APPENDIX B:
KENTUCKY STATEWIDE TRAFFIC MODEL

The Kentucky Statewide Traffic Model (KYSTM) has its roots in mainframe computer software dating from the early 1970's. The current TransCAD-based model stems from a version developed in 2005. Since that time, it has been modified and enhanced extensively. The KYSTM is one of KYTC's most powerful and valuable planning tools and has been used to support a wide variety of statewide transportation studies.

B.1 v8_KYSTMv19

The SWIPP used a model that built upon v8_KYSTMv19, the latest model version when the study started. The v8_KYSTMv19 had a base year of 2015 and a future year of 2045 with 5,972 traffic analysis zones (TAZs), running in TransCAD version 8. The v8_KYSTMv19 updated zonal socioeconomic data (e.g., population, households, employment, etc.) and the highway network to represent 2015 and 2045 conditions. All traffic volume estimates, speeds, and congestion levels were based on traffic counts and model traffic assignments.

The v8_KYSTMv19 uses zonal data for the base (2015) and future (2045) years and uses linear interpolation to estimate data for interim forecast years. Important features of the model are:

- The model covers the continental US and includes centroid connectors that extend into Canada and Mexico, comprising 5,972 TAZs. Zones in Kentucky are at a detailed level. There is a ring of zones around Kentucky within about 100 miles of the state line, with intermediate detail. Zones outside of this ring are large and contain less details. The zonal system also contains a set of special generators inside Kentucky. **Figure B.1** and **Figure B.2** illustrate the v8_KYSTMv19 TAZs and network respectively.
- The model calculates the free-flow speeds and capacities of all roadway links, following the methodologies described in 2010 Highway Capacity Manual.
- Zonal data include estimates of population, households, and employment for all zones (2015 and 2045).
- The model produces daily, capacity-restrained assignments (auto, light trucks, heavy trucks), with congested travel times and speeds for all links. Separate estimates are made for autos and trucks. Person trips are estimated for autos, and occupancy factors are applied to estimate vehicle trip tables.
- The model uses seed trip tables for:
  - o Long-distance trips (more than 50 miles) based on the 1995 American Travel Survey.
  - o Work trips based on 2000 Census Journey-to-Work data.
  - o Trucks (light and heavy) based on TRANSEARCH, and later enhanced using classified traffic counts and the OD Matrix Estimation (ODME) technique.
- Traditional trip generation methods and a gravity model are used to estimate short-distance non-work trips. Growth factor models, also known as Fratar models or Iterative Proportional Fitting (IPF), are used to factor the seed trip tables for other purposes. A gravity model is used to supplement the home-based work (HBW) and long-distance trips for TAZs that were empty in the base year.
- The model supports selected link assignments. In most cases, the selected links are composed of long study corridors. This feature was used extensively in this study.
- The model has a set of routines that can be used to create Transportation Economic Development Impact System (TREDIS – see Section 2.9) inputs for economic analysis. This feature was also used extensively in this study. The model produces a set of extensive evaluation metrics with every run.
- The model is set up to extract a subarea, which is useful for estimating external traffic for regional models (not used in this study).

Figure B.1 – v8_KYSTMv19 Traffic Analysis Zones (TAZ)

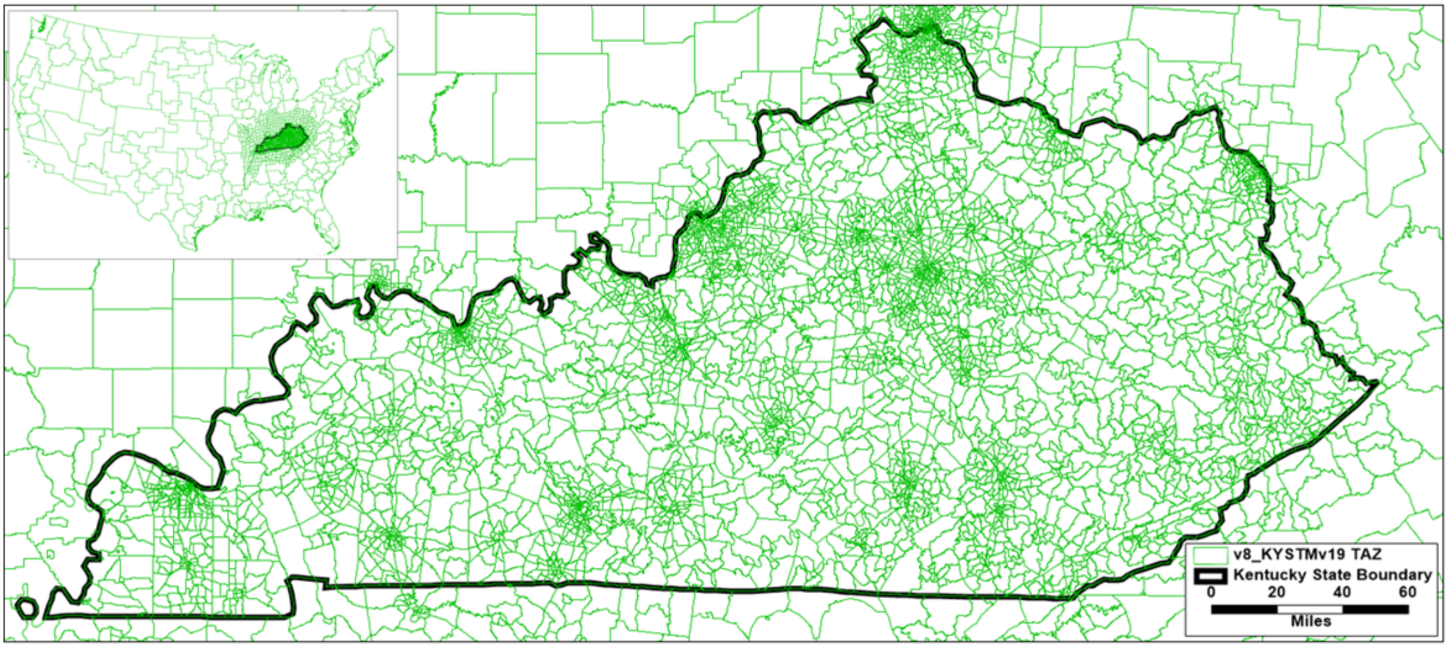
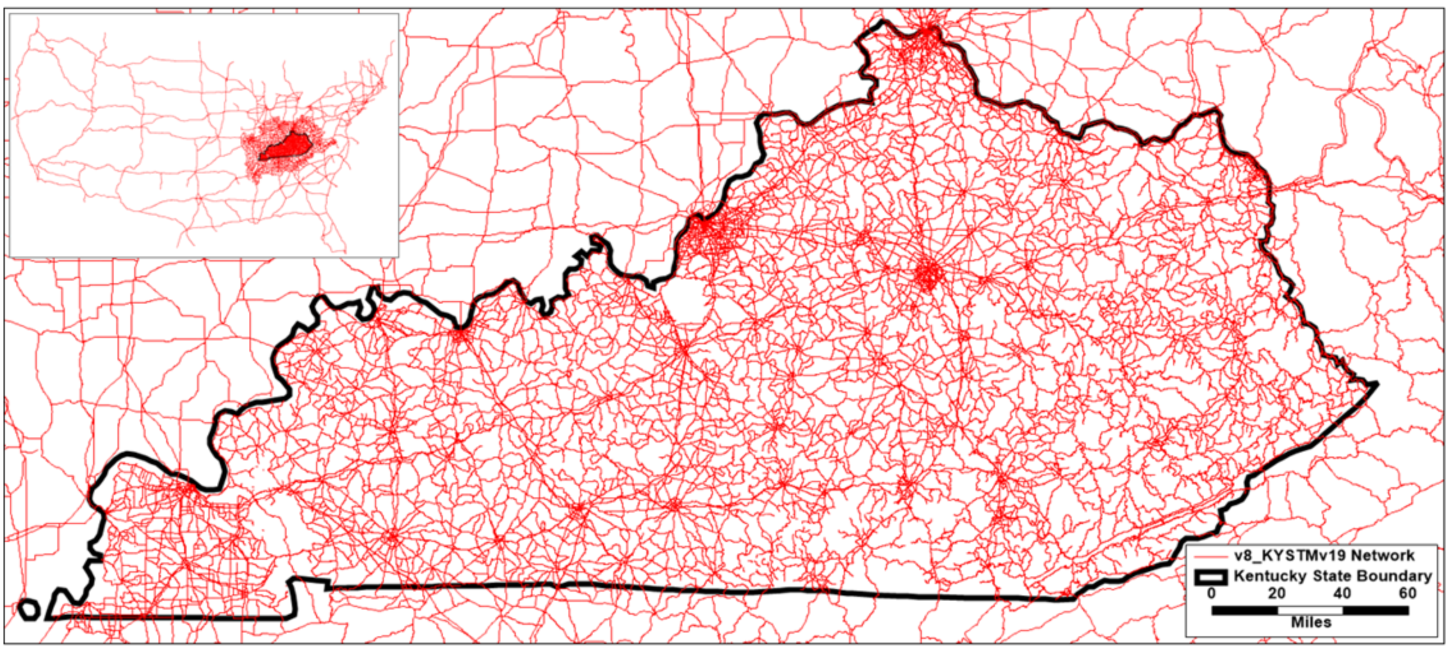


Figure B.2 – v8_KYSTMv19 Highway Network



B.2 Enhanced SWIPP Model

The v8_KYSTMv19 provided good statewide traffic estimates. But, like all statewide models, it might be less accurate than desired in specific corridors, including interstates and parkways, because of the great expanse (statewide), and diversity of the areas covered by the model (urban, rural, mountains, rolling and flat). Thus, an enhanced version of the v8_KYSTMv19 (the SWIPP Model) was developed and used for the study, by "adjusting out" known base year error. Also, since the SWIPP required consistent travel patterns during alternative analysis to reflect more comparable benefits from improvement strategies among statewide corridors, a procedure of applying a static trip table was employed for the SWIPP. The approach used to develop the enhanced SWIPP

Model is summarized below:

- Create a more recent Base Year (2019) Model .
  - o The Project Team had consensus on having 2019 as the base year to avoid the COVID-19 impact on traffic patterns.
  - o The roadway network was updated by including major capacity improvement projects recently completed by KYTC in or before 2019.
  - o The trip tables were calibrated to 2019 statewide traffic counts. The trip table calibration process was performed separately for private vehicles, single-unit (SU) trucks, and combination (COMB) trucks. The calibrated model greatly improved 2019 origin-destination (OD) travel movements and traffic flows on all links, especially on interstates and parkways. **Table B.1** shows the percent root mean square error (RMSE%) of the SWIPP Model and compared it to v8_KYSTMv19.

Table B.1 – RMSE% of the SWIPP Model

	v8_KYSTMv19	SWIPP Model
Vehicle Type	**SWIPP Corridors**	
All Vehicles	20.03	13.57
Private Vehicles	39.87	10.31
SU Trucks	73.26	26.18
COMB Trucks	30.10	11.86
Vehicle Type	**All Links**	
All Vehicles	39.45	15.72
Private Vehicles	57.07	19.03
SU Trucks	115.65	33.33
COMB Trucks	78.83	26.71

  - o All Base Year traffic assignments used the trip tables. Using the static trip tables was efficient because the trip generation and distribution steps could be skipped.
- Develop an Interim Year (2030) Model and a Future Year (2045) model.
  - o The roadway networks incorporated KYTC's existing and committed (E+C) projects with major capacity improvements, based on the anticipated completion timelines of the projects. **Appendix C** summarizes these E+C projects.
  - o The trip tables (by private vehicles, SU trucks, and COMB trucks) were derived from the calibrated 2019 trip table and the growth estimated by the v8_KYSTMv19. All Interim Year and Future Year traffic assignments used the corresponding static trip tables.
  - o It is noted that KYTC made extensive efforts to collect information of large-scale imminent developments near the SWIPP corridors (e.g., roughly within a 3-mile buffer). The imminent growths were incorporated in the 2030 and 2045 models, if they were missing from the default growth estimated by the original v8_KYSTMv19. **Appendix D** summarizes the identified imminent development.

The enhanced SWIPP Model was the primary analysis tool used in the SWIPP. Almost all transportation metrics developed and used in the SWIPP stem from the model. These metrics include reasonable and consistent forecasts of flows, capacities, volume/capacity (v/c) ratios, congestion and vehicle hour delays, speeds, vehicle miles traveled (VMT), and vehicle hours traveled (VHT) for No-Build and Build alternatives for all study corridors.

B.3 Transportation Systems Management and Operations (TSMO) Modeling Features

The evaluation of Transportation Systems Management & Operations (TSMO) projects in the SWIPP requires methods for accounting for these projects in the SWIPP Model. Generally, TSMO projects make sense only on urban freeways, where congestion levels are relatively high. In most cases, TSMO projects are beneficial at peak hours when traffic conditions are the worst. Thus, many TSMO treatments would be applied only during the peak hours.

Among the TSMO solutions proposed in the SWIPP (see Section 6.1.2), three types of TSMO projects required additional modeling features in the SWIPP Model to meet the study needs.

- Truck-only lanes
- Ramp metering
- Hard shoulder running

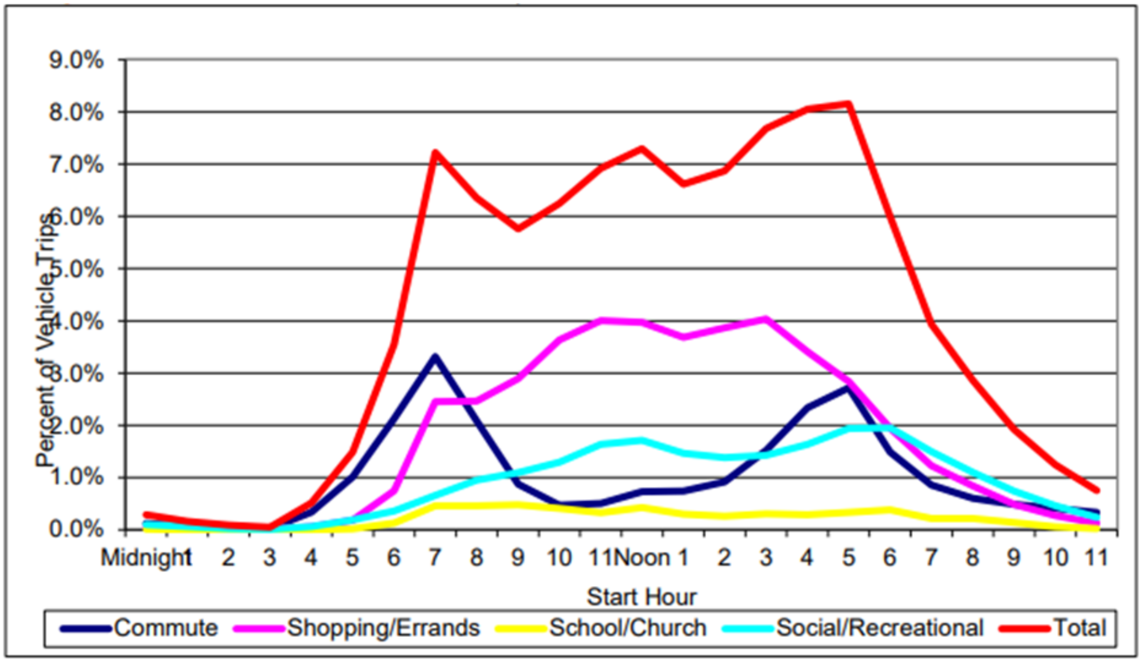
Representing these projects in the SWIPP Model is not straight-forward because it is a daily model. Thus, innovative methods for representing projects that are active only during part of the day were developed. It is noted that these methods are intended to be used at the planning-level based on the available information of the study corridors and potential TSMO solutions and could be adjusted if the conditions are substantially different from those presented here. Because of the need to represent conditions that occur only during part of the day, reasonable assumptions on the daily distribution of travel were required in a daily model. **Table B.2** lists the average percentage of travel in each hour, based on a 2011 report issued by the Bureau of Transportation Statistics (BTS) from the U.S. Department of Transportation (USDOT). **Figure B.3** shows more recent data from the 2017 National Household Travel Survey (NHTS), with a very similar distribution.

Table B.2 – Percentage Distribution of Trips by Time of Day

Trip start time	Percent	SE
Midnight-1 a.m.	0.4	0.02
1 - 2 a.m.	0.2	0.01
2 -3 a.m.	0.2	0.01
3 - 4 a.m.	0.1	0.01
4 - 5 a.m.	0.4	0.02
5 - 6 a.m.	1.0	0.03
6 - 7 a.m.	2.6	0.05
7 - 8 a.m.	6.2	0.08
8 - 9 a.m.	5.5	0.08
9 - 10 a.m.	4.9	0.07
10 - 11 a.m.	5.9	0.08
11 a.m - 12 p.m.	6.6	0.08
12 - 1 p.m.	7.4	0.08
1 - 2 p.m.	6.6	0.07
2 - 3 p.m.	7.3	0.09
3 - 4 p.m.	8.3	0.09
4 - 5 p.m.	7.8	0.08
5 - 6 p.m.	7.9	0.09
6 - 7 p.m.	6.7	0.09
7 - 8 p.m.	5.2	0.08
8 - 9 p.m.	3.9	0.07
9 - 10 p.m.	2.8	0.06
10 - 11 p.m.	1.6	0.05
11 - 12 p.m.	0.9	0.03
Total	100.0	

Source: Bureau of Transportation Statistics, 2011

Figure B.3 – Distribution of Vehicle Trips by Trip Purpose and Start Time of Trip



Source: 2017 National Household Travel Survey

Truck-Only Lanes

The truck-only lanes would restrict the traffic loading of a set of lanes to trucks. The SWIPP Model (and v8_ KYSTMv19) already integrated such a routine. For truck-only lanes modeling, the only step needed is to properly code the network links for desired truck-only lanes in the SWIPP model.

Ramp Metering

Ramp metering has been proven to be an effective method to improve traffic flows on freeways and has been used for many years throughout the U.S. The concept is to break up platoons of vehicles entering the mainline from ramps. Often, vehicles that enter freeway ramps are grouped in platoons, especially when the ramp terminal is signalized, but the platoons might have been formed earlier in the surface street grid. While platoons ease traffic flow on surface streets where signals control, they hinder freeway traffic flow.

A 2011 research study sponsored by the Florida Department of Transportation (*Integrated Database and Analysis System for the Evaluation of Freeway Corridors for Potential Ramp Signaling, FDOT*) found that ramp metering increased freeway throughput by 14%. If the ramp meters are active during the 13 most congested hours of the day (the green-shaded areas in **Table B.2**), then 86.2% of daily trips should see this benefit. Thus, the average daily improvement would be 86.2% x 14% = 12% daily increase in freeway mainline throughput. For freeway mainline segments downstream from where ramp meters are proposed, a proxy of a 12% increase of capacity is assumed.

To implement this method, the SWIPP Model integrated a new network coding mechanism for freeway mainline links within one mile downstream of the ramp entrance, which is assumed to be the influenced area of ramp meters. Capacities of the influenced mainline links will be increased by 12% by the model.

Hard Shoulder Running

Hard shoulder running has been identified as a promising strategy to increase capacity on certain freeway segments. Most practices suggest that this is a temporary treatment, and that the use should be limited to peak hours. A 2016 report from FHWA (*FHWA-HOP-15-023, Use of Freeway Shoulders for Travel – Guide for Planning, Evaluating, and Designing Part-Time Shoulder Use as a Traffic Management Strategy*) noted a range of capacity increases. Based on the findings of this report, a reasonable middle value of the capacity of a hard shoulder lane seems to be 1,500 vehicles per hour (vph). Assuming the shoulder running is active during the six hours with the most congestion of the day (40.5% of daily travel, as the red numbers in **Table B.2**), the effective daily capacity increase would be approximately 6,080 vehicles by assuming a K factor of 0.1 (i.e., 1,500 x 10 x 40.5% = 6,080).

To implement this estimation approach, the SWIPP Model integrated a new network coding mechanism for freeway segments where hard shoulder running is proposed. The freeway links with the new code will have a 6,080 increase of daily capacity to account for benefits from the usage of hard shoulder running.