To:	Scott Thomson Model Team Lead KYTC Division of Planning	From:	Mark Butler, AICP Graham Winchester, EIT Stantec
File:	Kentucky and Adams Street Improvements Study, Warren County	Date:	April 29, 2020

Reference: Kentucky and Adams Street Simulation Model Calibration Memorandum

Introduction

In support of the Kentucky and Adams Street Improvements Study, Stantec has developed a traffic simulation model depicting existing peak hour conditions using Caliper's TransModeler (version 5) simulation package. **Figure 1** presents the simulation model study area, which covers downtown Bowling Green including US 31W, US 68, and US 68X. The focused study area, shown in red, includes Kentucky and Adams Streets (US 68X).

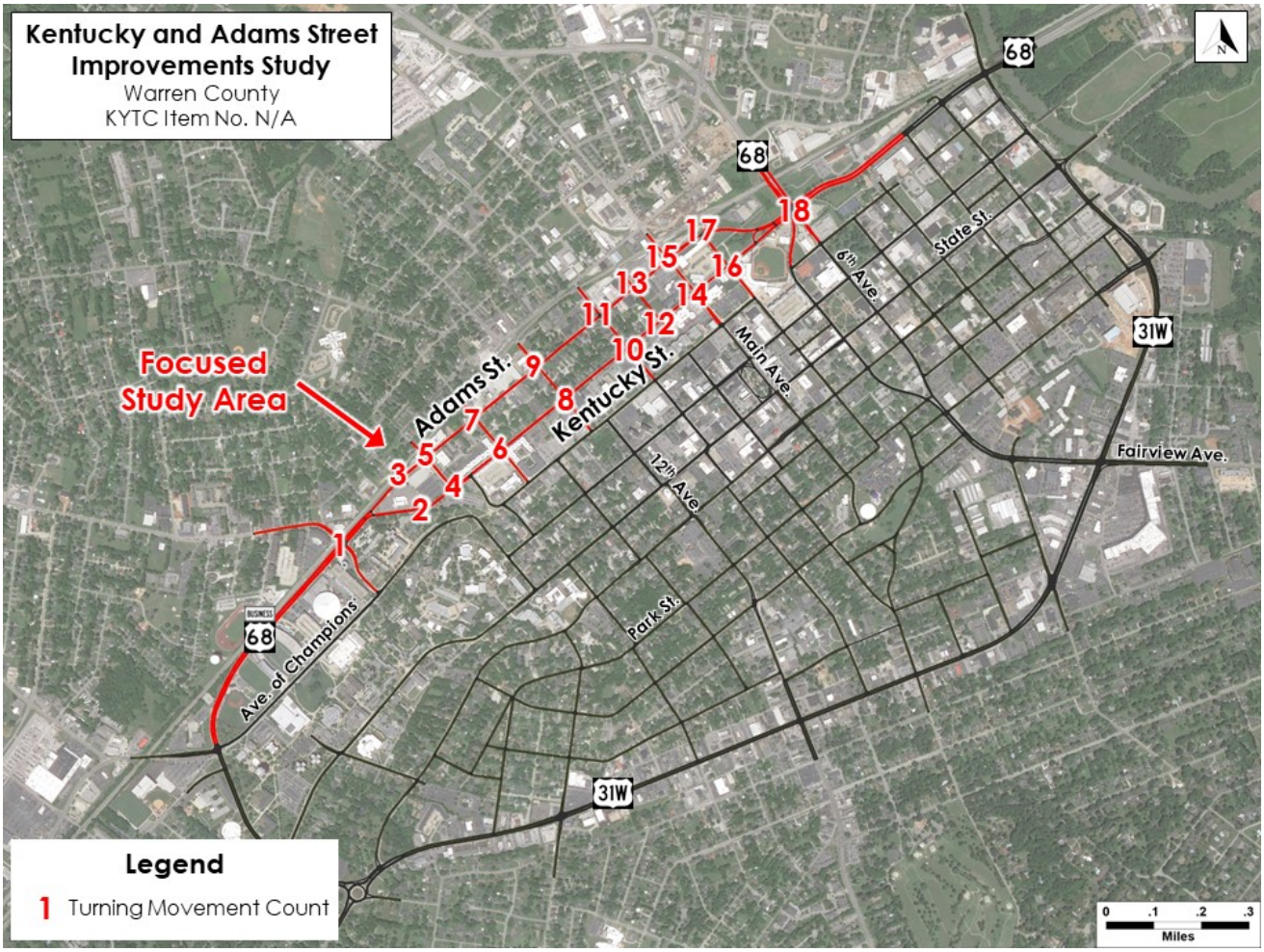

Figure 1: Kentucky and Adams Street Simulation Model Study Area

Site Visit

A site visit was performed for the Kentucky and Adams Street Improvements Study on February 4th and 5th, 2020. During the site visit, travel times, intersection queues, speed data, and roadway measurements were collected between Old Morgantown Road and West 6th Avenue. These data were used during the model validation process.

Model Development

The Bowling Green Downtown Circulation Study Model, developed in 2014, was used as the source for the simulation model and network. Separate model scenarios are included for the AM peak hour (7:30 am – 8:30 am) and the PM peak hour (4:30 pm – 5:30 pm). Aerial imagery and field notes were used to enhance and update the network to include the US 31W roundabout and all appropriate roadway attributes such as turn lanes and median widths and operational controls such as traffic signals and speed limits. Turning movement counts from the original model were used for most intersections. New counts were taken within the focused study area and additional counts from previous studies were used along US 68X and US 31W. New turning movement counts are listed below (as shown on Figure 1):

1) University Drive (US 68X) at Old Morgantown Road
2) Kentucky Street (US 68X) at CVS
3) Adams Street (US 68X) at CVS
4) Kentucky Street (US 68X) at Alumni Avenue
5) Adams Street (US 68X) at Alumni Avenue
6) Kentucky Street (US 68X) at 13th Avenue
7) Adams Street (US 68X) at 13th Avenue
8) Kentucky Street (US 68X) at 12th Avenue
9) Adams Street (US 68X) at 12th Avenue
10) Kentucky Street (US 68X) at 11th Avenue
11) Adams Street (US 68X) at 11th Avenue
12) Kentucky Street (US 68X) at 10th Avenue
13) Adams Street (US 68X) at 10th Avenue
14) Kentucky Street (US 68X) at Main Avenue
15) Adams Street (US 68X) at Main Avenue
16) Kentucky Street (US 68X) at 8th Avenue
17) Adams Street (US 68X) at 8th Avenue
18) Kentucky Street (US 68X) at 6th Avenue (US 68)

Additional counts from the 2019 Russellville Road (US 68X and US 231X) Planning Study and the Warren County Metropolitan Planning Organization (MPO) US 31W Bypass Study were used to update model counts at the following locations:

- University Drive (US 68X) at Russellville Road (US 231X)
- University Drive (US 68X) at Creason Street
- University Drive (US 68X) at Normal Street
- University Drive (US 68X) at Nashville Road (US 31W)
- Nashville Road (US 31W) at Chestnut Street

- Nashville Road (US 31W) at Cabell Drive
- Nashville Road (US 31W) at Broadway Avenue (US 231X)
- Nashville Road (US 31W) at 10th Avenue

The turning movement counts were then aggregated by link to populate the following fields on the link layer within the simulation model network:

- AMcount_AB
- AMcount_BA
- PMcount_AB
- PMcount_BA

Modeling Meeting

A modeling status meeting was held at the Stantec office in Lexington, KY on January 28, 2020 at 12:30 p.m. EST. The following individuals were in attendance:

Jay Balaji – Central Office Planning
Jacob Huber – Central Office Planning
Connor Schurman – Central Office Planning
David Souleyrette – Central Office Planning
Scott Thomson – Central Office Planning

Brian Aldridge – Stantec
Mark Butler – Stantec
Dan O'Dea – Stantec
Graham Winchester – Stantec

The purpose of the meeting was to update the project team on progress to date for the Kentucky/Adams Streets simulation model and other ongoing efforts related to modeling.

Simulation model parameters from KYTC's recent project, *Standardizing Microsimulations for Local Conditions: Case Study in Developing Kentucky Statewide Guidelines,* were discussed. These parameters, including vehicle classification, time headway, acceleration and deceleration rates, run-yellow thresholds, stopped gaps, and speeds are discussed in later sections.

Model Trip Tables

Trip tables for the AM and PM peak hours were developed for a 124 x 124 matrix representing each of the external nodes and centroids in the network. Trip tables from the previous 2014 model were used as seed matrices.

The seed matrices and turning movement counts were used as inputs for TransModeler's origin-destination matrix estimation procedure to develop trip tables for the AM and PM peak hours. Turning movement counts, which were collected in 15-minute intervals, were analyzed to develop the time distribution curve of traffic in the trip tables. **Table 1** and **Table 2** present the time distribution of traffic for the AM and PM peaks, respectively.

Table 1: Time Distribution for AM Peak

Time	% of Total
7:30	27.5%
7:45	30.4%
8:00	24.0%
8:15	18.1%

Table 2: Time Distribution for PM Peak

Time	% of Total
4:30	26.1%
4:45	25.1%
5:00	24.9%
5:15	23.9%

In lieu of using a generic preload procedure during the simulation startup, warmup matrices were developed to ensure the network is sufficiently loaded for the startup of the simulation period. Turning movement counts were analyzed and it was found that the 30-minute period prior to the AM peak includes 40 percent of the peak hour traffic. Similarly, the 30-minute period prior to the PM peak includes 46 percent. The AM and PM matrices were multiplied by these percentages to develop warmup matrices.

Vehicle Class Parameters

The vehicle fleet mix used for the more recent 2019 Russellville Road simulation model was used in place of the default Caliper values. This mix was based on a KYTC analysis of regional vehicle registration data and classification count data. Based on a survey of the turning movement counts, truck percentages were found to be approximately three percent single-unit and one percent multi-unit trucks. The vehicle fleet mix used for the Kentucky and Adams Street Improvements Study is as follows:

- Car Low MPR (High performance passenger cars) – 5.31%
- Car Mid MPR (Middle performance passenger cars) – 35.05%
- Car High MPR (Low performance passenger cars) – 7.10%
- Pickup/SUV – 44.82%
- Single-Unit Truck – 3.00%
- Multi-Unit Truck – 1.00%
- Bus – 0.31%
- Motorcycle – 3.41%

Figure 2 shows the vehicle fleet mix used in this simulation model compared to default Caliper values and Kentucky averages from KYTC's *Standardizing Microsimulations for Local Conditions: Case Study in Developing Kentucky Statewide Guidelines*.

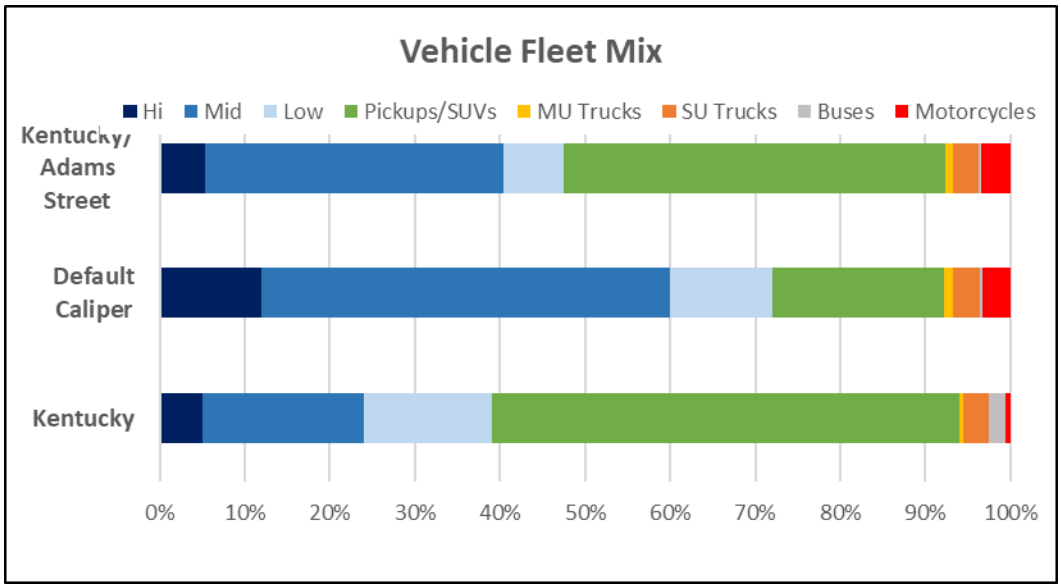

Figure 2: Kentucky/Adams Streets Vehicle Fleet Mix

Time Headway

Time headway is the gap (seconds) that vehicles maintain between themselves and the vehicle in front of them. Different drivers will tolerate nearness to the lead vehicle by varying degrees. Default Caliper values assume an even distribution of headway among drivers. With such a large study area and wide range of intersection types (traffic lights, stop- controlled, roundabout), the default values were used, as shown in **Table 3**.

Table 3: Time Headway Summary

Default Percentage of Drivers	Streets (sec)
10%	0.14
10%	0.20
10%	0.23
10%	0.26
10%	0.29
10%	0.31
10%	0.34
10%	0.37
10%	0.40
10%	0.46

Acceleration/Deceleration

A vehicle's ability to accelerate and decelerate can be affected by several variables including grade, pavement type, weather, speed, power, and weight. Caliper differentiates between different states of vehicle movement to determine rates of acceleration and deceleration.

Default values were used to reflect acceleration and deceleration trends in the Bowling Green downtown area, as shown in **Table 4**.

Table 4: Acceleration/Deceleration Summary

State	Mean (sec)	Std. Dev. (sec)	Lower (sec)	Upper (sec)
Stopped	1.0	0.5	0.5	2.0
Decelerating	0.5	0.0	0.5	0.5
Cruising	1.0	0.0	1.0	1.0
Accelerating	1.0	0.0	1.0	1.0
Changing Lanes	0.5	0.0	0.5	0.5

Stopped Gaps

When a vehicle comes to a stop, the spacing between vehicles can have a significant impact on queue length and capacity. Based on KYTC's recent study *Standardizing Microsimulations for Local Conditions: Case Study in Developing Kentucky Statewide Guidelines,* stopped gaps in Kentucky average 9.47 feet in urban areas and 11.7 feet in rural areas. Caliper's default parameters do not differentiate between urban and rural areas, instead differentiating between stopping behind a non-heavy vehicle and stopping behind a heavy vehicle. To better reflect conditions in an urban Kentucky study area, the mean stopped gap with a non-heavy vehicle in front was raised from eight to 9.4 feet, as shown in **Table 5**.

Table 5: Stopped Gaps Summary

Scenario	Default Mean (ft.)	Updated Mean (ft.)	St. Dev. (ft.)
Non-heavy vehicle in front	8	9.4	4.0
Heavy vehicle in front	12	12.0	4.0

Run Yellow Threshold

At signalized intersections, the run yellow threshold determines whether a vehicle will enter the intersection during a yellow traffic signal indication. If the expected travel time is less than the threshold, the vehicle will proceed through the intersection. Otherwise, it will decelerate and stop at the stop bar. The Caliper default run yellow threshold of 1.5 seconds was used.

Speed

There are a variety of parameters used by a simulation model that affect the vehicle speeds, including: maximum speed as a function of mass-to-power ratio and road grade; speed as a function of its current lane; speed as a function of driver comfort; and turning speed. Default Caliper values were used for speeds of simulation model roads based on road classification. A comparison of model speeds versus actual speeds can be found in the 'Calibration' section.

Calibration

The criteria used to confirm that the simulation model has been sufficiently calibrated were taken from FHWA's *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software, July 2004 (FHWA Publication No. FHWA-HRT-04-040)*. The specific criteria, which were originally developed by the Wisconsin Department of Transportation, are found in Table 4 on page 64 of that document. The criteria consist of three general metrics: 1) visual audits, 2) traffic flow, and 3) travel speeds. Traffic flow and travel speeds are quantifiable based on observed data and the model output while the guidance says that visual audits are to be conducted to the "analyst's satisfaction."

Visual audits were performed throughout the calibration process. At the beginning of the process, areas with heavy congestion were specifically targeted to ensure that these areas reflected existing traffic conditions.

Intersections were checked to ensure that the turning movement and link-based counts were accurate. Once errors in data and the model geography were resolved, areas where the traffic was inconsistent with expected volumes were examined. In rare cases where necessary for low volume external nodes, minor adjustments were made to trip tables to reflect professional judgement of expected minimal traffic levels from those locations. An iterative process of incremental adjustments made in isolation was used to bring model volumes closer to counts and ensure the overall balance of the model was maintained.

To compare traffic flows, link-based trip volumes were averaged over five runs and compiled for each direction of each link and compared to actual traffic counts on the segments. Several statistical measures were used to compare model assignment volumes to matched observed counts. The most important of these measures is percent root-mean-square error (%RMSE) with a target threshold of 20 percent or lower to confirm the model was sufficiently calibrated for assigned volumes. **Table 6** presents the calibration statistics for both the AM and PM models for the full model and the focused study area.

Table 6: Volume Calibration Statistics

Total Volume to Count:	AM Peak Hour		PM Peak Hour	
	Full Model	Focused Study Area	Full Model	Focused Study Area
Target: within 5% of count				
Sum of assignment	84,524	21,679	99,017	25,840
Sum of counts	82,656	20,739	99,784	24,831
Sum assign/counts (within 5%)	2.26%	4.53%	0.77%	4.06%
Links with <700 vehicle count	208	71	176	67
Link assignments within 100 vehicles of count	193	69	166	67
Target: within 85% of links	93%	97%	94%	100%
Links between 700 and 2700 count	25	6	57	13
Link assignments within 20% of count	24	6	50	13
Target: within 85% of links	96%	100%	88%	100%
Percent Root Mean Square Error				
Target: < 20.00%	14.34%	11.56%	12.23%	9.67%

Model speeds and travel times were collected using the Corridor Travel Time output feature. Selection sets were created for the links that comprise Kentucky Street and Adams Street and data was collected on each of these corridors for the five runs. Model speeds and travel times were compared to actual data collected during the February site visit. The first step in calibrating the speeds was to ensure that the default road classification speed limit and actual speed limit were the same. Locations with posted speed limits that did not match up with the default road classification speed limit were corrected. Signal timing plans and driver parameters were also checked to validate speeds and travel times. **Table 7** presents the comparison of HERE and measured speeds to model speeds and **Table 8** presents the travel time comparisons.

Table 7: Model Speed Comparisons

Route	AM Peak			PM Peak		
	HERE Speed (mph)	Measured Speed (mph)	Model Speed (mph)	HERE Speed (mph)	Measured Speed (mph)	Model Speed (mph)
Kentucky St.	23.9	23.5	23.5	24.2	20.5	22.6
Adams St.	26.9	27.5	24.7	26.0	22.8	23.8

Table 8: Model Travel Time Comparisons

Route	AM Peak		PM Peak	
	Measured Travel Time (sec)	Model Travel Time (sec)	Measured Travel Time (sec)	Model Travel Time (sec)
Kentucky St.	187	188	215	195
Adams St.	161	179	194	186

Next Steps

The next steps involve developing 2030 and 2045 traffic forecasts and an E+C network, which will be discussed at the first project team meeting.

STANTEC CONSULTING SERVICES INC.

Mark Butler, AICP
Senior Associate
Phone: (859) 422-1855
Mark.Butler@stantec.com

cc: Steve De Witte
Benjamin Hunt