devices, such as beacons, traffic signals, signs with electrical components, lighting, dynamic message signs (DMS), and cameras.

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 noted, dollar amounts are in 2022 U.S. dollars (USDs).

# METHODOLOGY

## Highway Safety Overview

KYTC's safety needs are estimated on all public roads in Kentucky by extrapolating historical spending or obligated fund amounts for engineering and behavioral countermeasures through the end of the planning period in 2045 and then making an adjustment for the inadequacy of historical spending to address all safety needs. The extrapolation is done by converting historical spending for engineering countermeasures derived from Highway Safety Improvement Program (HSIP) reports and behavioral countermeasures derived from National Highway Traffic Safety Administration (NHTSA) reports to 2022 USDs, calculating the historical geometric growth rate and applying this growth rate to the last year of recorded data to forecast annual spending needs through 2045. Spending needs for engineering and behavioral countermeasures are extrapolated separately, and this forecast derived from geometric growth rates is retained as long as the growth rate is not negative nor unreasonably high. When the historically derived geometric growth rate is unreasonably high, annual baseline needs for that category of safety spending needs are the average annual historical spending for the years available in 2022 USDs rather than future extrapolations of historical spending. These baseline needs are

[1] Federal Highway Administration (2021). "What is TSMO?" *Organizing and Planning for Operations*. Updated August 16, 2021. Retrieved from https://ops.fhwa.dot.gov/tsmo/.
[2] Kentucky Office of Highway Safety (n.d.). "Mission." Retrieved from https://transportation.ky.gov/HighwaySafety/Pages/default.aspx.
[3] Kentucky Transportation Cabinet (2022). "Intelligent Transportation Systems." Retrieved from https://transportation.ky.gov/Maintenance/Pages/Intelligent-Transportation-Systems.aspx.

supplemented with additional safety spending needs for engineering countermeasures and behavioral safety culture derived from KYTC analysis to account for the fact that historical funding has not typically been adequate to address all safety needs.

## ITS Overview

KYTC's ITS needs include maintenance of infrastructure and capital expenses. Costs for ITS maintenance are derived from the Operations Management System (OMS) for costs of state-owned non-rural secondary roads. Costs for the rural secondary system are calculated via historical spending provided by the Office of Budget and Fiscal Management (OBFM). Historical costs are extrapolated into the future from each of these data sets and converted to 2022 USDs to estimate baseline ITS maintenance needs. Subsequently, they are adjusted upward to account for the lost purchasing power due to rising prices outstripping general inflation. The maintenance technical memo provides details of these calculation steps. The second component of ITS needs is for capital spending, which was examined using historical ITS capital spending between 1993 and 2021 provided by KYTC.

## Data Sources

The primary safety data used in this analysis is historical spending for engineering countermeasures on Kentucky roads collected from the state's HSIP annual reports and spending on behavioral countermeasures collected from the annual reports of the Kentucky Office of Highway Safety. This data on historical spending is supplemented by data from the U.S. Bureau of Labor Statistics on the historical inflation rate that is used to convert historical spending to 2021 USDs and inflation rate expectations from the Federal Reserve Bank of New York that is used to convert 2021 USDs to 2022 USDs, in which needs are reported. The primary data sources used to assess ITS maintenance needs are historical spending from OMS and OBFM, while historical ITS capital spending data provided by KYTC is a basis for examining ITS capital needs. Table 1 lists these data sources.

Table 1: Primary Data Sources

| Description | Source | Purpose in Methodology |
|---|---|---|
| Obligated safety spending from FYs 2013 to 2020. | Highway Safety Improvement Program Annual Reports for Kentucky for FY 2013 to FY 2020.[4] | Collect historical spending for engineering safety countermeasures. |
| Spending on behavioral safety countermeasures from FYs 2005-2009 and FYs 2011-2020. | Annual Reports for the Kentucky Office of Highway Safety for FYs 2005-2009 and FYs 2011-2020.[5] | Collect historical spending for behavioral safety countermeasures. |
| State spending on highway law enforcement and safety for all highways and for state administered highways from 2015 to 2019 | Federal Highway Administration (2015-2019). Highway Statistics. Table SF-2: Disbursements by States for Highways and Table SF-4: Disbursements by States for State-administered Highways. | Assess share of state safety needs on state-owned roads. |
| Historical maintenance spending between fiscal years (FY) 2006 and 2020 (in-house labor, equipment, and materials for state-owned non-rural secondary system) and FYs 2007 and 2021 (rural secondary system). | State-owned non-rural secondary system<br>• **In-house labor, equipment, and material costs:** Operations Management System (OMS)[6]<br>• **Contract costs:** OMS<br>Rural secondary system<br>• KYTC Office of Budget and Fiscal Management (OBFM) | Establish trends in historical ITS maintenance spending as basis for extrapolating future ITS maintenance spending. |
| Historical ITS capital spending from FY 1993 to FY 2021 | Provided by KYTC | Estimate annual ITS capital needs. |
| Analysis on additional safety needs | KYTC (2022). *10 Year Safety Needs and Investment Opportunities*. | Add additional safety needs that are not met by historically derived spending. |
| Spending by activity code for FE01 for FY 2021. | KYTC Office of Budget and Fiscal Management (OBFM) | Divide FE01 spending into categories associated with maintenance, transportation systems operations and management (TSMO), pavement markings and signs, traffic signals, and other needs categories. |

[4] FHWA (n.d.). Highway Safety Improvement Program (HSIP) – Reporting. Retrieved from https://safety.fhwa.dot.gov/hsip/reports/.
[5] NHTSA (n.d.). State Highway Safety Plans and Annual Reports. Retrieved from https://www.nhtsa.gov/highway-safety-grants-program/state-highway-safety-plans-and-annual-reports.
[6] Provided by Aaron Collins on December 1, 2021.

| Description | Source | Purpose in Methodology |
|---|---|---|
| Historical national inflation rates | Consumer Price Index (CPI) Inflation Calculator.[7] | Convert historical year of expenditure (YOE) amounts to 2022 USDs. |
| 1-year and 3-year inflation rate expectations | Federal Reserve Bank of New York | Generate assumptions for inflation rate. |

## Assumptions

The following primary assumptions support the analysis.

- Inflation will average 6.0% between calendar years 2021 and 2022, 3.0%[8] from 2022 to 2024, and 2.0% subsequently. The first two rates are provided by the 1-year and 3-year inflation expectations reported by the Federal Reserve Bank of New York.[9]
- Lost purchasing power since 2012 has eroded a real maintenance need. Adjusting for this lost purchasing power approximates the maintenance needs that exist beyond historical spending.
- Spending needs will not decrease in constant dollars for any maintenance category.

## Processing

### Highway Safety – Engineering Countermeasures

The geometric growth rate describes compound growth and is appropriate for phenomena that grow by the same percentage every year as opposed to the same absolute amount of growth, which a linear extrapolation would model. The geometric growth rate was calculated using the following equations for engineering countermeasures for the following time periods: 2013-2020, 2014-2020, and the average of 2014-2016 data and the average of 2018-2020 data. These all produced unrealistic growth rates (-9.8%, 11.4%, and 6.8% respectively), reflecting the fact that historical spending for safety countermeasures has been highly variable and does not show a clear trend.

$$geometric\ growth\ rate = \left(\frac{amount_{2020}}{amount_{2013}}\right)^{(1/2020-2013)} - 1$$

$$amount_{future} = amount_{2020} \times (1 + geometric\ growth\ rate)^{future-2020}$$

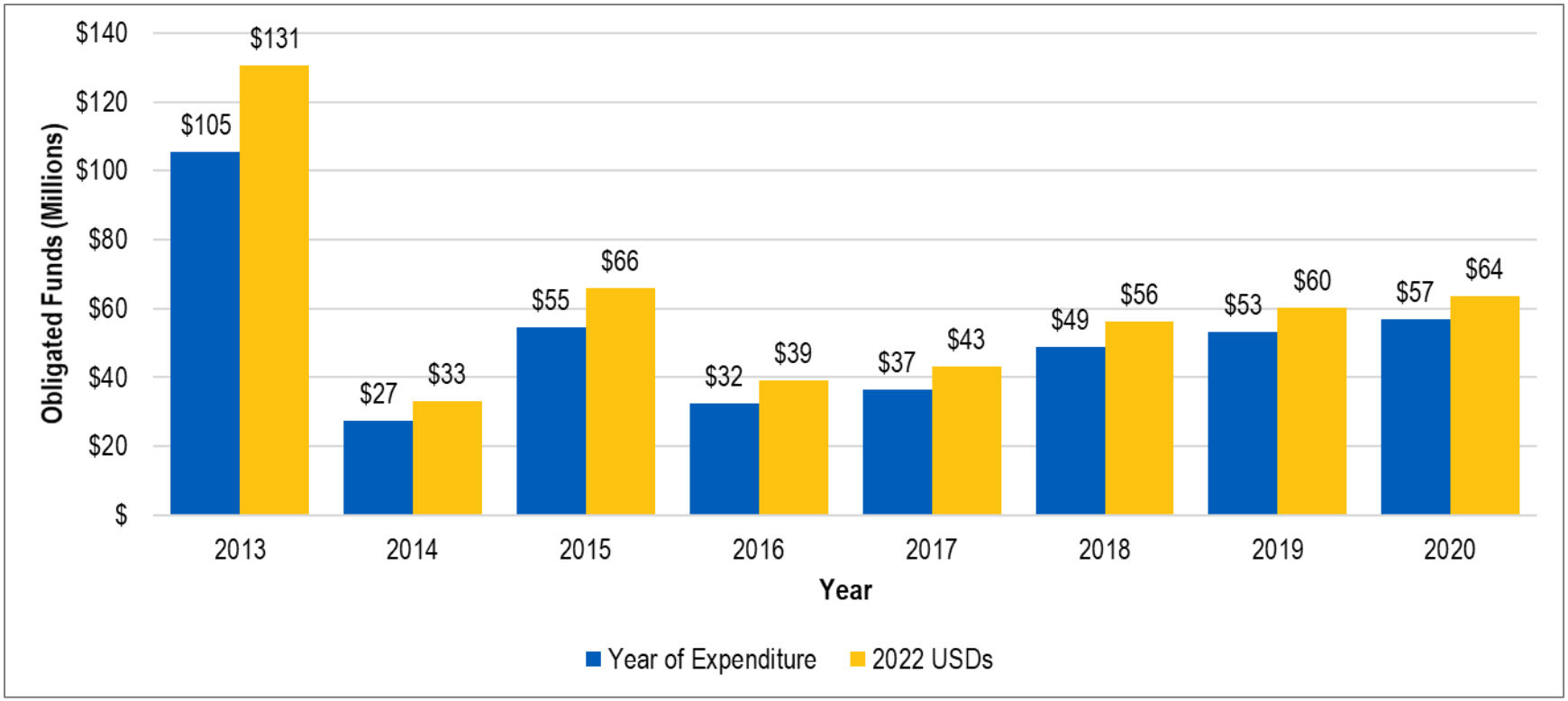
[7] U.S. Bureau of Labor Statistics (n.d.). CPI Inflation Calculator. Accessed November 22, 2021. Retrieved from https://www.bls.gov/data/inflation_calculator.htm.
[8] As of December 20, 2021, the 3-year inflation expectations reported by the Federal Reserve Bank of New York are 4.0%, while the 1-year inflation expectations are 6.0%. 3.0% is the inflation rate used for 2023-2024 and 2024-2025 because the average of two years of 3.0% inflation with one year of 6.0% inflation equals 4.0%, which is the 3-year inflation expectation.
[9] Federal Reserve Bank of New York (2021). Inflation Expectations. Accessed December 20, 2021. Retrieved from https://www.newyorkfed.org/microeconomics/sce#/inflexp-1.

Where,

- $amount_{2020}$ is the obligated spending amount in 2020 in 2022 USDs.
- $amount_{2013}$ is the obligated spending amount in 2013 in 2022 USDs.
- $amount_{future}$ is the baseline annual spending needed for engineering countermeasures in year $future$.

Because of the lack of a clear trend, the average of historical spending was applied to future years. First, historical spending was converted to 2021 USDs using the CPI Inflation Calculator and subsequently to 2022 USDs using a 6.0% inflation rate. Figure 1 shows the obligated funds for engineering countermeasures in both year-of-expenditure and 2022 USDs. The average of spending from 2013-2020 in 2022 USDs was taken, and this average was applied to years from 2022 to 2045. The average of spending from 2013-2020 in 2022 USDs was taken, and this average was applied to years from 2022 to 2045 and it totals $61.52 million in 2022 USDs.

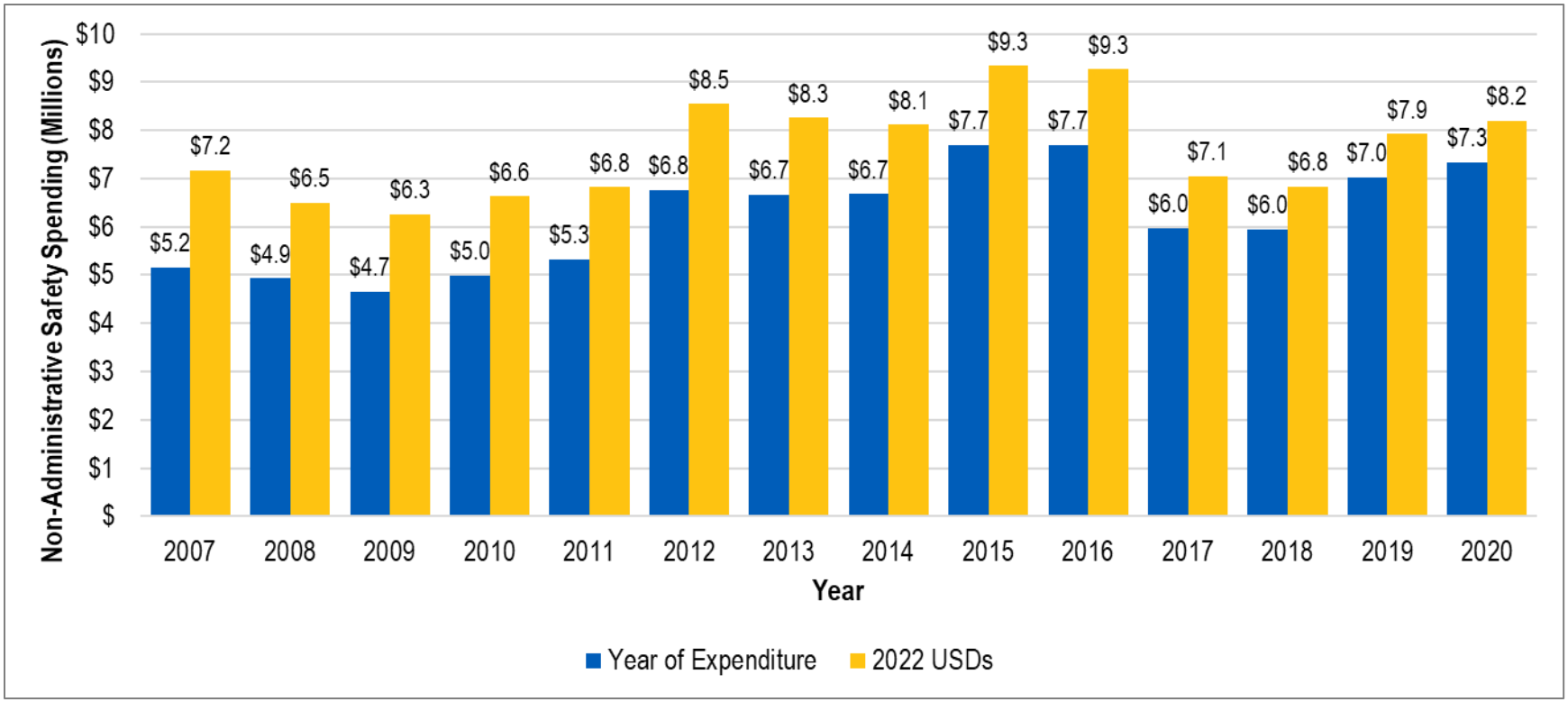
Figure 1: Obligated Funds (Millions of Year-of-Expenditure USDs)



## Highway Safety – Behavioral Countermeasures

Similar to engineering countermeasures, the geometric growth rate was calculated for historical safety spending on behavioral countermeasures in 2022 USDs using the following equation. All safety spending is accounted for except for planning and administration since the needs forecast generally excludes administrative functions. There is a clearer trend and more years of data from which to derive the growth rate than for engineering countermeasures as shown in Figure 2. The average growth rate in spending is 1.0% per year. This geometric growth rate was applied to the last collected spending data in 2020 to calculate annual needs for behavioral countermeasures between 2022 and 2045. Needs range from $8.37 million in 2022 to $10.62 million in 2045, representing 26.9% growth.

Figure 2: Non-Administrative Safety Spending (Millions of Year-of-Expenditure Dollars)




*Note: 2010 spending was unavailable through the State Highway Safety Plans and Annual Reports. Therefore, the value populated for 2010 is the average of 2009 and 2011 spending.*

$$geometric\ growth\ rate = \left(\frac{amount_{2007}}{amount_{2020}}\right)^{(1/2020-2007)} - 1$$

$$amount_{future} = amount_{2020} \times (1 + geometric\ growth\ rate)^{future-2020}$$

Where,

- $amount_{2020}$ is the obligated spending amount in 2020 in 2022 USDs.
- $amount_{2007}$ is the obligated spending amount in 2007 in 2022 USDs.
- $amount_{future}$ is the baseline annual spending needed for engineering countermeasures in year $future$.

## Highway Safety – Assess Share of KYTC Safety Needs on State-Owned Roads

The previous analysis of highway safety needs has not considered whether spending occurred on state-owned roads or on non-state-owned roads. Assessing on which highway systems historical spending has occurred can show which share of needs relates to the state-owned system and which relates to non-state-owned roads. To do this, historical spending data from the FHWA's Highway Statistics Series was collected between 2015 and 2019 for tables SF-2: Disbursements by States for Highways and SF-4: Disbursements by States for State-administered Highways. Comparing state spending for each year between these two tables reveals the share of safety-related spending by the state occurring on state-administered highways. Table 2 shows that all state safety spending was on state-administered highways since the amounts in the two tables are equal. This indicates that KYTC's safety needs for public roads are entirely related to the state-owned system and that these safety needs show no state contribution to non-state-owned roads, such as local roads.

Table 2: Disbursements by States (Millions of Year-of-Expenditure Dollars)

| Year | SF-2 | SF-4 |
|---|---|---|
| 2015 | $109.17 | $109.17 |
| 2016 | $107.78 | $107.78 |
| 2017 | $98.05 | $98.05 |
| 2018 | $102.57 | $102.57 |
| 2019 | $119.74 | $119.74 |

## Highway Safety – Add Safety Needs Not Accounted for by Historical Spending

KYTC's analysis has identified additional safety needs related to behavioral safety culture of $10 million annually and project-related needs of $560 million, which would take approximately 15-16 years to implement at current HSIP funding levels. The behavioral-related needs are added to the historically derived needs for each year of the analysis period, and the project-related needs are added for the first 16 years of the analysis period.

## ITS – Maintenance

Steps in calculating ITS maintenance needs (including traffic signals, operations, lighting, and ITS) are detailed only in the maintenance technical memo to avoid duplication. The following primary steps serve to calculate ITS maintenance needs.

### Categorize Historical Maintenance Spending by Activity Code

Each OMS activity code was matched with a key word to group similar ITS activities together. Similarly, FE01 activity codes were matched with ITS-related activities to summarize ITS-related historical spending in year-of-expenditure (YOE) dollars.

### Extrapolate Historical Maintenance Spending

Historical OMS and FE01 spending are converted from YOE to 2022 USDs by applying multipliers derived from the CPI Inflation Calculator to convert the amounts to 2021 USDs, and then assuming a 6.0% inflation rate between 2021 and 2022 to convert to 2022 USDs. The multipliers go from July in the year of expenditure to July 2021. Historical spending was originally reported in fiscal years rather than calendar years. Therefore, annual fiscal year spending was converted to annual calendar year spending prior to conversion to 2022 USDs by assigning half of the fiscal spending to the same calendar year and half to the next calendar year.

### Estimate Different Categories of Maintenance Needs

*In-House Costs for State-Owned Non-Rural Secondary Roads*

2006-2020 spending in reported in constant 2022 USDs for each needs category is linearly extrapolated through 2045. When linear extrapolation leads to a decrease in annual maintenance needs for any needs category, they are replaced with the average spending between 2006 and 2020 in 2022 USDs. The total ITS maintenance needs for the rural secondary system between 2022 and 2045 is the sum of the relevant annual needs between these years.

*Rural Secondary Roads*

Total FE01 historical spending in constant 2022 USDs is linearly extrapolated through 2045. The extrapolated annual spending amounts are converted from total spending to the spending categories based on the share of FE01 FY 2021 spending that is associated with each category. The share for each category is multiplied by the extrapolated annual spending. The ITS need for each year is the share of categories included in the maintenance need as listed in Table 3 times the FE01 spending for that year.

Table 3: Share FY 2021 FE01 Spending by Category

| Category | Share |
|---|---|
| Maintenance | 86.38% |
| Rest Areas | 0.05% |
| Signs | 0.86% |
| Pavement Markings | 5.53% |
| Traffic Signals | 0.27% |
| Ferry Operations | 0.04% |
| ITS | 0.02% |
| Lighting | 0.01% |
| Safety | 0.33% |
| Operations | 1.83% |
| Administration | 4.68% |
| **Total** | **100.00%** |

**Adjust for Lost Purchasing Power**

The baseline need derived from historical spending is adjusted to account for ITS needs that historical spending has been insufficient to meet. As measured by the Kentucky Construction Cost Index, KYTC's maintenance budget's purchasing power has declined by $87 million between 2012 and 2017, equating to a loss of 25.0% of purchasing power out of the 2017 budget of $347.46 million.[10] Maintenance spending would need to increase by 33.4% to make up for this loss in purchasing power. Therefore, all historically derived ITS needs are increased by 33.4% to adjust for the loss in purchasing power.

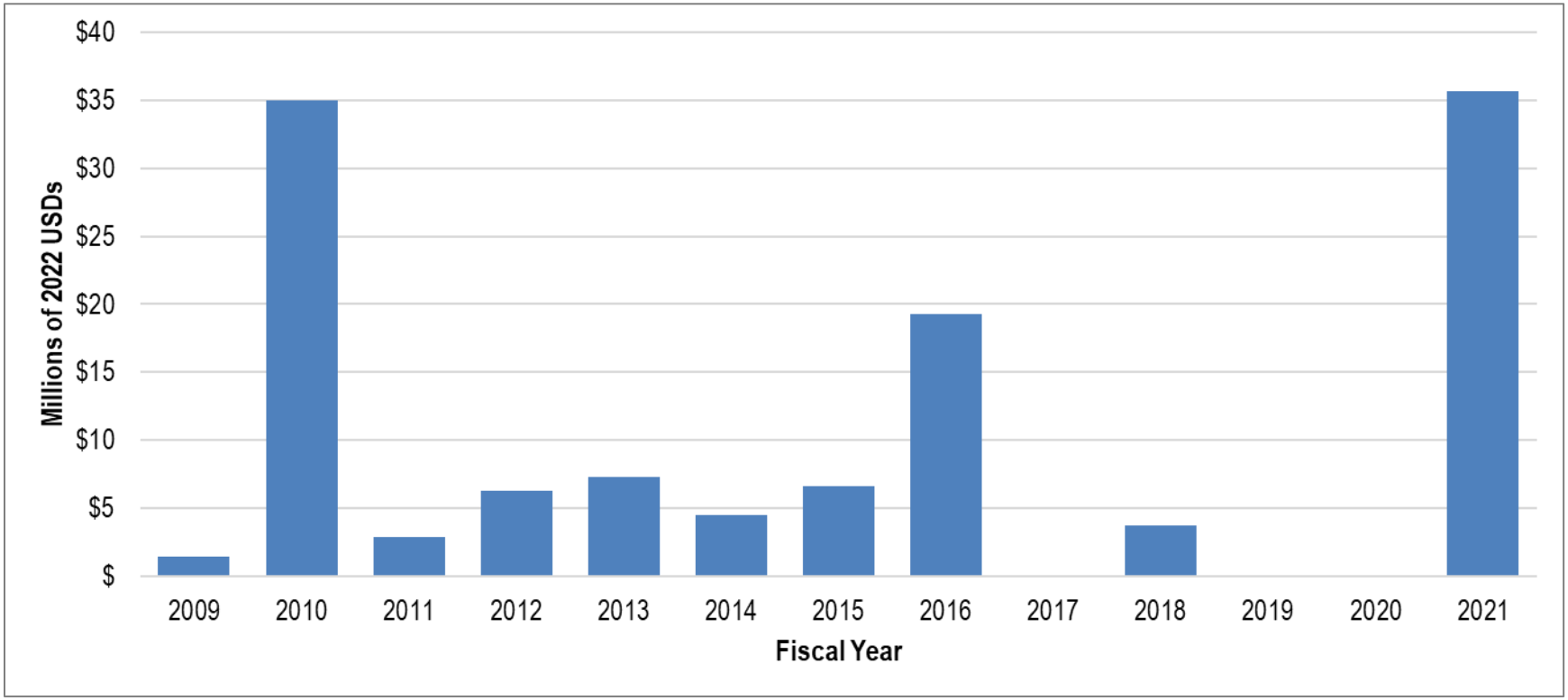
## ITS – Capital Spending

Historical ITS capital spending was examined for FY 1993 to FY 2021. First, the capital spending was summed for each year, and then the summed values were converted from year-of-expenditure dollars to constant 2022 USDs using multipliers derived from the U.S. Bureau of Labor Statistics' CPI Inflation Calculator. ITS capital spending is highly variable, and there are many years (1993-1998, 2001, 2002, 2017, 2019, and 2020) for which

[10] KYTC (n.d.). Allocation of KYTC Maintenance Budget. Provided by KYTC Assistant State Highway Engineer on November 29, 2021.

ITS capital spending is zero or data was not available. Capital needs equal the inflation-adjusted ITS spending from fiscal years 2009 to 2021, which averaged $12.27 million per year.[11] Figure 3 shows the historical ITS capital spending.

Figure 3: Historical ITS Capital Spending




## ITS – Traffic Signals

In addition to the already noted historical spending on traffic signals, needs derived from historical spending on FE04 and needs for traffic signal controller replacement are also added. FE04 is the operating budget for KYTC's Division of Traffic Operations, and also includes funds used to pay for KYTC's consulting services around signal systems and for district allocations for signals. FE04 covers signal capital, maintenance, and operations.[12] Historical FE04 spending was collected from OBFM. Amounts were first converted from fiscal years to calendar years by assigning half of each fiscal year's spending to the preceding calendar year and half to the current year. For instance, FY2015 spending was evenly split between

[11] Inflation adjustment is made via the CPI Inflation Calculator by the U.S. Bureau of Labor Statistics.
[12] Meeting with Tim Tharpe and Joe Thompson, KYTC, November 23, 2021.

calendar years 2014 and 2015. Then, amounts were converted from year of expenditure dollars to 2022 USDs by applying the same inflation-related conversions as for historical safety spending described on page 4. Finally, FE04 spending was linearly extrapolated. These needs were not adjusted to account for currently unfunded needs since FE04 funds are perceived to be largely adequate to meet traffic signal-related needs.[13]

KYTC has additional needs for traffic signal controller replacement. KYTC has been upgrading its controllers to new controllers with more functionality. Out of the approximately 3,500 signals on state-owned roads, approximately 1,000 have been upgraded so far, with most upgrades occurring in the past four to five years. Eventually all signals will need controllers. Controllers are estimated to cost about $3,000 per unit, which is greater than the estimated $1,100 that KYTC's former controller technology costed. KYTC subject matter experts estimated that it will take approximately five more years to replace the remaining controllers. The following equation summarizes the calculation of controller replacement-related needs for each of those five years. The result of the equation is $950,000 in additional annual spending beyond costs associated with older controllers. These annual costs are added to the traffic signal needs. There may be additional needs that are currently too uncertain to be quantified, such as those related to installation of radar detection devices at intersections.[14]

$$needs\ per\ year\ for\ controllers = \frac{(signals\ in\ state - controllers\ already\ replaced) \times (new\ cost\ per\ unit - old\ cost\ per\ unit)}{5\ years}$$

Where,

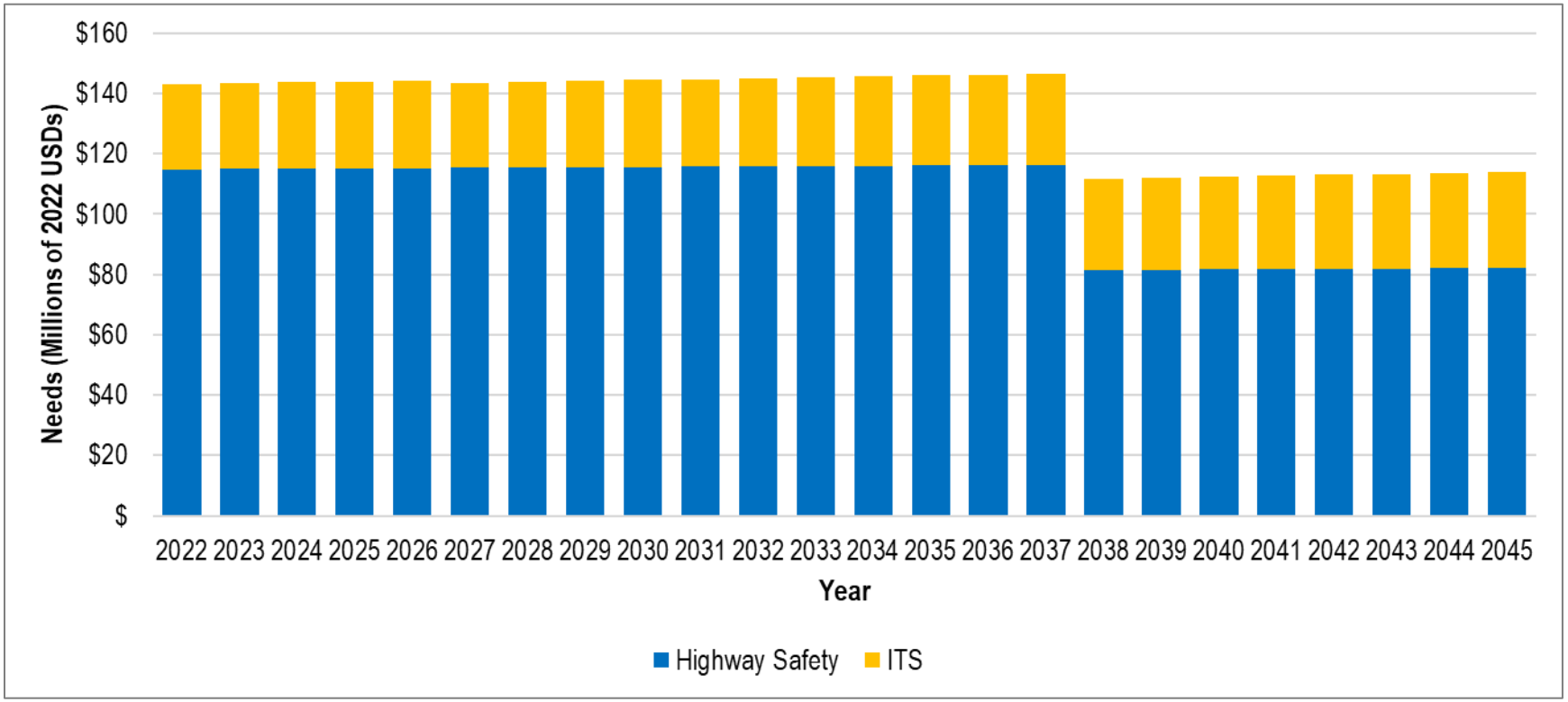
- $signals\ in\ state$ is the approximate number of state-owned signals (3,500).
- $controllers\ already\ replaced$ is the approximate number of controllers that have already been replaced with new, upgraded units (1,000).
- $new\ cost\ per\ unit$ is the approximate amount that KYTC is paying now or is expected to pay in the near-term future for controllers ($3,000).
- $old\ cost\ per\ unit$ is the approximate amount that KYTC has historically paid for "170 controllers" with older technology ($1,100).

[13] Meeting with Tim Tharpe and Joe Thompson, KYTC, November 23, 2021.
[14] Meeting with Tim Tharpe and Joe Thompson, KYTC, November 23, 2021.

# RESULTS

TSMO needs for the 24-year period from 2022 to 2045 total $3.23 billion. Annual needs range from a low of $112.30 million in 2038 to $146.99 million in 2037, as shown in Figure 4. The following subsections break down the highway safety and ITS needs categories into their components.

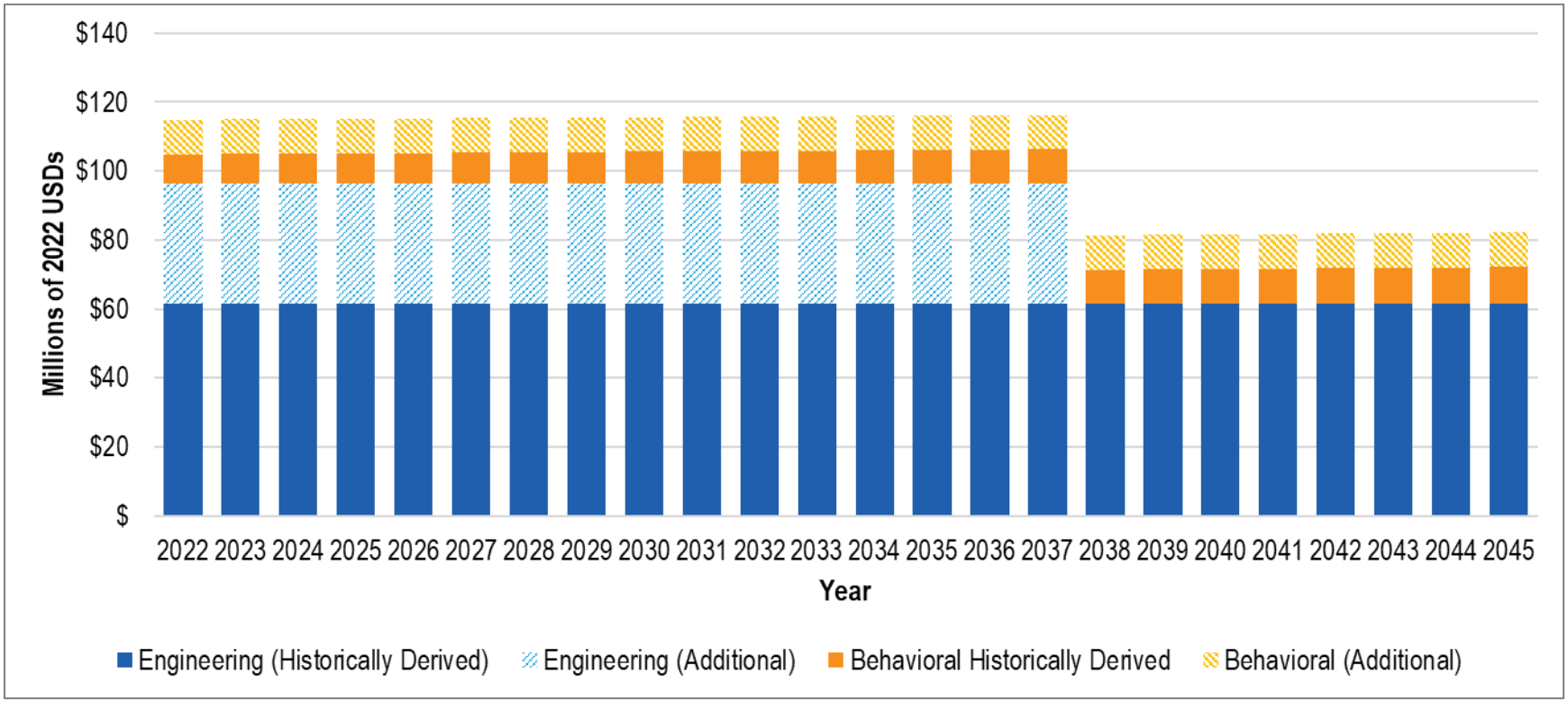
Figure 4: Annual TSMO Needs (2022 USDs)



## Highway Safety

Highway safety needs for the 24-year period from 2022 to 2045 total $2.50 billion (an annual average of $104.31 million). Figure 5 shows annual highway safety needs. Needs derived from historical spending are $1.70 billion, of which 13.3% are associated with behavioral countermeasures and 86.7% are associated with engineering countermeasures. An additional $400 million are associated with additional needs that are unmet by historical spending. Total safety needs range from $81.40 million to $116.30 million. Sixty-eight percent of the needs are not accounted for by historical spending.

Figure 5: Annual Highway Safety Needs (2022 USDs)



## Intelligent Transportation Systems

ITS needs total $723.98 million, as shown in Table 4. The following subsections display annual needs for traffic signals and subsequently for ITS devices, operations, and lighting.

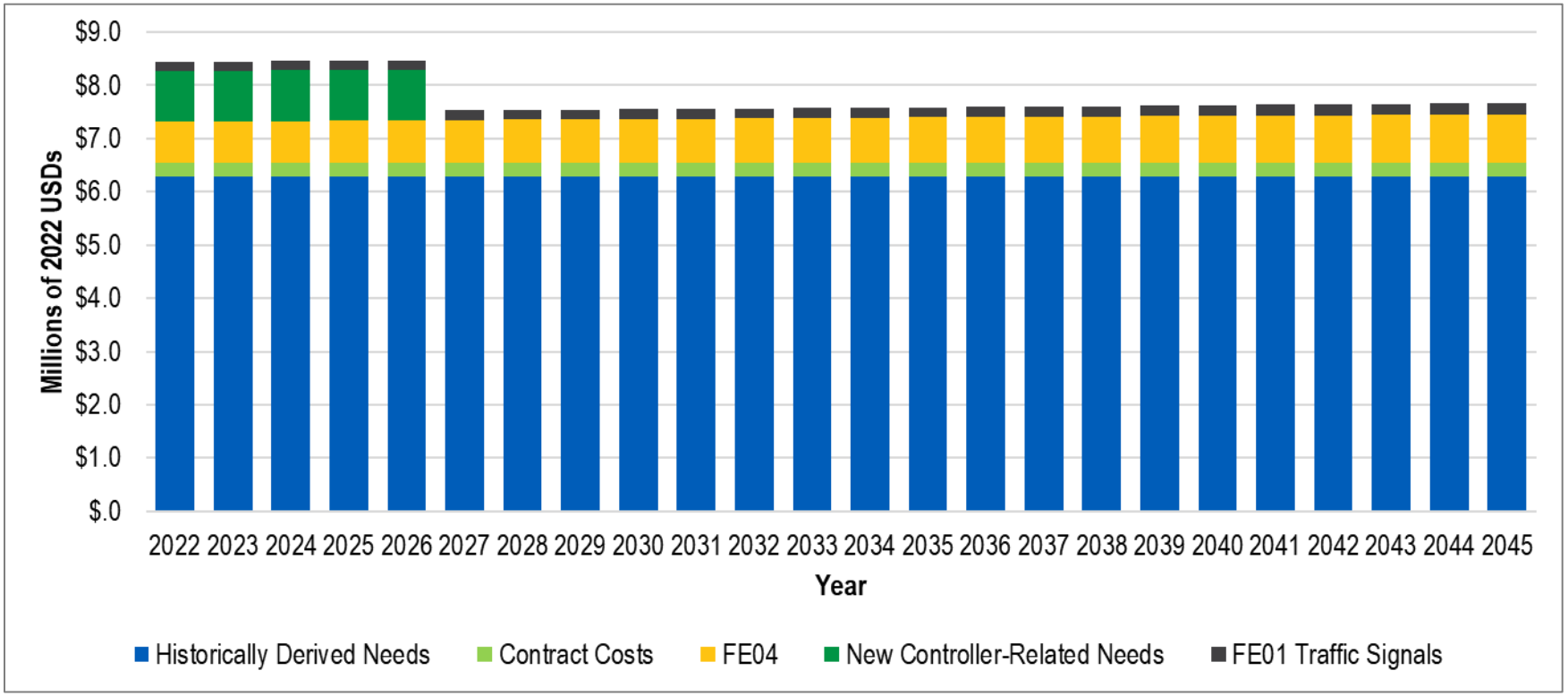
Table 4: ITS Needs from 2022 to 2045 (Millions of 2022 USDs)

| Category | Total Needs |
|---|---|
| ITS Device Maintenance | $5.12 |
| Operations | $124.17 |
| Lighting | $53.38 |
| Traffic Signals | $186.61 |
| Adjustment for Lost Maintenance Purchasing Power | $60.24 |
| ITS Capital Needs | $294.47 |
| **Total** | **$723.98** |

## Traffic Signals

Figure 6 shows the additional needs for traffic signals. Traffic signal needs total $186.61 million, of which $150.79 million is derived from historical spending, $6.31 million is derived from contract costs, $20.22 million is derived from FE04 spending, $4.54 million is derived from FE01 spending, and $4.75 million is related to controller replacement.

Figure 6: Annual Traffic Signals Needs (2022 USDs)

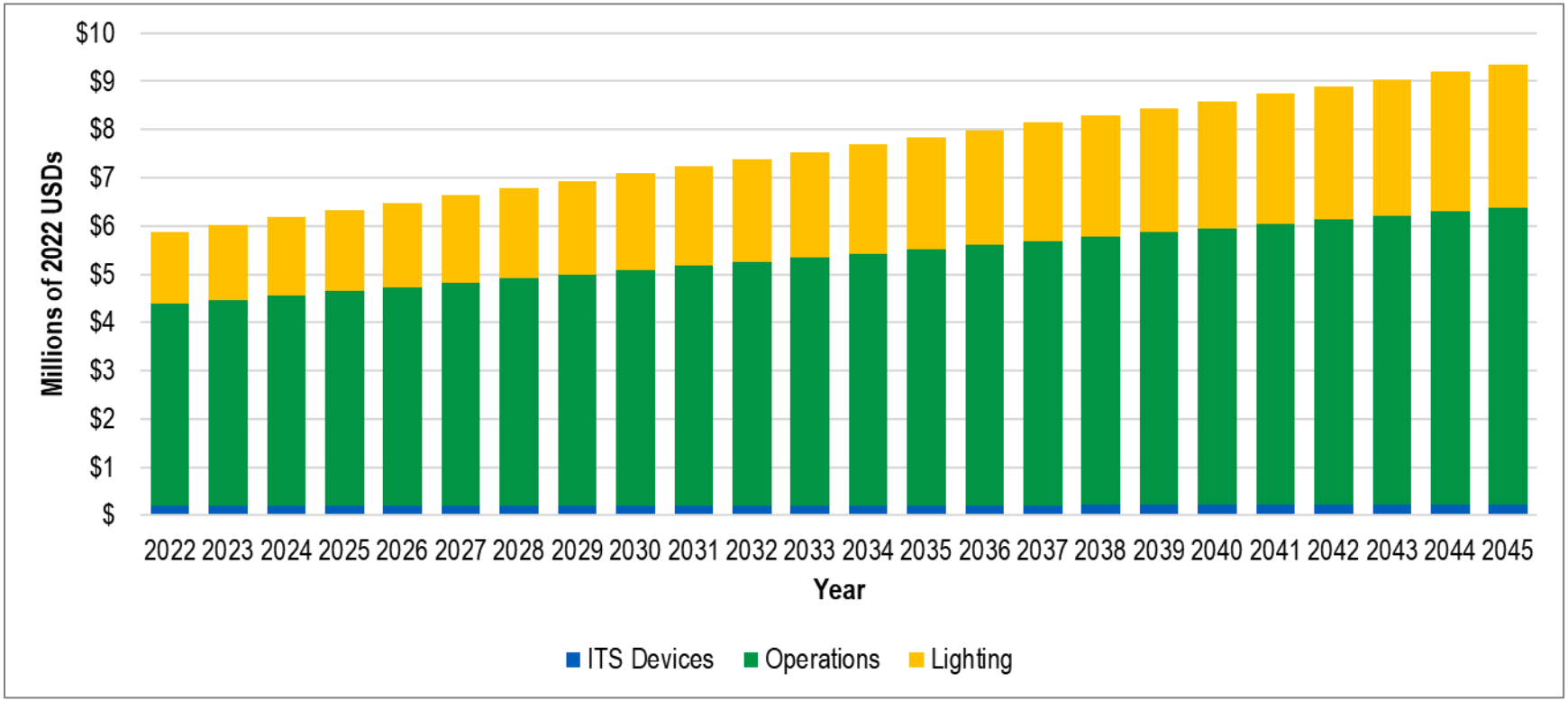


## Intelligent Transportation Systems

### Maintenance

ITS maintenance needs are $192.67 million between 2022 and 2045. They range from $5.88 million in 2022 to $9.34 million in 2045. Figure 7 shows the annual ITS maintenance needs.

Figure 7: Annual ITS Maintenance Needs Excluding Traffic Signals (2022 USDs)




### Capital

ITS capital needs are $294.47 million between 2022 and 2045, which equals $12.27 million per year.

# SUBAPPENDIX A: ALIGNMENT BETWEEN OMS MAINTENANCE ACTIVITIES AND CATEGORIES

Table 5: Alignment Between Maintenance Activities and Categories (TSMO-Related Categories Only)

| Activity | Activity Code | Category |
|---|---|---|
| 1304 Highway Assistance Patrol | P040 | Operations |
| Portable DMS *(Not in Field Operations Guide. Manually assigned.)* | P050 | ITS Devices |
| 1420 Traffic Contract Expenditures & Engineering Expenses for Traffic Signing Projects | T400 | Traffic Signals |
| 1502 Traffic Signal Head Maintenance | T410 | Traffic Signals |
| 1503 Traffic Signal Controller Maintenance (Shop) | T430 | Traffic Signals |
| 1504 Traffic Signal Modification | T440 | Traffic Signals |
| 1505 Highway Lighting Installation & Maintenance | T460 | Lighting |
| 1506 Maintenance of Electrically Operated Signs | T480 | ITS Devices |
| 1507 Maintenance of Navigation Lighting Systems | T490 | ITS Devices |
| 1508 Highway Sign Lighting Maintenance | T500 | ITS Devices |
| 1508 Highway Sign Lighting Maintenance | T550 | ITS Devices |
| 1509 Traffic Contract Expenditures & Engineering Expenses for Traffic Signal & Lighting or Other Electrical Contracts | T590 | Traffic Signals |
| Traffic Data Collection *(Not in Field Operations Guide. Manually assigned.)* | T600 | Operations |
| Traffic Data Analysis *(Not in Field Operations Guide. Manually assigned.)* | T610 | Operations |
| Hazardous Material Removal *(Not in Field Operations Guide. Manually assigned.)* | T700 | Operations |
| Traffic Stock Account – Materials *(Not in Field Operations Guide. Manually assigned.)* | T800 | Operations |
| Traffic Stock Account – Personnel and Equipment *(Not in Field Operations Guide. Manually assigned.)* | T810 | Operations |
| Miscellaneous Traffic *(Not in Field Operations Guide. Manually assigned.)* | T990 | Operations |

Note: This table includes all activities in the *Field Operations Guidance Manual*.[15] Some activities present in the historical spending and absent from the *Field Operations Guidance Manual* were assigned manually.

[15] Kentucky Transportation Cabinet (2011). *Field Operations Guidance Manual*. Retrieved from https://transportation.ky.gov/Organizational-Resources/Pages/Policy-Manuals-Library.aspx.