Appendix L:
Highway Capacity

GET THERE TOGETHER.

Kentucky's Long-Range Transportation Vision

INTRODUCTION

Highway capacity is defined as, the maximum number of vehicles that can pass a given point during a specified period under prevailing roadway, traffic and control conditions. This assumes that there is no influence from downstream traffic operation, such as backing up of traffic into the analysis point.[1] Some of the factors affecting highway capacity include:

1. Lane width	2. Width of shoulder
3. Lateral clearance	4. Commercial vehicles
5. Road alignment and geometry (curves, Super elevation etc.)	6. Existence of intersections.
7. One way or two-way traffic and number of lanes	8. Drivers and vehicular characteristics
9. Single type or mixed traffic	10. Flow speed
11. Weather condition	12. Parking
13. Presence of pedestrians	

WHAT IS CONGESTION?

Congestion occurs when traffic volumes approach or exceed capacity, which is the maximum amount of traffic capable of being handled by a given highway section and which can be significantly impacted by traffic control devices. It is often characterized by stop-and-go traffic. Locations which experience recurring congestion caused by traffic volumes routinely exceeding capacity are referred to as bottlenecks. The severity of these bottlenecks varies over time with fluctuations in traffic[2]. In addition, non-recurring congestion can occur due to events such as:

1. **Traffic Incidents** – Events like crashes or vehicle breakdowns affect normal flow and slow traffic down.
2. **Work Zones** – Roadway construction often results in temporary capacity reductions such as lane closures and narrowing of lanes and shoulders.
3. **Weather** – Snow, rain or other weather events can affect traffic flow.
4. **Special Events** – Happenings like sporting events or concerts can have a dramatic effect on traffic.

This study considered congestion in two ways. The first way looked at the physical capacity of how much traffic a given cross-section of roadway can accommodate. When traffic exceeds that physical capacity, bottlenecks occur. The second way looked at reliability which can measure the influence of factors such as work zones, weather, or special events; poor reliability leads to unpredictable travel times, which can create logistical difficulties for businesses and the traveling public.

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1 Highway Capacity Manual 7th Edition A Guide for Multimodal Mobility Analysis (2022)

2 Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation https://ops.fhwa.dot.gov/congestion_report/executive_summary.htm

METHODOLOGY

Overview

Kentucky's transportation needs reflect a "bottom-up" approach compiling project specific needs with projected network-based improvements across time periods, local geographies, as well as state-maintained and locally managed systems. Needs are defined as network-based and project-specific capital costs reflective of the sources and methods which generate them.

Results of the needs assessment should be interpreted in light of some methodology limitations including:

- **Planning Level Estimates** - Quantifying statewide multimodal transportation needs to 2045 is challenged due to future variables. Highway and non-highway project and asset improvement needs vary across regions based on local demand and underlying infrastructure. So, while useful, planning-level estimates should be interpreted as order-of-magnitude outcomes.
- **Snapshot-in-Time Needs** - Estimates cannot predict but only infer changing conditions likely to occur over 30 years as there is a high degree of uncertainty as to how conditions will change in 30 years. Changes may occur unevenly across Kentucky's urban and rural geographies and may be impacted by factors like technology infrastructure. Kentucky's 2022 - 2045 Long-Range Statewide Transportation Plan (LRSTP) forecast is based on best available data informed by future infrastructure deterioration and demand as well as short-term agency policy, projects, and programs like the Strategic Highway Investment Formula for Tomorrow (SHIFT).
- **Statewide Travel Demand Model (KY Model)** – This is a tool used to predict future statewide travel demand that limits specifying highway expansion needs to currently planned projects. The needs for this capacity analysis were determined from the model as well as the MPO Plans and the Kentucky Statewide Corridor Plan, *Linking Kentucky*.

This section of the document focuses on the capacity issues caused by a breakdown in traffic performance on sections of the highway system and calculates the needs associated with those sections.

Data Sources

The needs were determined by using the KY Model, MPO Metropolitan Transportation Plans (MTPs) and the Statewide Corridor Plan. (See Figure 1.) Cost estimates by various cross-section on a per mile basis were developed as part of the Statewide Corridor Plan. These numbers were used along with proposed cross-section types for the calculation of a per mile cost and is the foundation of the needs assessment. All the calculations were done in Year 2022 dollars. The MPO plans were used to identify their fiscally constrained projects, then additional capacity improvement projects were identified, and a GIS layer containing both the planned MPO-area projects and the newly-identified projects was developed. The KYOVA MPO (for the Tri-State area of West Virginia, Kentucky, and Ohio) was not included in the analysis since their plan did not identify any capacity-adding projects in Kentucky. Table 2 shows the primary data sources that were used to generate highway capacity needs.

Figure 1: Congestion Gap Analysis Process

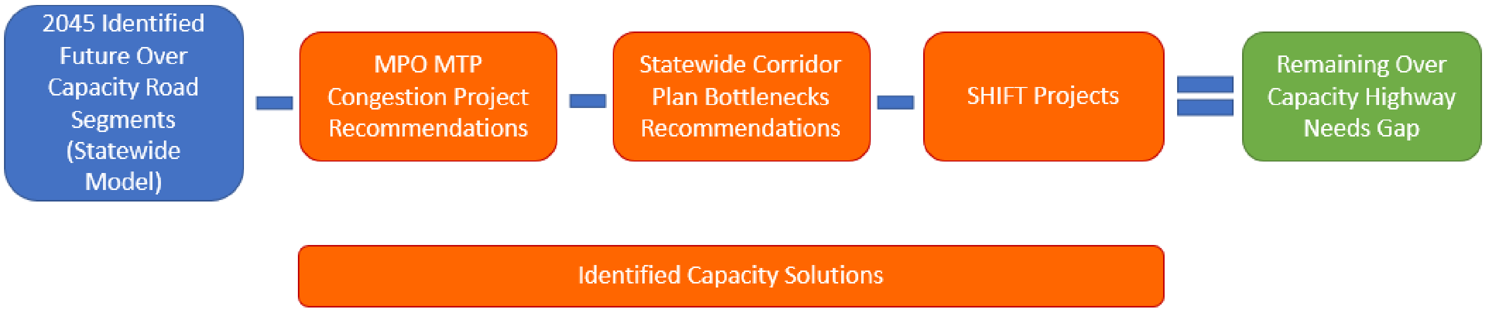


Table 1: Primary Data Sources

Source	Description	Purpose in Methodology
Kentucky Statewide Travel Demand Model	Statewide system with modeled future traffic	Used to determine over-capacity segments
Kentucky Statewide Corridor Plan	Overview of corridor issues	Used to identify projects outside of model
Bowling Green MTP	MPO's project needs with estimated costs	Used to identify needs not currently met
Clarksville MTP	MPO's project needs with estimated costs	Used to identify needs not currently met
Evansville MTP	MPO's project needs with estimated costs	Used to identify needs not currently met
KIPDA MTP	MPO's project needs with estimated costs	Used to identify needs not currently met
Radcliff-Elizabethtown MTP	MPO's project needs with estimated costs	Used to identify needs not currently met
Lexington MTP	MPO's project needs with estimated costs	Used to identify needs not currently met
OKI MTP	MPO's project needs with estimated costs	Used to identify needs not currently met
Owensboro MTP	MPO's project needs with estimated costs	Used to identify needs not currently met

The identified Strategic Highway Investment Formula Tomorrow (SHIFT) projects were used as part of this analysis. SHIFT is KYTC's data-driven approach to prioritize limited transportation funds. SHIFT identifies a recommended priority list of projects based on available funds and identifies other projects which could be funded if additional funds were generated. Based on five key categories (safety, asset management, congestion, economic growth, and benefit/cost), SHIFT uses measurable data to assess the need for and benefits of proposed projects and compares them to each other.

Assumptions

Kentucky has nine MPOs that develop their own metropolitan transportation plans (MTPs) at least every 4-5 years focused on their individual metropolitan planning areas (MPAs). Six of the nine MPOs either border neighboring states or include portions of neighboring states in their MPAs. MPOs are federally required to develop MTPs with a minimum 20-year planning horizon; planning horizons for the current MTPs are between 2040 and 2050. These MTPs contain both short-term projects which are also included in their Transportation Improvement Programs (TIPs) and long-range projects with planning-level cost estimates in year-of-expenditure dollars. The MTP project information was reviewed extensively and compared to KYTC's databases to eliminate duplicates, check cost estimates, and verify project descriptions. For consistency, prior year values or nominal forecasted values were inflated or deflated to bring all estimates to a 2022 base year for this analysis.

Some data assumptions include the following:

- Transportation needs come from data, tools, plans, and expert input on asset deficiencies, traffic safety challenges, highway congestion and reliability, multimodal network gaps, and other critical issues that are part of maintaining and operating a safe, efficient, and reliable system.
- Not all needs are the same – fiscally constrained needs are more immediate and associated with existing plans and programs; unconstrained needs are aspirational and focus on long-term transportation visions and goals.
- Required spending such as debt service, routine maintenance, and administrative costs are considered mandatory and are not reflected as needs.
- Transportation systems require upkeep for safe and reliable use.
- The 2022 - 2045 LRSTP will help KYTC prioritize approaches to address these needs, leading to future investments by mode, timeframe, and system responsibility.

It should be noted that in working with these various data sets from MPOs as well as the SHIFT projects, consistency is an issue as far as items such as data coverage and the methodology for determining year of expenditure costs. Future, relatively simple changes for consistency in MPO plans could help KYTC when completing future statewide analyses.

Processing

Unit or per mile costs were calculated from GIS shapefiles and MTPs provided by Kentucky MPOs. Typical cost per mile by improvement category and KYTC District, as detailed in the KY Statewide Corridor Plan, are summarized in Table 3.

Table 2: Costs by Improvement Category and KYTC District

Improvement Category	Unit	KYTC Districts 5.6, and 7 (Cost in Millions)				KYTC Districts 1, 2, 3, 4, 8, and 9 (Cost in Millions)				KYTC Districts 10, 11 and 12 (Cost in Millions)			
New Roadways		D	R	U	C	D	R	U	C	D	R	U	C
New 4 Lane Expressway	Per Mile	$1.5	$2.0	$0.4	$10.0	$1.2	$1.6	$1.2	$13.0	$1.0	$0.85	$0.5	$10.0
New Super 2 Highway	Per Mile	$1.5	$2.0	$0.4	$10.0	$0.5	$1.3	$1.1	$6.0	$0.65	$0.625	$0.275	$6.0
New 2 Lane Highway	Per Mile	$1.125	$1.5	$0.3	$7.5	$0.5	$1.2	$1.1	$4.0	$0.65	$0.625	$0.275	$6.0
Major Widening (Divided Road)		D	R	U	C	D	R	U	C	D	R	U	C
4 Lane to 6 Lane (Rural)	Per Mile	$1.0	$2.0	$0.4	$10.0	$1.5	$0.6	$0.5	$4.0	$1.0	$0.7	$0.5	$12.5
4 Lane to 6 Lane (Urban))	Per Mile	$1.8	$6.5	$1.5	$12.0	$1.0	$1.2	$0.8	$5.2	$2.0	$3.5	$1.5	$25.0
2 Lane to 4 Lane (Rural)	Per Mile	$1.0	$2.0	$0.4	$10.0	$1.1	$0.6	$0.5	$4.0	$1.0	$0.7	$0.5	$12.5
2 Lane to 4 Lane (Urban)	Per Mile	$1.8	$6.5	$1.5	$12.0	$1.0	$1.2	$0.8	$5.2	$2.0	$3.5	$1.5	$25.0

Minor Widening (Undivided Road)		D	R	U	C	D	R	U	C	D	R	U	C
2 Lane to 4 Lane (Rural)	Per Mile	$1.2	$1.6	$0.32	$8.0	$1.1	$0.6	$0.4	$04	$0.6	$0.42	$0.3	$7.5
2 Lane to 4 Lane (Urban)	Per Mile	$1.8	$6.5	$1.5	$12.0	$1.5	$1.2	$0.7	$5.2	$1.2	$2.1	$0.9	$15.0
Arterial Upgrade to Pkwy/Expwy		D	R	U	C	D	R	U	C	D	R	U	C
Upgrade with Pavement Reconstruction	Per Mile	n/a	n/a	n/a	n/a	$1	$0.75	$1.2	$8	$2	$3.5	$1.5	$15.0
Upgrade with Pavement Rehab	Per Mile	n/a	n/a	n/a	n/a	$0.5	$0.2	$0.1	$1.0	$1.0	$0.7	$0.5	$12.5

Source: Statewide Corridor Plan, Linking Kentucky, September 2021

All of Kentucky's MTPs were reviewed, and the MPO projects identified as congestion mitigation projects were selected from each, and further categorized by proposed cross section and KYTC District as defined by the Statewide Corridor Plan. Each of the congestion mitigation project's length was multiplied by the unit cost by improvement category and KYTC District (Table 3 above) to calculate a project cost.

This cost was converted to 2022 dollars to keep the values consistent with other cost estimates in this study. The congestion mitigation project lengths and costs were further grouped by functional classification using spatial data provided by KYTC. The cost and distance were averaged for each functional class to create a typical cost per mile that accounts for cost variations between KYTC Districts and urban/rural areas. The results of these calculations are listed in Table 4. The following limitations with respect to the cost estimates should be noted:

1. The cost estimation may not include additional costs to address the potential impacts of major utilities (e.g., gas line, major water supplier, transmission line) within the proximity of the corridor, due to the lack of data when the cost was estimated.
2. Cost estimation was based on 2022 dollars. A 2% inflation rate was used to inflate or deflate costs to Year 2022.
3. Any project used to benchmark cost is on a state-maintained facility and identified as a congestion mitigation project.

Table 3: Average Cost Per Mile by Functional Class for Congestion Mitigation Projects

Functional Class	Unit Costs (2022 Dollars)
Interstate	$11,762,828
Other Freeway	$10,372,672
Principal Arterial	$8,355,070
Minor Arterial	$9,649,536
Major Collector	$8,272,795
Minor Collector	$5,725,227
Local	$4,722,482

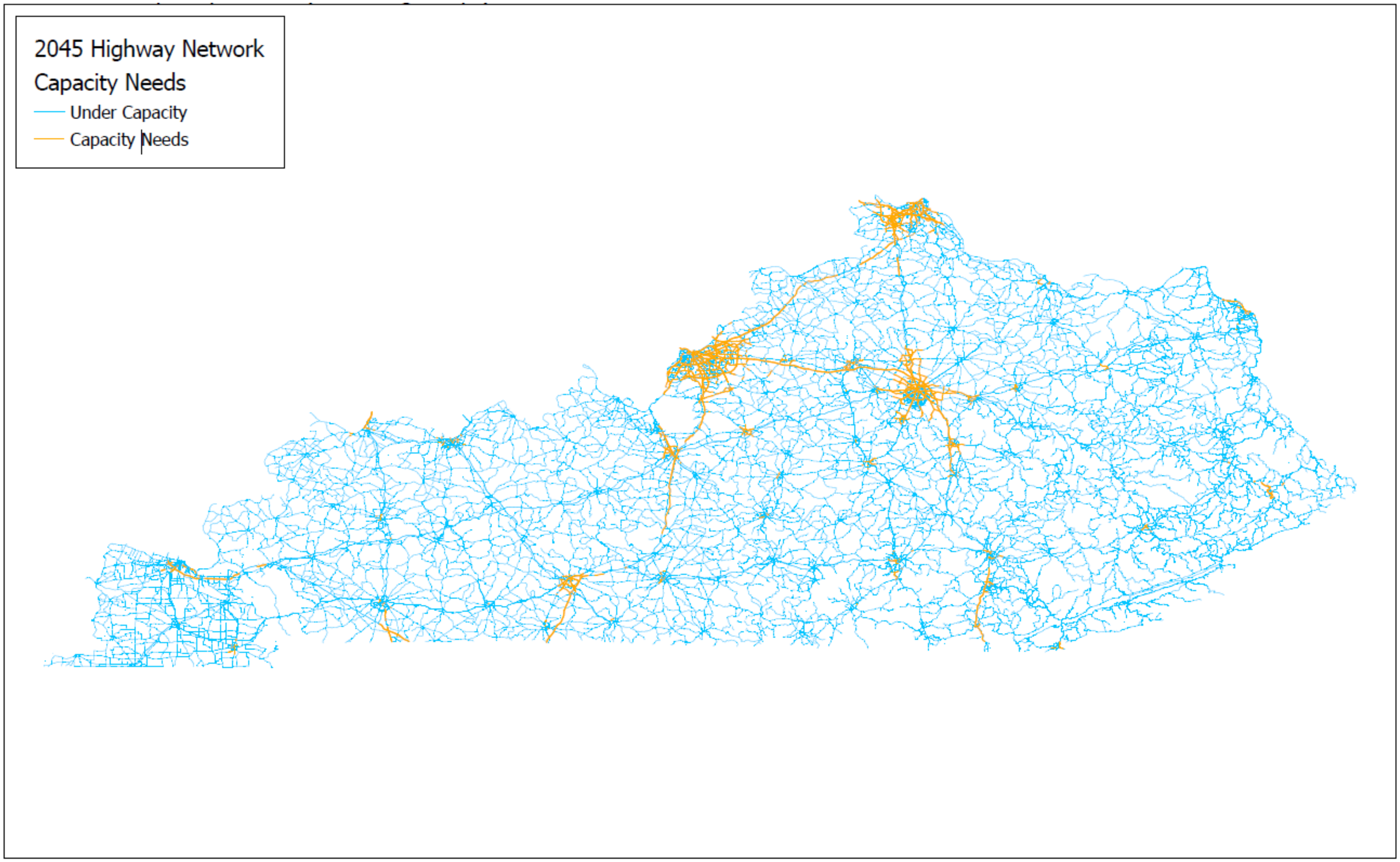
IDENTIFIED VOLUME TO CAPACITY NEEDS

One of KYTC's powerful planning tools is the KY Model. It provides information regarding roadway capacities, traffic flows, future growth patterns, and socio-economic benefits of proposed corridor improvements. The KY Model was used to estimate the need for increased capacity (lane-miles) in Year 2045 for roadways maintained by the State. This estimate reflects the travel demand associated with demographic and socio-economic forecasts for Year 2045 and roadway system capacity circa 2017. The travel model provides daily traffic demand and congestion estimates.

Capacity need estimates were based on identifying segments of road that exceed an average annual daily traffic volume-to-capacity ratio of 60%. This threshold reflects the level of daily demand where peak period travel times become unreliable and was based on conversations with KYTC staff. Capacity needs estimates were calculated for each state-maintained roadway segment in the travel demand model and aggregated by roadway functional class, and by county.

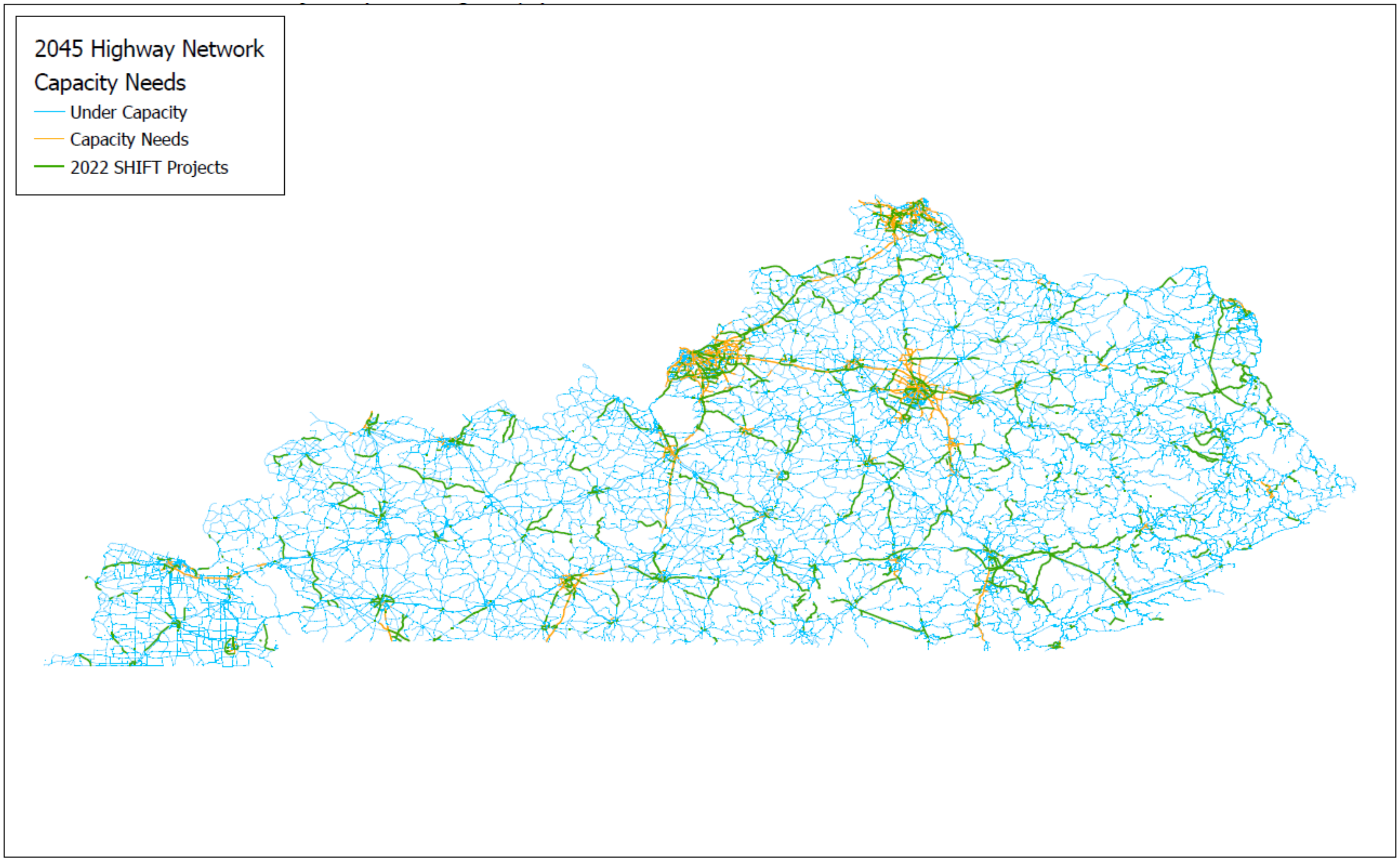
The MPO Plans identified congestion mitigation projects, and the SHIFT 2022 project locations were identified in GIS. These projects represented addressed all needs through the 2045 horizon year regardless of funding status. These projects were then overlaid on the map of capacity needs to determine if a SHIFT or MPO project addressed capacity needs. If a SHIFT or an MPO project overlapped with an area that was identified as over-capacity, then those needs were eliminated from the analysis, leaving the remaining identified needs. Figures 2, 3 and 4 illustrate these overlays and the remaining needs.

Figure 2 - Capacity Needs from Statewide Model



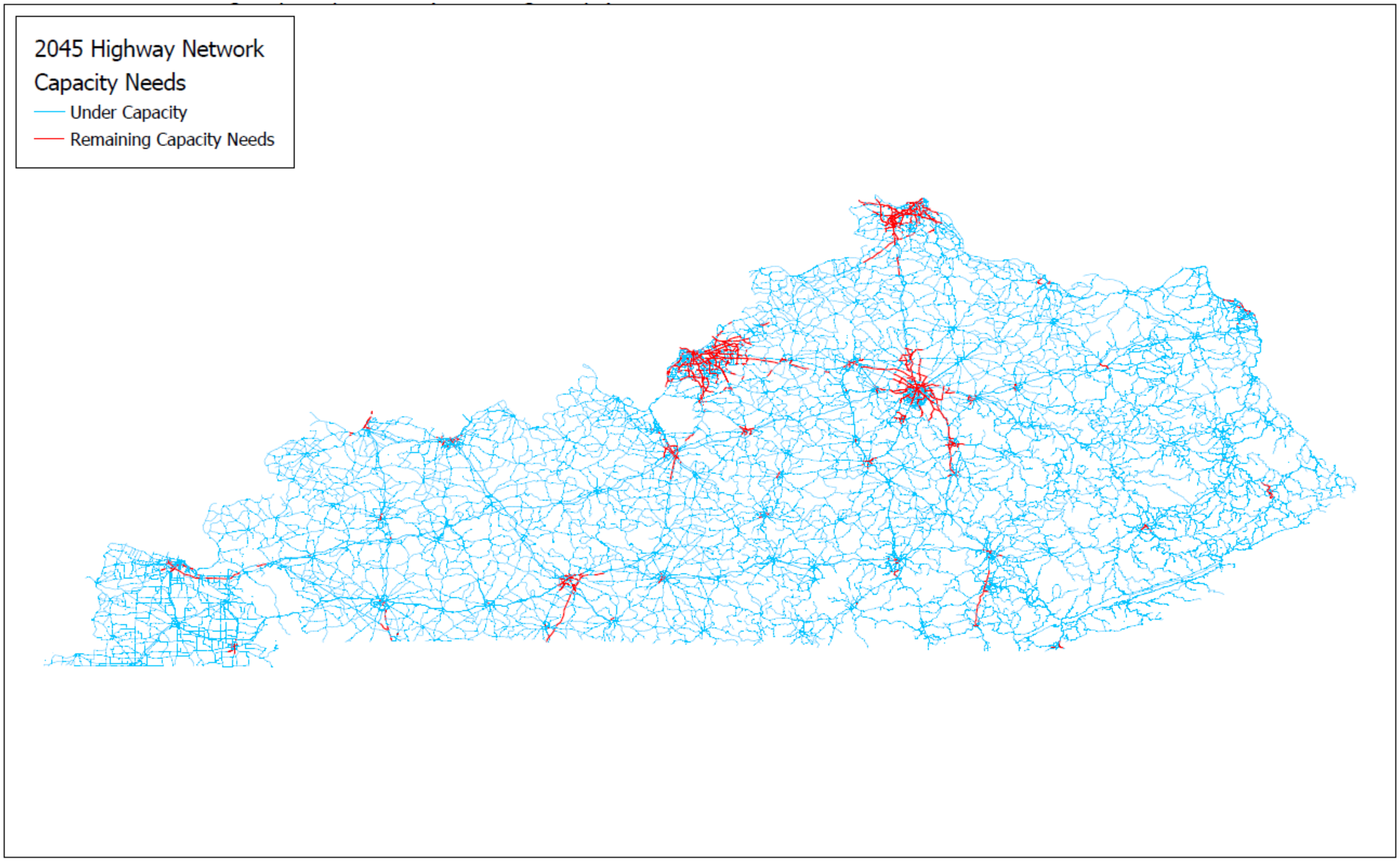
Current segments over-capacity identified on the Statewide Model.

Figure 3 - Capacity Needs from Statewide Model with SHIFT Overlay



Capacity needs overlaid by the SHIFT projects, identifying need not currently covered by plans in Kentucky.

Figure 4 - Capacity Needs from Statewide Model after SHIFT Projects Removed



Remaining statewide capacity needs after SHIFT projects removed.

ADDITIONAL NEEDS – STATEWIDE CORRIDOR PLAN

To build upon the SHIFT process, KYTC initiated the Kentucky Statewide Corridor Plan (SWCP), also known as *Linking Kentucky*, in the fall of 2019. The plan identified regional corridors which have the greatest potential for improved safety, reduced travel time, improved system reliability, and economic benefits to Kentucky through better transportation service to people and goods.

Using a data-driven approach, Linking Kentucky was unrolled in two tiers to identify the most impactful corridors based on existing (2015), intermediate (2030), and long-term (2045) transportation needs. Tier 1 started with 52 long corridors (aka Statewide Corridor Network) and narrowed them to 26 corridors that had the greatest potential to better link Kentucky's regions and improve safety, mobility, and accessibility. Tier 2 subdivided the 26 corridors into 45 segments for more detailed analysis and then selected 20 priority segments by accounting for comprehensive, quantitative, and qualitative factors as well as input from stakeholders.

Traffic bottlenecks were identified for each visioning corridor. A traffic bottleneck is a localized section of highway that experiences reduced speeds and greater delays due to a recurring operational influence, according to the definition of FHWA's Localized Bottleneck Reduction (LBR) Program. General characteristics of capacity and congestion bottlenecks according to the LBR are:

1. A traffic queue upstream of the bottleneck
2. A beginning point for the queue
3. Free flow traffic conditions downstream
4. A predictable recurring cause
5. Traffic volumes that exceed the capacity of the confluence[3]

Bottlenecks contribute to recurring congestion. They are measurable in design and function and are therefore candidates for remediation. The remaining sources of congestion are nonrecurring and random. In addition, high traffic volumes approaching capacity, maintenance or short-term construction (e.g., work zone), incidents or weather, are typical causes for poor reliability that trigger high variability in operating speeds and travel times. The LRSTP requires ensuring dependable, effective, and efficient facilities. Therefore, it is important to reduce bottlenecks to improve the mobility and reliability of movements, leading to less congestion, fewer infrastructure repairs, and lower emissions.

What was determined as acceptable or unacceptable congestion by the SWCP study was where the volume-to-capacity (V/C) ratio is less than 0.85 in urban areas or less than 0.7 in rural areas, the roadway was considered "Acceptable"; otherwise, it was considered "Unacceptable".[4] This is shown in Figure 5.

The corridor projects identified from the SWCP that were identified outside of the needs identified by the travel demand model, SHIFT and the MPO projects were included in the following analysis to develop a list of needs by functional class.

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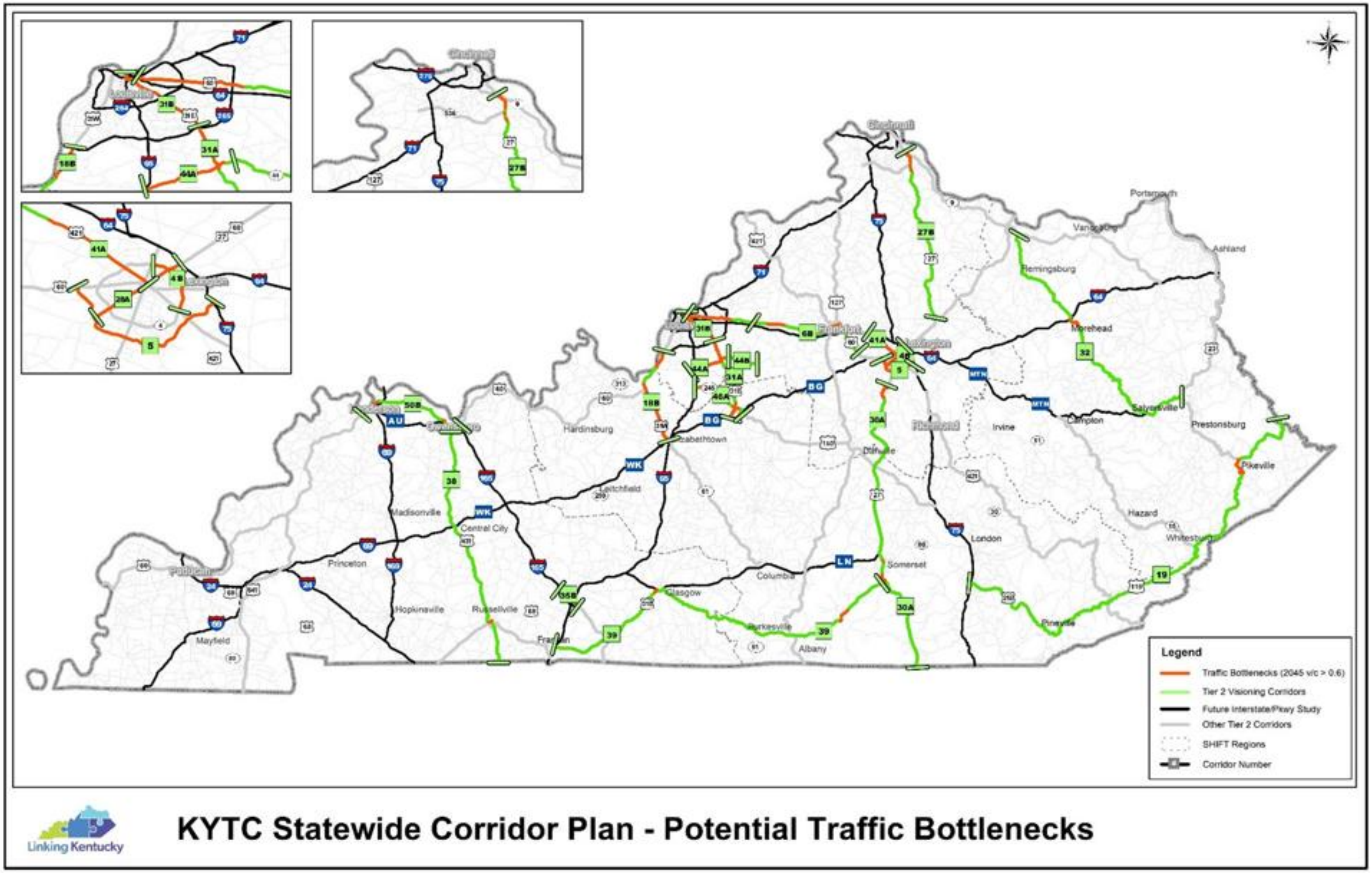
[3] FHWA Localized Bottleneck Reduction Program, https://ops.fhwa.dot.gov/bn/lbr.htm#g3
[4] Statewide Corridor Plan, Linking Kentucky, September 2021

Figure 5 - SWCP Potential Bottleneck Locations



CONGESTION NEEDS RESULTS

The cost of the identified remaining needs was calculated using the length of additional number of lanes needed on the segment of roadway and the functional class typical cost per mile. The Statewide Corridor Plan identified additional bottleneck projects to address congestion along the corridors. The bottleneck projects were reviewed to determine if SHIFT projects address those needs. In some cases, projects weren't addressed, and the costs of these projects were also totaled as a remaining need and added to the total cost. The costs for all remaining needs are summed below by functional class in Table 5.

Table 4: Congestion Needs

Description	Total Lane Mile Capacity Needs (Traffic Model)	Lane Capacity Miles Accounted for in SHIFT 2022 Projects	Lane Capacity Miles Remaining Needs	Typical Cost per Mile (2022 Dollars)	Total Cost of Remaining Needs
Interstate	592.16	234.83	357.33	$11,762,828	$4,203,215,346
Other Freeway	38.54	13.89	24.64	$10,372,672	$255,616,173
Principal Arterial	852.20	214.50	637.70	$8,355,070	$5,328,035,361
Minor Arterial	672.10	162.07	510.04	$9,649,536	$4,921,610,063
Major Collector	151.38	22.81	128.56	$8,272,795	$1,063,571,801
Minor Collector	8.37	3.68	4.68	$5,725,227	$26,806,600
Local	27.09	10.79	16.30	$4,722,482	$76,968,428
Bottleneck Projects (SWCP)*			44.10	$6,859,410	$302,500,000
Total Spending Needs					$16,178,323,762

**These projects fall outside the Kentucky SHIFT identified project list and MPO project lists.*

The resulting total spending needs for strictly congestion projects that were identified were approximately **$16 billion** to meet the anticipated congestion problems currently identified in Kentucky to the year 2045.

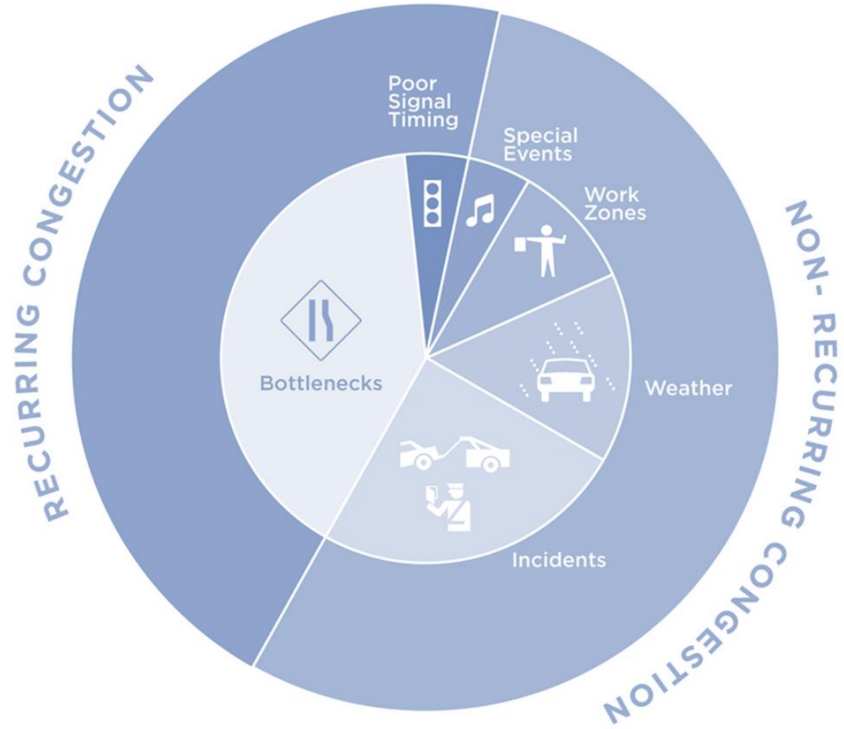
RELIABILITY AND ITS EFFECT ON CONGESTION

Travel time index (TTI), defined as the ratio of peak period travel time to free-flow travel time, is used to quantify congestion on a facility and gives a measure of how well traffic is flowing in the peak period as compared to "free flow" conditions. The travel time index or TTI can be calculated using the following equation:

Travel Time Index = Peak Period Travel Time / Free Flow Travel Time

In the case of arterial roadways, the free-flow speed is often defined as the uncongested speed or speed that travelers attain during periods of light traffic not to exceed the posted speed limit. As measured data is often scarce on arterial facilities, the speed limit is often used as the free-flow speed in place of uncongested measured speeds. This in turn makes the free-flow travel time equal to the travel time when traveling at the speed limit.[5] Sources of congestion are shown in Figure 6.

Figure 6 - Types of Congestion



Source: Incorporating Travel-Time Reliability into the Congestion Management Process (CMP): A Primer, Chapter 1, Figure 1

[5] Incorporating Travel-Time Reliability into the Congestion Management Process (CMP): A Pr

Reliability Data Source

Reliability data was obtained from Regional Integrated Transportation Information System (RITIS). Travel times are based on 2019 weekday hourly travel times from the National Performance Management Research Data Set (NPMRDS) obtained by the Federal Highway Administration (FHWA). The analysis used MAX TTI, the maximum hourly value over all hours of day, to identify road segments with moderate to high congestion. TTI thresholds for levels of congestion are rated on the following scale:

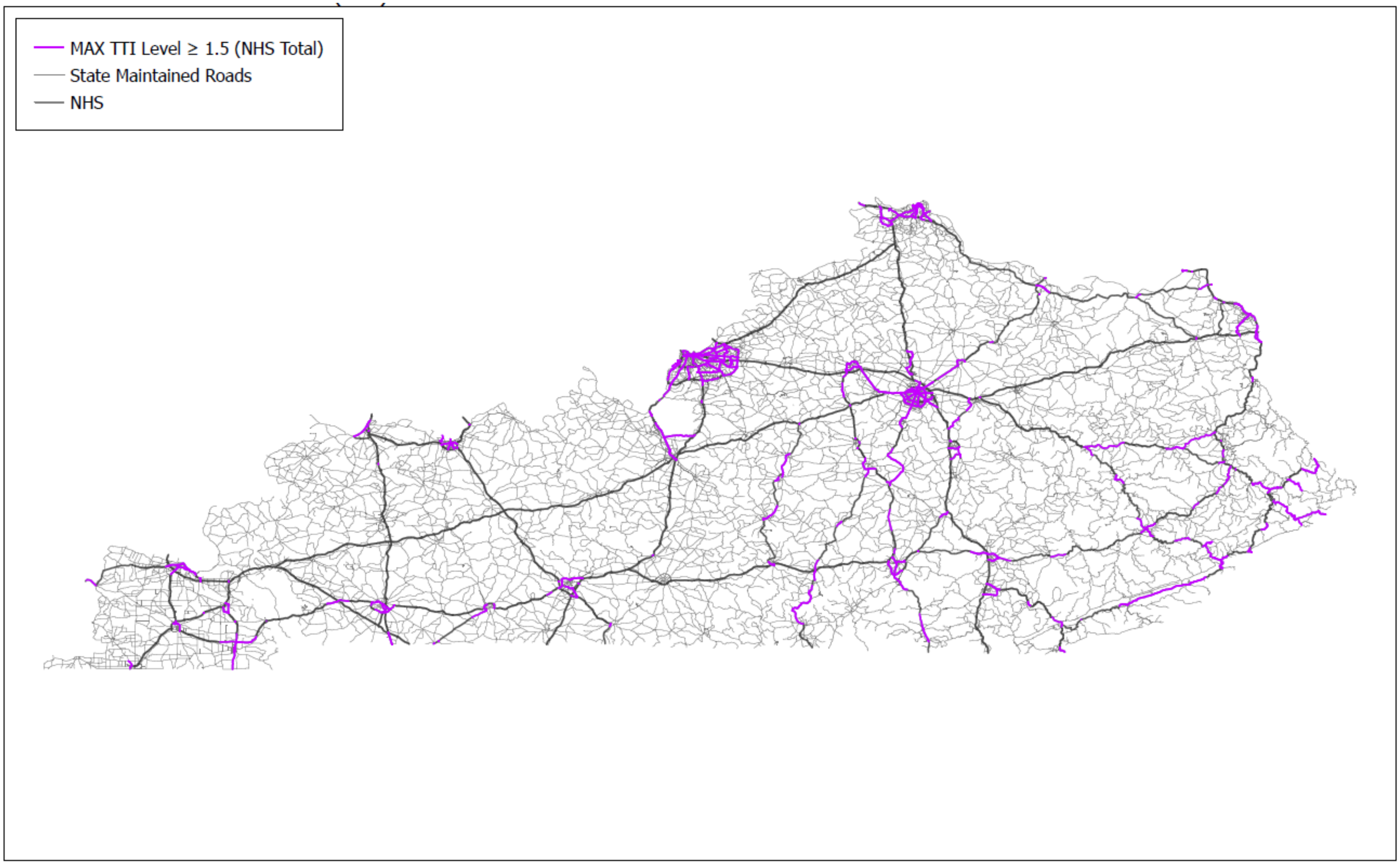
- No Congestion (<1.3)
- Low Congestion (1.3-1.5)
- Medium Congestion (1.5-2.0)
- High Congestion (2.0-4.0)
- Severe Congestion (>4.0)

Areas of congestion with a TTI ≥ 1.5, meaning travel time that is 50% longer than at free flow speeds, were identified and grouped by functional class to match the capacity analysis data. The road segments contained in a 2022 SHIFT project area were then removed. The remaining road segments are areas of interest for continued investigation into road reliability improvements. These areas only include roads that are part of the Kentucky National Highway System, not the entire state-maintained road system used in the capacity analysis.[6]

To identify segments of roadway that had a poor reliability, anything that required 50% or greater travel time beyond the free flow speed limit was flagged. Figure 7 illustrates these segments.

[6] Kentucky National Highway System (NHS) Congestion and Reliability Map https://tmp-map.s3.amazonaws.com/kentucky/kentucky-congestion-and-reliability.html

Figure 7 - Travel Time Index (TTI)



Then, as done with the bottleneck capacity projects, the locations with poor reliability were overlaid with the SHIFT projects to determine unaddressed needs. These are illustrated in Figure 8 below. The entire reliability process is shown in Figure 9.

Figure 8 - Travel Time Index (TTI) after SHIFT Projects Removed

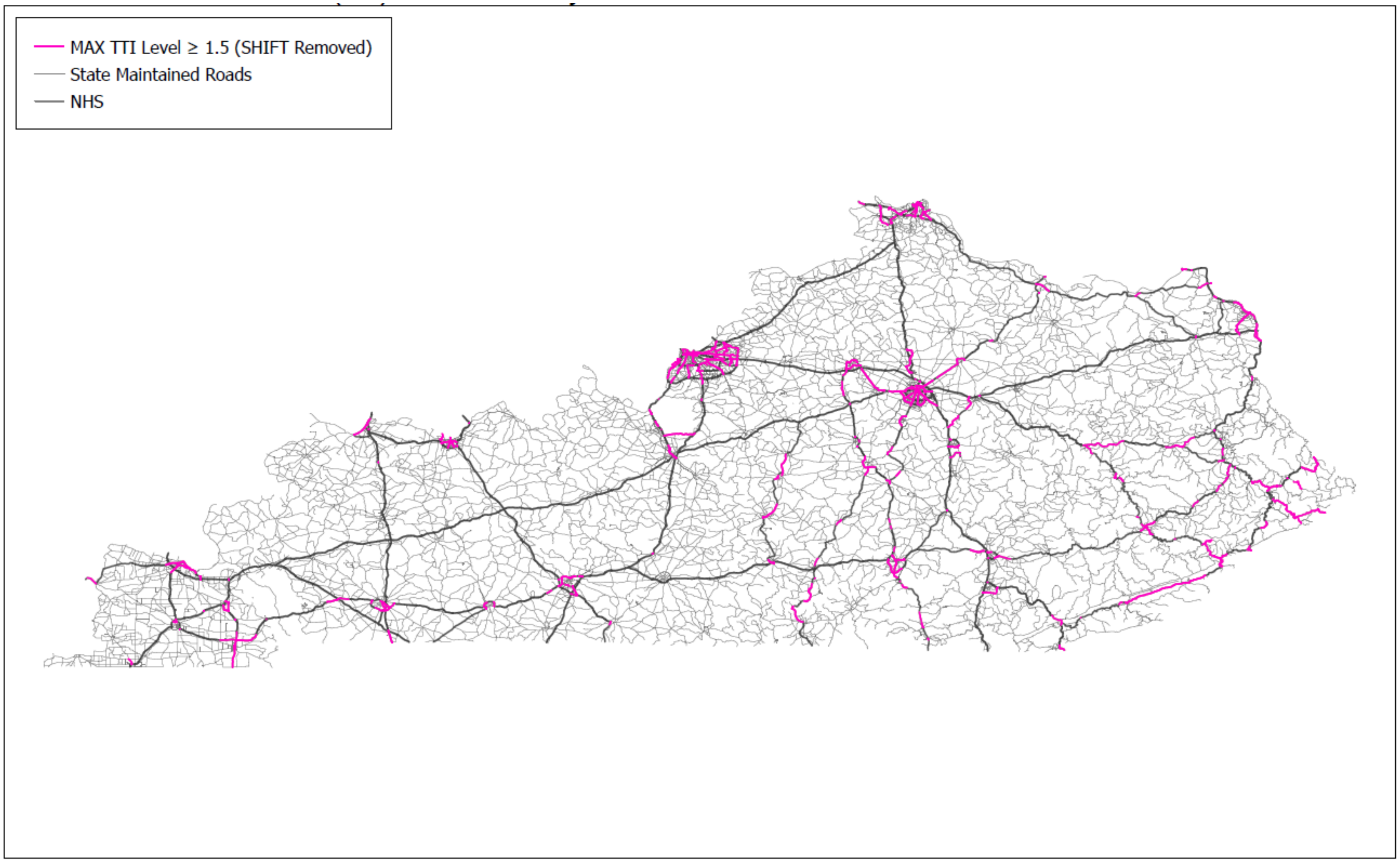
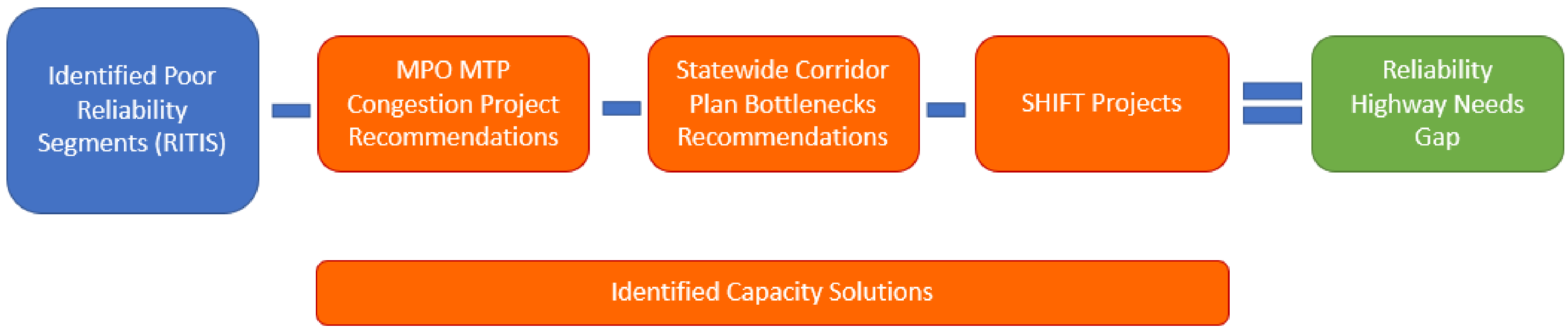


Figure 9 - Reliability Gap Analysis Process



The unaddressed miles of roadway reliability by functional classification are shown in Table 6.

Table 5 – Unaddressed Roadway Reliability

Functional Class	TTI ≥ 1.5 (Miles)
Interstate	73.21
Other Freeway	34.63
Principal Arterial	1261.43
Minor Arterial	38.11
Major Collector	31.21
Minor Collector	0.87
Local	10.00
Total Miles	1449.47

Why Does Reliability Matter Now?

Traffic congestion due to non-recurring events such as traffic incidents, weather, road work zones, and special events accounts for most of the total traffic congestion-related delay in the United States. Up until recently, there were few options for cost-effectively collecting data for non-recurring events, particularly unplanned events such as crashes. MPOs and states that recognized the importance of travel-time reliability early on developed proxy objectives and performance measures, such as reducing collisions. Most agencies, however, have focused their congestion management processes (CMPs) on recurring congestion.

The focus on recurring congestion in CMPs has been easier to quantify from a monitoring standpoint but has led to improvement strategies that focus on capacity expansion. Capacity expansion is increasingly difficult and expensive to implement. Expanding the scope of CMPs to address non-recurring congestion would mean more data collection and analysis. However, it would also lead to an expanded toolbox of improvement strategies that would incorporate transportation system management and operations (TSM&O). TSM&O strategies are generally easier and less expensive to implement.

With the growing field of inexpensive travel-time monitoring technologies and new prediction tools available, it is now feasible to develop reliability performance measures. Analysis tools have been developed to identify current reliability problems and to predict reliability problems in the future.

Three major factors have also contributed to driving the focus on travel-time reliability by Federal, State, and Metropolitan Planning Organizations:

1. **Constraints on Expansion of the Transportation System** - The era of new roadway construction has largely ended in most of the major metropolitan areas of the country. In addition, the practice of widening existing roadways is also falling out of favor due to high costs, the built-out nature of many urbanized areas, and community desires for more multi-modal options. As the physical capacity of our roadways is consumed by the growth in traffic, they become more vulnerable to disruptions caused by traffic incidents, inclement weather, special events, and work zones. These non-recurring events can occur at any time and place and can cause congestion even in areas that don't usually experience recurring congestion. Variability in travel times is increasing on more roadways and for more times of the day, in part because non-recurring congestion has not typically been addressed in the traditional transportation planning process. The highway transportation system has become more fragile and more susceptible to major disruptions due to traffic incidents.
2. **Expectations of the Traveling Public** - Surveys of the traveling public and freight shippers repeatedly show that they value travel-time reliability more than speed. They are aware that technologies have been developed to extract data from mobile devices and to monitor real-time traffic conditions. They expect that public agencies will use this data to provide real-time information and to alleviate the effects of disruptions on the roadway and transit network.
3. **Federal Surface Transportation Reauthorization Law** - On July 6, 2012, President Obama signed into law the Moving Ahead for Progress in the 21st Century Act (MAP-21) [4]. MAP-21 established a new paradigm for states and MPOs called "performance-based planning and programming" (PBPP). This means that MPOs, state departments of transportation (DOT), and transit operators became involved in data-driven performance measurement, target setting, and reporting on the outcomes of their transportation investments. MAP-21 began this process by setting seven national goals, and subsequently prescribing performance measures for each. One of the seven goals, Goal 4, was System Reliability – To improve the efficiency of the surface transportation system. [7]

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[7] Incorporating Travel-Time Reliability into the Congestion Management Process (CMP): A Primer https://ops.fhwa.dot.gov/publications/fhwahop14034/ch1.htm#fn1

Improving Travel Time Reliability

Reliability in travel time is important to understand as reliable travel times usually mean safer and more efficient transport for passengers and freight. If travel times are unreliable that leads to frustration and delay as well as intermittent recurring congestion. To manage reliability requires an understanding of travel time reliability.

Some options that can be used to improve travel time reliability are shown in Table 7 and include tools to:

- change business processes to support travel time reliability,
- monitor travel time reliability and usefully preserve the data,
- evolve the institutional arrangements (flexible work times for example) of agencies,
- improve traffic incident scene management, and
- improve overall systems operations and management.[8]

Given the variety of potential causes and solutions for reliability deficiencies, this analysis does not quantify the cost of reliability improvements on the basis of lane-miles of additional capacity as was done with the capacity portion of the congestion analysis. In future plans, as data sources and analytics advance, highly complex analysis of observed data can be cross-referenced with causal factors such as incidents, weather events, work zones, and seasonal traffic patterns to further refine the understanding of reliability deficiencies and identify appropriate solutions.

[8] Improving Travel Time Reliability https://onlinepubs.trb.org/onlinepubs/shrp2/ImprovingTravelTimeReliability.pdf

Table 6 - Tools for Reliable Travel Times[9]

	Incidents	Regional Operations Academy to help mainstream operations strategies. Executive workshops to convey the value of operations strategies to agency mission. Interagency Training for incident responders.
	Weather	Travel information guide and analysis tool for selecting design treatments that improve reliability. Part of a new method to address reliability in the Highway Capacity Manual.
	Work Zones	Tools for travel time monitoring. Models for real-time congestions management.
	Fluctuation in Demand	Performance Measures. Value of Reliability. Incorporating reliability into planning & programming. Economic Evaluation model.
	Special Events	Travel time monitoring. Organizational strategies to improve travel time reliability. Improving data for traveler information.
	Traffic Control Devices	Reliability Monitoring Systems. Methods for estimating capacity of urban streets.
	Inadequate Base Capacity	Guide for geometric designs that advance reliability. Analytical model for assessing effectiveness of strategies. Ways to incorporate reliability into planning & programming.

[9] Improving Travel Time Reliability https://onlinepubs.trb.org/onlinepubs/shrp2/ImprovingTravelTimeReliability.pdf