US 169/I-70 North Loop
Planning & Environmental Linkages Study

VISSIM Calibration Document

Draft – April 13, 2018

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BEYOND THE LOOP

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List of Acronyms and Abbreviations

Abbreviation	Term/Phrase/Name
AADT	Average Annual Daily Traffic
ADT	Average Daily Traffic
AM	Morning Peak Hour
AWSC	All-Way Stop Controlled
CBD	Central Business District
DOT	Department of Transportation
EB	Eastbound
HCM	Highway Capacity Manual
HCS	Highway Capacity Software
ITE	Institute of Transportation Engineers
LOS	Level of Service
NB	Northbound
O-D	Origin - Destination
PHF	Peak Hour Factor
PM	Evening Peak Hour
SB	Southbound
v/c	Volume to Capacity Ratio
WB	Westbound

1. Overview

The purpose of this report is to detail calibration strategies used in the formation of the existing (year 2015) morning and evening peak hour VISSIM models of the Kansas City, Missouri Downtown Loop roadway system. The importance of calibration is to have a model, whose existing conditions is believed to be in alignment with actual traffic conditions, to accurately determine the effect of existing changes to the model and evaluate the existing conditions. The goal of calibration is to ensure that all measurable traffic parameters are in alignment with the traffic measurements typical conditions. Typical conditions are generally referred to as a Tuesday through Thursday with normal conditions traffic conditions and no incidents.

The Kansas City, Missouri Downtown Loop system network included in the VISSIM model encompasses the freeway system roadways, system on/off-ramps, Broadway corridor within the loop, and 5th and 6th Street in proximity to the north loop. Figure 1.1 shows the VISSIM model extents in teal for the existing condition configurations.

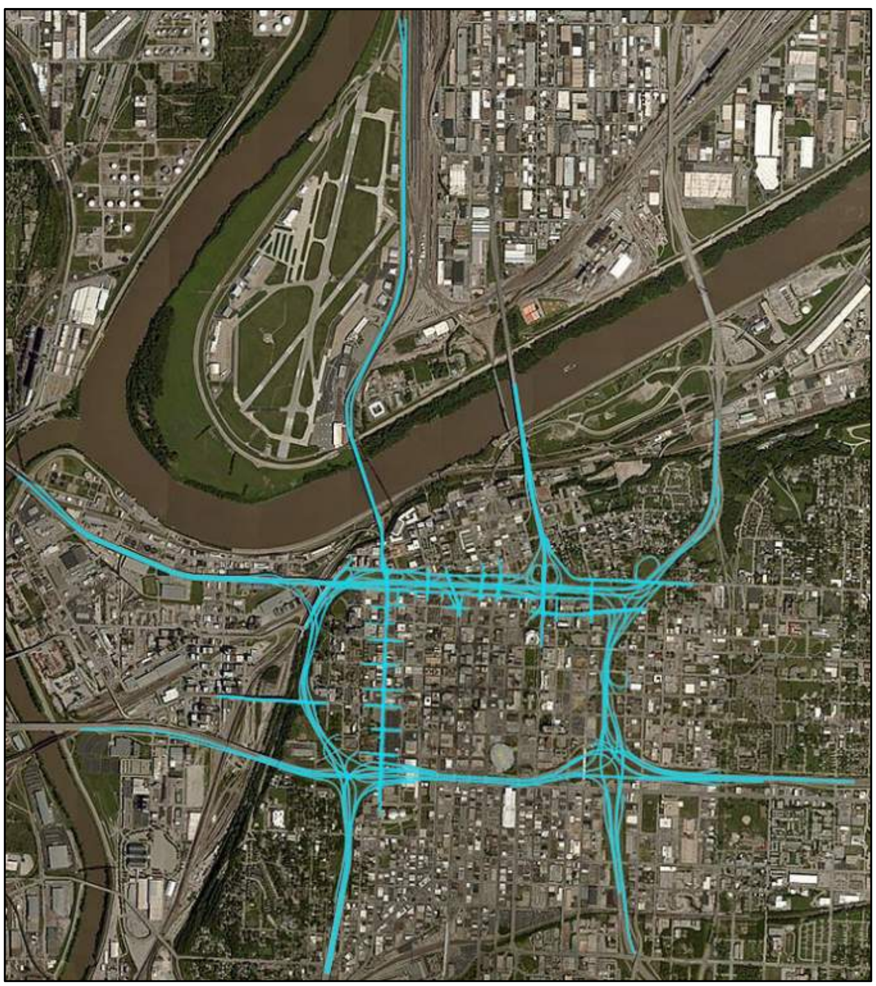


Figure 1.1: Existing Condition VISSIM Model Extents (teal)

Figure 1.2 shows the VISSIM model network extents regarding the CBD.

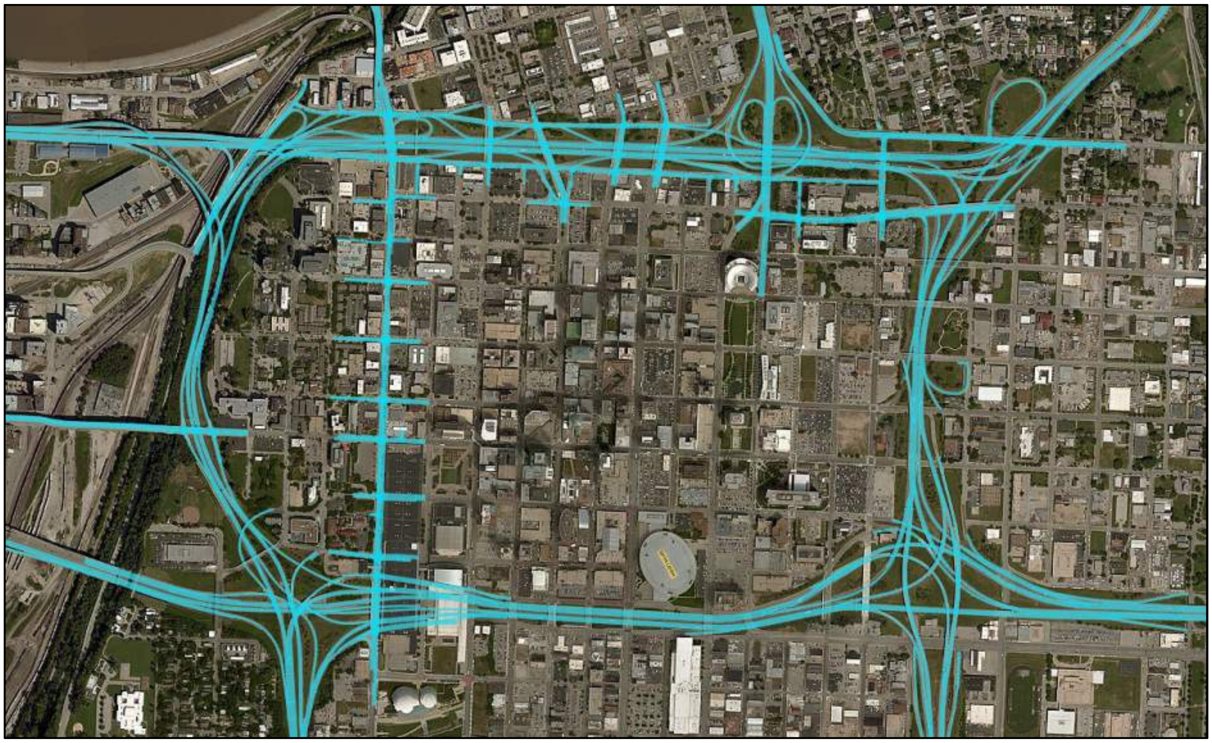


Figure 1.2: Existing Conditions VISSIM Model Extents for the CBD

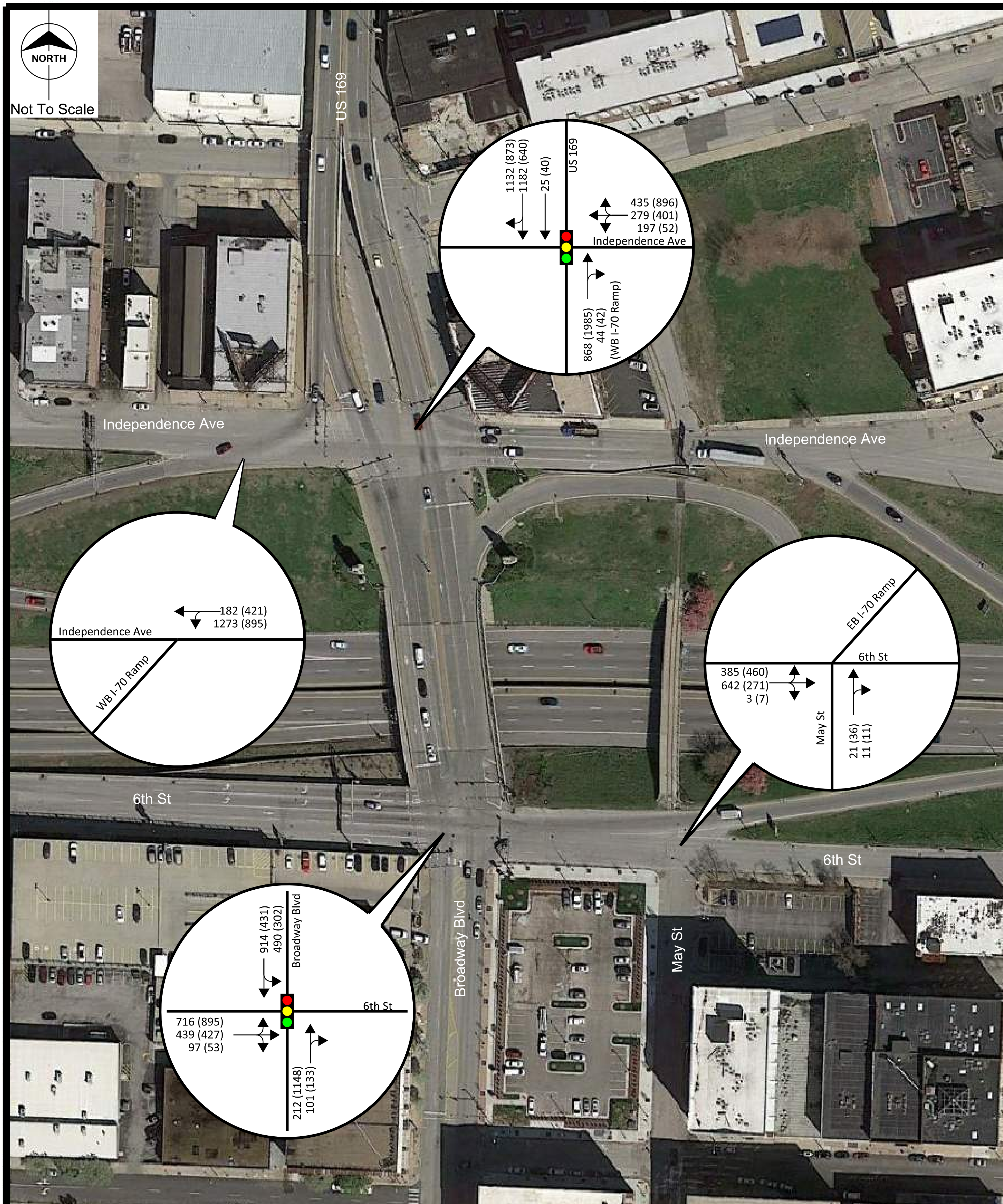
2. Data Types

Traffic Volumes

Existing traffic data was assessed and collected in a variety of methods. Data types compiled for the existing year traffic models include:

- Traffic Volumes
- Vehicle Routes
- Queue Lengths
- Vehicle Speeds
- Vehicle Travel Times
- Local Knowledge

Traffic volumes were collected and compared through multiple data sources to determine a balance of expected traffic volumes through the Downtown Loop freeways and ramps. Traffic counts were performed at the intersections of 5th Street & Broadway Boulevard and 6th Street & Broadway due to the intersection's importance to the roadway network. Morning and evening peak hour traffic counts performed in May of 2017 are shown in Figure 2.1.



BURNS McDONNELL

date May 2017

designed J. Hartman

Jackson County, MO
Broadway Bridge
Traffic Impact Study

2016 - 2017 Average Counts
Peak Hour Volumes

LEGEND

- Study Intersection
- Signalized
- Stop Controlled
- Roundabout
- XX (XX) AM (PM) Peak Hour Volumes

Major roadway input volumes were compiled through assessing KC Scout measured traffic volumes via the KC Scout portal. A data query of multiple days was used to determine an acceptable range of anticipated traffic volumes for each major roadway approach and freeway on/off-ramps.

Two of the Downtown Loop major freeway approaches did not have readily available KC Scout traffic counts. For this reason, Skycomp manual traffic counts were collected for Route 9 north of the Loop and I-70 in the northeast corner of the Loop. The Broadway Boulevard corridor, 5th Street and 6th Street segments of the Downtown network were compiled using a composition of KC OpenData intersections reports and the KC City-wide Synchro model.

Minor roadway connections and on/off-ramps were assessed directly from the Skycomp matrices. Aside from the freeway system, the SB I-70 on-ramp from 10th Street on the east side of the Loop was not collected during the Skycomp analysis period due to a closure of the SB I-70 to WB I-670 ramp. This closure occurred during the morning peak hour and was not readily available within the KC Scout database. For the purposes of simulating a typical condition, traffic volumes for the SB I-70 to WB I-670 ramp were collected through a separate project, "kcICON", in which the south VISSIM model extents included the SB I-70 on-ramp from 10th Street.

Vehicular Routing

Vehicular routing decisions were developed through Skycomp vehicle tracking. Skycomp provided morning and evening peak hour O-D matrices detailing percentage-based routing decisions by vehicle origin. Additional information pertaining to Skycomp methodologies is included in Appendix A.

Since Skycomp data focused on major roadways, vehicle routes for roadway segments not assessed in the Skycomp routing matrices were developed through determining a O-D pairs in conjunction with connection points to the Skycomp matrices and KC OpenData intersection studies. Volume balancing and PHF adjustments were performed for each O-D pair.

Queue Lengths

During regular weekdays, typical traffic queues are experienced along specific roadway segments. For example, during every weekday morning peak hour, an approximately 0.5 to 1.0 mile queue accumulates on the SB Hwy 169 approach to Downtown. Traffic congestion is also regularly seen on SB I-35/I-70 on the East side of the Loop during the morning peak hour. EB I-670 routinely generates traffic queues extending from approximately the I-670/I-35 interchange to the Hickory Street overpass. Figure 2.2 shows GoogleMaps typical Tuesday traffic queues during the morning and evening peak hours.

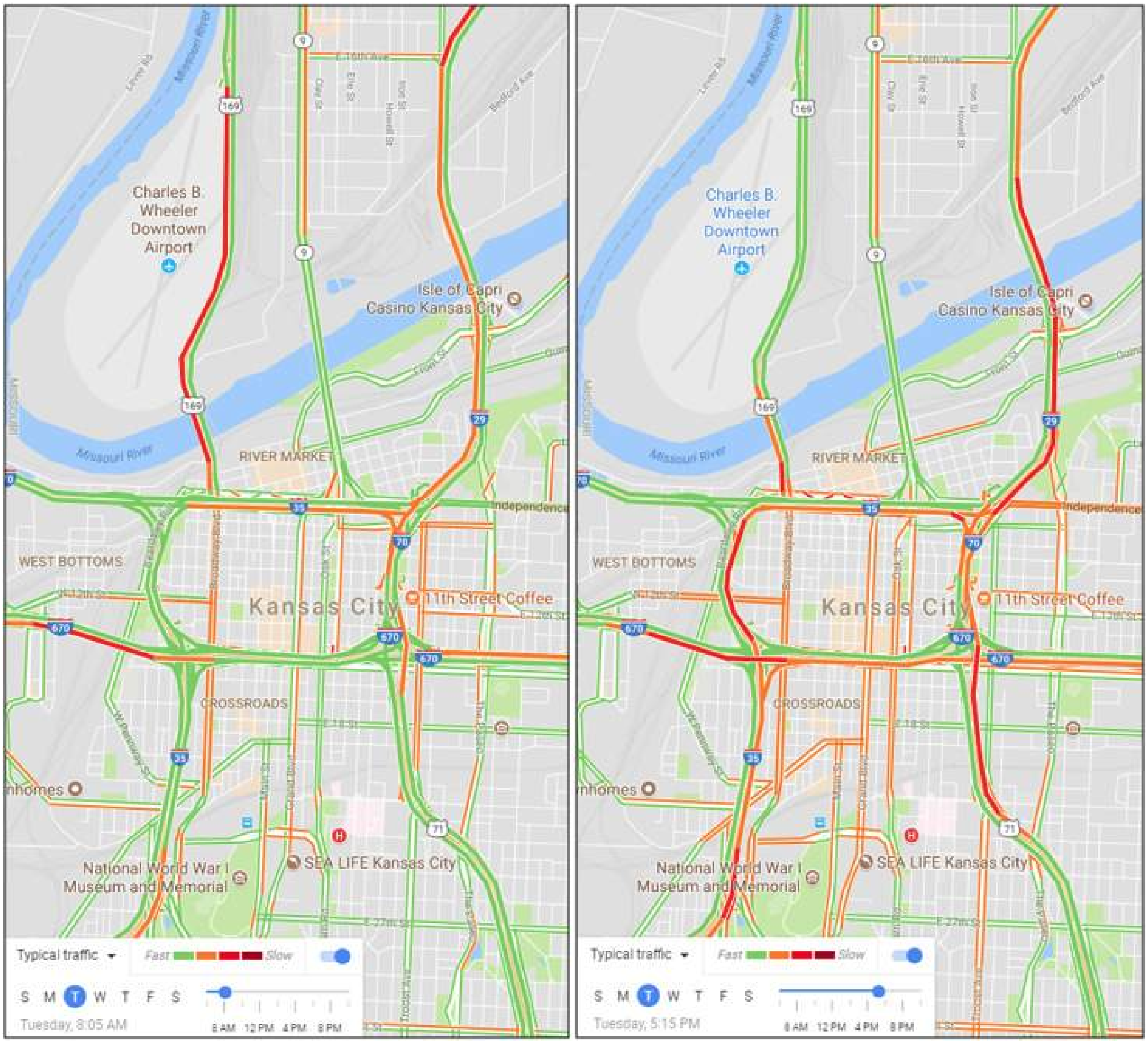


Figure 2.2: Typical Tuesday GoogleMaps Peak Hour Travel Speeds (A.M.-Left, P.M.-Right)

Average travel speeds throughout the Downtown freeway system are collected regularly by KC Scout. These travel speeds were recorded from the KC Scout database for comparison purposes to the VISSIM collected travel speeds.

Travel Times

Various travel time paths were recorded during the data collection process. During the vehicle routing data collection process in October and November of 2016, travel times along specific routes in the Skycomp survey area were measured. Using the existing aligned imagery, vehicles were traced using Skycomp's SkyTracker program to measure relatively precise travel times.

Survey Dates:
Tuesday, October 18, 2016 (4:00-6:00 pm)
Tuesday, November 15, 2016 (7:00-9:00 am)

Travel times suggested by GoogleMaps were also compiled for comparison purposes. Data collection of GoogleMaps travel times encompassed performing a point-to-point estimated travel time for a typical Tuesday during morning and evening peak hour for all major movements. Figure 2.3 shows travel time collection O-D pairs.

Figure 2.3: Skycomp (Green) and GoogleMaps (Orange) Travel Time Collection O-D Pairs

Skycomp travel time results are shown in Table 2.1 below.

Table 2.1: Skycomp Measured Travel Time Results

Collection Path	Travel Time
Point 1 AM to 2	6:49
Point 1 AM to 3	6:48
Point 2 to 1 PM	1:58
Point 3 to 1 PM	6:22

GoogleMaps typically outputs a range of anticipated travel times for a selected path. These travel time ranges for major routes in the Downtown network are less precise than the Skycomp travel times and are shown in Table 2.2 for the morning peak hour and in Table 2.3 for the evening peak hour.

Table 2.2: GoogleMaps Travel Time Range for Major Routes During the A.M. Peak Hour

Destination (columns); Origin (rows)

A.M. Peak Hour Travel Times (Minutes)	WB I-70 NW Corner	NB US 169	NB MO 9	NB I-29 NE Corner	EB I-70 SE Corner	SB US-71 SE Corner	SB I-35 SW Corner	WB I-670 SW Corner
EB I-70 NW Corner	X	4-7	4	4	4-7	4-7	3	5-8
SB US 169	9-18	X	10-20	10-20	10-22	10-22	10-18	12-22
SB MO 9	3	4-7	X	3	3-6	3-6	5	4-7
SB I-29 NE Corner	4	5-8	5	X	3	3	4-6	4
WB I-70 SE Corner	4	5-9	3-6	2	X	3	3	3
NB US-71 SE Corner	4	5-9	3-6	3	4	X	3	3
NB I-35 SW Corner	3	5-8	4	4	3	3	X	2
EB I-670 SW Corner	5-7	6-10	5-8	4	3	3	2	X

Table 2.3: GoogleMaps Travel Time Range for Major Routes During the P.M. Peak Hour

Destination

Origin	P.M. Peak Hour Travel Times (Minutes)	WB I-70 NW Corner	NB US 169	NB MO 9	NB I-29 NE Corner	EB I-70 SE Corner	SB US-71 SE Corner	SB I-35 SW Corner	WB I-670 SW Corner
	EB I-70 NW Corner	X	4-10	4	4-9	4-9	4-8	3	5-9
	SB US 169	4-7	X	5-12	6-14	6-14	6-14	5-8	7-14
	SB MO 9	3	5-9	X	3-6	3-6	4	4	4-7
	SB I-29 NE Corner	3	5-9	5	X	3	3	5	4
	WB I-70 SE Corner	4-8	6-20	3-7	4	X	3	3	3
	NB US-71 SE Corner	4-9	7-20	4-8	3	4	X	4	3
	NB I-35 SW Corner	3-9	8-20	5-12	5-9	3-6	3-6	X	2
	EB I-670 SW Corner	5-9	8-16	5-10	4-9	3-7	3	2	X

3. Model Parameter Adjustments

Vehicle volume inputs were adjusted and balanced throughout the existing conditions VISSIM network to include PHF fluctuations. This involved developing 15-minute vehicle inputs based on 15-minute existing volume count PHFs.

Vehicle routes were coded so that each routing decision is in a unit of vehicles per hour. This adjustment was performed to maintain an easy check of the model and to more fully understand coded interactions between the freeways/ramps and side streets in terms of cumulative volumes. Similar to the vehicle volume inputs, vehicle routes were adjusted to include PHF alterations. These 15-minute volumes were then carried through the Broadway Boulevard corridor, 5th Street, and 6th Street O-D pair generation calculations.

Driver behaviors used within the existing conditions VISSIM model originated from the KCMO regional VISUM model. Adjustments to the driver behaviors were performed for the purposes of furthering the queuing behavior calibration. Initial traffic queue assessments while incorporating calibrated traffic volumes showed severe queues along the east side of the Loop and insignificant queues along the north side of the Loop. Queuing inconsistencies were limited to weaving segments involving heavy traffic volumes. Through calibration, two adjusted driver behaviors were developed; Aggressive Weave and Freeway (Heavy Weave). Each are utilized within heavy weaving segments, but each have slightly altered reactions. All other driver behaviors used within the VISSIM model match VISUM model settings. A summary of the adjusted driver behaviors includes:

- Aggressive Weave: Involves the same lookahead and Wiedemann 99 settings as default Freeway driver behavior but includes reduced lane change acceleration/deceleration rates. The aggressive weave driver behavior differs from the Freeway (Heavy Weave) driver behavior by utilizing increased lane change acceleration/deceleration rates and more aggressive cooperative lane change settings than Freeway (Heavy Weave).

- Freeway (Heavy Weave): Involves increased lookahead distances, Wiedemann 99 reduced headways, and reduced lane change acceleration/deceleration rates from the Freeway driver behavior. The Freeway (Heavy Weave) driver behavior also utilizes cooperative lane change settings.

Traffic signal coding and ring barrier control signal files match the KCMO VISUM regional model which utilizes the latest KCMO signal timing schemes. These signals, detectors, and files were imported into the existing conditions VISSIM model to maintain the latest timing schemes.

4. Validation Measures

The existing conditions VISSIM morning and evening peak hour models were assessed through a 10-run analysis beginning at random seed 1000 with a step of 767 per run. A simulation speed of 10 simulation steps per second was implemented in each scenario and the signal controller frequency of 1. All vehicle inputs were set to "non-stochastic" and all vehicle routes were coded to "per hour volumes". Each simulation run was set to run for 4800 seconds with a 1200 second seed time. VISSIM results attributes of Data Collection Points, Links, Vehicle Network Performance, and Vehicle Travel Times were collected from 1200-4800 seconds for the purposes of this report.

Data Collection Points

Traffic volumes between the major to major movements and majors and ramps were evaluated from various sources. Counts for several locations were collected from Skycomp, KC Scout, and MoDOT. These counts were then evaluated using the Geoffrey E. Havers Equation (shown below) to evaluate the volume falling within the acceptable range. In the cases where we have counts with overlapping counts from various sources we used the source with the lowest GEH. Based on FHWA Traffic Modeling Calibration, paragraph 5.3.2, the objective is to satisfy the GEH < 5 for > 85% of cases. The tables below show volumes organized by quadrants and data collection locations we have sources for as well as the VISSIM model generated volume. Each specific table shows AM or PM comparisons for the noted corner of the Loop. The color designation for the GEH column is denoted as "green" for optimal (GEH<5), "yellow" for acceptable (GEH<10), and "red" for not optimal (GEH>10).

$$GEH = \sqrt{\frac{2(M-C)^2}{M+C}}$$

Where: M = Model output volume
C = Real traffic count

Northwest (NW) Quadrant

VISSIM model generated output volumes were compared to measured traffic volumes in the NW quadrant. Table 4.1 shows the comparison in the NW quadrant during the morning peak hour.

Table 4.1: A.M. Peak Hour VISSIM Volume Comparison within the NW Quadrant

Location	VISSIM Volume	GEH	Source Volume
100: Loc 100: WB I-70	1764	9.90	1372
101: Loc 101: EB I-70	2328	8.67	1928
103: Loc 103: EB I-70	1921	12.36	1416
104: Loc 104: NB I-35 to WB I-70	283	2.15	248
105: Loc 105: EB I-70 to SB I-35	408	3.51	482
106: Loc 106: EB I-70 to Beardsley Rd	0	8.25	34
109: Loc 109: SB I-35	2593	9.36	3092
110: Loc 110: NB I-35	1340	17.81	2076
118: Loc 118: EB I-70 from EB 6th St	360	7.02	506
119: Loc 119: EB I-70	2473	7.11	2132
122: Loc 122: WB I-70 to Independence	398	6.51	539
123: Loc 123: EB I-70 to EB 6th St	279	11.67	511
124: Loc 124: EB I-70	2553	3.50	2733
125: Loc 125: WB I-70	3122	0.65	2656
126: Loc 126: WB I-70 from Independence	51	12.20	183
127: Loc 127: EB I-70 from EB 6th St	278	4.63	206
128: Loc 128: WB I-70 to Independence	367	6.30	498
226: Loc 226: SB I-35 Off Ramp	251	2.31	289
227: Loc 227: NB I-35 On Ramp	79	5.50	136

Four locations were found to result in a GEH value greater than 10.0 in the NW quadrant during the morning peak hour. These locations all lay along I-70 and I-35. Loc 103 was recorded to be approximately 500 vehicles higher than the recorded source volume and Loc 110 was found to be approximately 700 vehicles lower than the recorded source volume. It is thought that the recorded volume at Loc 103 and Loc 110 may be errant due to current volume metrics further west, east, and north being in calibration. The ramps of Loc 123 and Loc 126 have a discrepancy due to keeping the downstream volumes calibrated on I-70. Table 4.2 shows volume comparisons in the NW quadrant during the evening peak hour.

Table 4.2: P.M. Peak Hour VISSIM Volume Comparison within the NW Quadrant

Location	VISSIM Volume	GEH	Source Volume
100: Loc 100: WB I-70	2294	4.03	2491
101: Loc 101: EB I-70	2215	12.17	1678
103: Loc 103: EB I-70	1843	4.05	2021
104: Loc 104: NB I-35 to WB I-70	269	8.37	425
105: Loc 105: EB I-70 to SB I-35	371	0.16	368
106: Loc 106: EB I-70 to Beardsley Rd	18	0.00	18
109: Loc 109: SB I-35	2055	10.96	2583
110: Loc 110: NB I-35	1824	2.47	1931
118: Loc 118: EB I-70 from EB 6th St	453	10.03	693
119: Loc 119: EB I-70	2260	1.31	2198
122: Loc 122: WB I-70 to Independence	225	10.81	419
123: Loc 123: EB I-70 to EB 6th St	113	3.71	156
124: Loc 124: EB I-70	2598	0.24	2586
125: Loc 125: WB I-70	2808	3.11	2975
126: Loc 126: WB I-70 from Independence	244	9.80	423
127: Loc 127: EB I-70 from EB 6th St	544	1.06	569
128: Loc 128: WB I-70 to Independence	287	3.42	348
226: Loc 226: SB I-35 Off Ramp	145	0.17	143
227: Loc 227: NB I-35 On Ramp	172	3.70	224

Four locations were found to result in a GEH value greater than 10.0 in the NW quadrant during the evening peak hour. These locations all lay along I-70 and I-35. Loc 103 was recorded to be approximately 600 vehicles higher than the recorded source volume and Loc 109 was found to be approximately 500 vehicles lower than the recorded source volume. It is thought that the recorded volume at Loc 103 and Loc 109 may be errant due to current volume metrics further west, east, and north being in calibration. The on-ramps of Loc 118 and Loc 122 have a discrepancy due to keeping the downstream volumes calibrated on I-70. Figure 4.1 shows a visual representation of locations of volume count comparisons.

Figure 4.1: Locations of data collection point within the NW quadrant

Northeast (NE) Quadrant

VISSIM model generated output volumes were compared to measured traffic volumes in the NE quadrant. Table 4.3 shows the comparison in the NE quadrant during the morning peak hour.

Table 4.3: A.M. Peak Hour VISSIM Volume Comparison Within the NE Quadrant

Location	VISSIM Volume	GEH	Source Volume
127: Loc 127: EB I-70 from EB 6th St	278	4.63	206
128: Loc 128: WB I-70 to Independence	367	6.30	498
129: Loc 129: EB I-70 to EB 6th St	580	8.31	798
130: Loc 130: SB Hwy 9 to WB I-70	613	0.96	637
131: Loc 131: EB I-70	2256	15.59	3060
132: Loc 132: WB I-70	2878	12.34	2253
133: Loc 133: SB Hwy 9 to EB I-70	541	3.00	613
135: Loc 135: NB Hwy 9 Off Ramp	51	6.49	14
137: Loc 137: EB I-70	2797	1.66	2710
138: Loc 138: WB I-70	2190	6.72	2516
139: Loc 139: SB I-35	1933	5.96	2204
141: Loc 141: EB I-70 to SB I-35	1395	1.82	1328
142: Loc 142: NB I-35	3466	2.98	3293
143: Loc 143: SB I-35	4502	1.00	4435
149: Loc 149: SB I-70 On Ramp	418	1.91	458
151: Loc 151: SB I-70	4377	1.64	4486
152: Loc 152: NB I-70	3829	2.07	3958
153: Loc 153: SB I-70 Off Ramp	308	5.29	408
154: Loc 154: SB I-70 On Ramp	60	13.40	218
155: Loc 155: SB I-70	4068	8.43	3548
156: Loc 156: NB I-70	3779	2.88	3958
157: Loc 157: NB I-70 On Ramp	30	5.88	72
160: Loc 160: NB I-70	1489	2.07	1570

Three locations along I-70 were found to result in a GEH value greater than 10.0 in the NE quadrant during the morning peak hour. Loc 131 resulted in volumes approximately 800 less than source volumes and Loc 154 resulted in volumes approximately 150 less than recorded source volumes. These locations are considered acceptable due to upstream and downstream volume comparisons resulting in calibrated metrics. Loc 132 for WB I-70 was observed to result in traffic volumes approximately 300 higher than source recorded volumes. This location is also shown to have upstream and downstream calibrated comparisons.

Table 4.4 shows volume comparisons in the NE quadrant during the evening peak hour.

Table 4.4: P.M. Peak Hour VISSIM Volume Comparison Within the NE Quadrant

Location	VISSIM Volume	GEH	Source Volume
127: Loc 127: EB I-70 from EB 6th St	544	1.06	569
128: Loc 128: WB I-70 to Independence	287	3.42	348
129: Loc 129: EB I-70 to EB 6th St	600	2.60	538
130: Loc 130: SB Hwy 9 to WB I-70	508	0.31	515
131: Loc 131: EB I-70	2540	14.89	3348
132: Loc 132: WB I-70	2590	15.66	1852
133: Loc 133: SB Hwy 9 to EB I-70	361	0.78	376
135: Loc 135: NB Hwy 9 Off Ramp	55	6.12	18
137: Loc 137: EB I-70	2895	7.49	3312
138: Loc 138: WB I-70	1973	17.86	2850
139: Loc 139: SB I-35	1674	3.16	1806
141: Loc 141: EB I-70 to SB I-35	1321	1.09	1361
142: Loc 142: NB I-35	4440	3.50	4676
143: Loc 143: SB I-35	3964	0.00	3964
149: Loc 149: SB I-70 On Ramp	692	0.11	689
151: Loc 151: SB I-70	4262	4.61	4568
152: Loc 152: NB I-70	4253	8.47	3718
153: Loc 153: SB I-70 Off Ramp	120	4.60	176
154: Loc 154: SB I-70 On Ramp	881	0.03	880
155: Loc 155: SB I-70	4125	9.82	3518
156: Loc 156: NB I-70	4029	5.00	3718
157: Loc 157: NB I-70 On Ramp	118	0.00	118
160: Loc 160: NB I-70	1117	1.74	1176

Three locations along I-70 were found to result in a GEH value greater than 10.0 in the NE quadrant during the evening peak hour. Loc 131 was observed to be approximately 800 vehicles less than source volumes. Traffic volume locations immediately downstream and upstream of this location show calibration and is therefore not considered significant. Loc 132 results show approximately 733 vehicles more than source recorded volumes and Loc 138 shows approximately 850 fewer vehicles than source recorded volumes. Similar to the EB direction, WB volume assessment locations immediately upstream and downstream show calibration. Therefore, these discrepancies are not considered significant due to daily variation. Figure 4.2 shows a visual representation of locations of volume count comparisons.

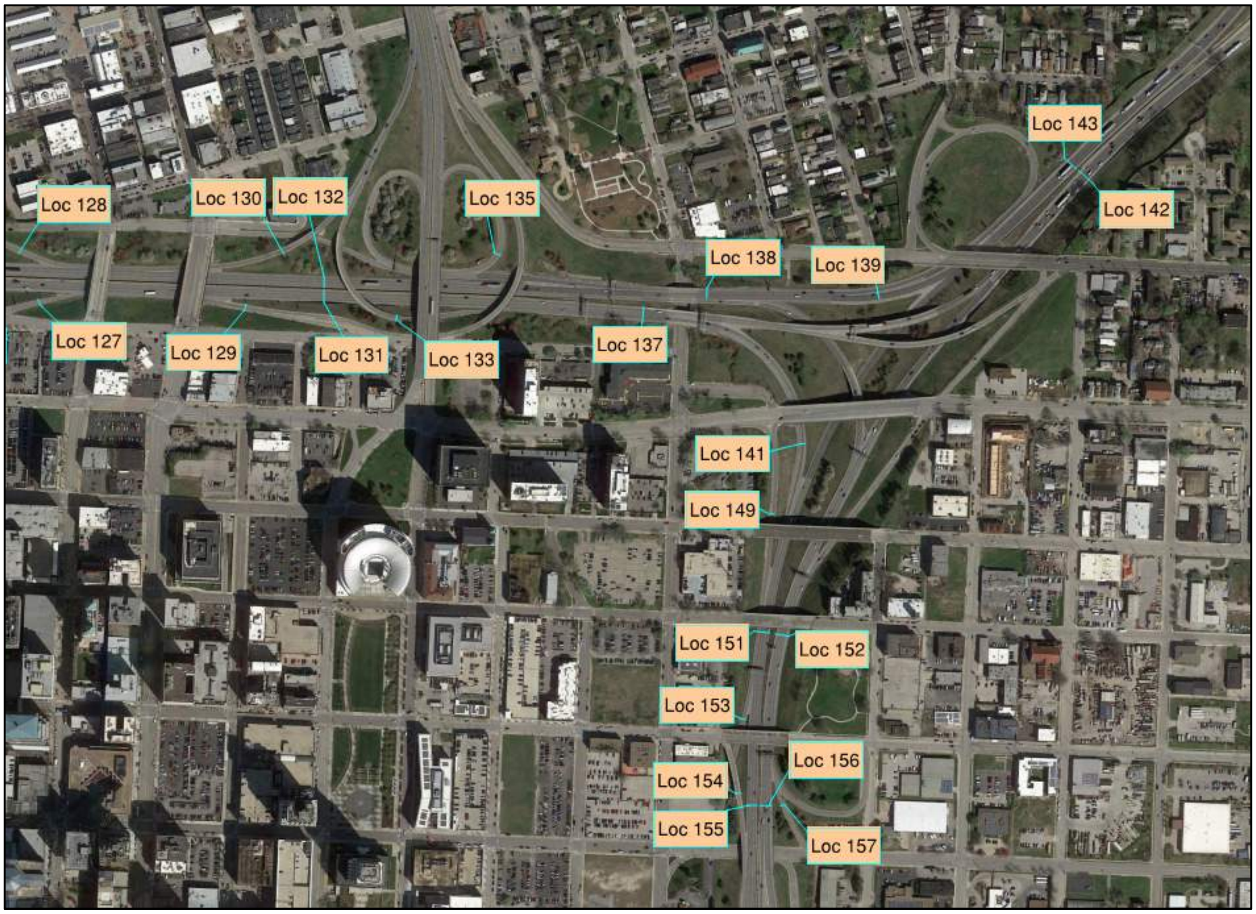


Figure 4.2: Locations of data collection point within the NE quadrant

Southeast (SE) Quadrant

VISSIM model generated output volumes were compared to measured traffic volumes in the SE quadrant. Table 4.5 shows the comparison in the SE quadrant during the morning peak hour.

Table 4.5: A.M. Peak Hour VISSIM Volume Comparison Within the SE Quadrant

Location	VISSIM Volume	GEH	Source Volume
164: Loc 164: WB I-670 to NB I-70	642	24.00	1411
166: Loc 166: WB I-70 Off Ramp	80	1.81	97
170: Loc 170: WB I-70 Off Ramp	321	1.54	294
172: Loc 172: WB I-70	6256	3.01	6020
173: Loc 173: EB I-70	2921	0.04	2919
177: Loc 177: EB I-70	1959	16.07	2738
178: Loc 178: WB 13th St	805	2.72	884
181: Loc 181: NB US-70	2399	3.88	2593
183: Loc 183: EB I-670 to SB US-70	910	6.29	1110
184: Loc 184: NB US-70	3642	4.76	3935
185: Loc 185: SB US-70	3632	6.19	4015
187: Loc 187: WB I-670	4752	20.57	3436
188: Loc 188: EB I-670	3509	29.62	1960
189: Loc 189: EB I-670 On Ramp	160	8.78	292

Four locations were found to result in a GEH value greater than 10.0 in the SE quadrant during the morning peak hour. These locations all lay along I-70 and I-670. Loc 164 was recorded to be approximately 750 vehicles lower than the recorded source volume and Loc 188 was found to be approximately 1549 higher than the recorded source volume. It is thought that the recorded volume at Loc 188 may be errant due to current volume results further west, east, and north being in calibration. Table 4.6 shows volume comparisons in the SE quadrant during the evening peak hour.

Table 4.6: P.M. Peak Hour VISSIM Volume Comparison Within the SE Quadrant

Location	VISSIM Volume	GEH	Source Volume
164: Loc 164: WB I-670 to NB I-70	1252	0.62	1274
165: Loc 165: SB I-70 to EB I-70	2006	11.26	2543
166: Loc 166: WB I-70 Off Ramp	598	2.98	673
170: Loc 170: WB I-70 Off Ramp	69	2.77	94
172: Loc 172: WB I-70	3630	0.07	3634
173: Loc 173: EB I-70	5107	3.88	5388
177: Loc 177: EB I-70	2822	24.09	1679
178: Loc 178: WB 13th St	218	0.00	218
181: Loc 181: NB US-71	2071	14.44	1464
183: Loc 183: EB I-670 to SB US-71	1193	4.21	1052
184: Loc 184: NB US-71	3461	0.12	3468
185: Loc 185: SB US-71	3578	0.65	3539
187: Loc 187: WB I-670	3861	19.91	2719
188: Loc 188: EB I-670	5271	26.44	3518
189: Loc 189: EB I-670 On Ramp	1134	0.03	1133

Five locations were found to result in a GEH value greater than 10.0 in the SE quadrant during the evening peak hour. These locations include one location along NB US-71 and four locations along I-70 and I-670. Loc 181 was recorded to be approximately 600 vehicles lower than the recorded source volume. Loc 177 was recorded to be approximately 1200 vehicles higher than the recorded source volumes, and Loc 187 and Loc 188 are recorded to be approximately 1100 vehicles, and 1800 vehicles high respectively. These discrepancies are primarily due to volume balancing to expected counts at the NB I-35 ramps in the NW quadrant and to the counts expected on the I-670 counts in the SW quadrant. Loc 165 was observed to be approximately 500 vehicles lower than source volumes, however, downstream and upstream volumes show calibration. Locations 172 and 173 also show close volume representation in the VISSIM model outputs. Figure 4.3 shows a visual representation of locations of volume count comparisons.

Figure 4.3: Locations of Data Collection Points Within the SE Quadrant

Southwest (SW) Quadrant

VISSIM model generated output volumes were compared to measured traffic volumes in the SW quadrant. Table 4.7 shows the comparison in the SW quadrant during the morning peak hour.

Table 4.7: A.M. Peak Hour VISSIM Volume Comparison Within the SW Quadrant

Location	VISSIM Volume	GEH	Source Volume
193: Loc 193: EB I-670	3198	7.29	3624
194: Loc 194: WB I-670	4424	9.57	5084
195: Loc 195: WB I-670 Off Ramp	740	9.13	1010
196: Loc 196: NB I-35	4762	23.15	6499
197: Loc 197: SB I-35	5708	4.33	6040
199: Loc 199: SB I-35	6107	4.37	5770
202: Loc 202: NB I-35 Off Ramp	1045	8.71	1346
207: Loc 207: EB I-670 to SB I-35	834	1.10	866
208: Loc 208: SB I-35 to EB I-670	307	7.71	186
210: Loc 210: EB I-670 Off Ramp	627	0.12	630
213: Loc 213: SB I-35 On Ramp	302	4.88	393
214: Loc 214: WB I-670 to NB I-35	369	4.53	287
215: Loc 215: NB I-35 Off Ramp	470	5.01	585
217: Loc 217: SB I-35 On Ramp	91	2.64	118
218: Loc 218: EB I-670	3031	0.18	3041
219: Loc 219: WB I-670	1891	3.09	2028
222: Loc 222: SB I-35 On Ramp	176	2.17	206
224: Loc 224: NB I-35	1544	17.57	2316
225: Loc 225: NB I-35 Off Ramp	566	5.52	442
226: Loc 226: SB I-35 Off Ramp	251	2.31	289
227: Loc 227: NB I-35 On Ramp	79	5.50	136

Two locations were found to result in a GEH value greater than 10.0 in the SW quadrant during the morning peak hour. These locations include two locations along NB I-35. Loc 196 was recorded to be approximately 1,700 vehicles lower than the recorded source volume and Loc 224 was recorded to be approximately 770 vehicles lower than the source. However, these discrepancies are primarily due to volume balancing to expected counts at the NB I-35 ramps in the NW quadrant.

Table 4.8 shows volume comparisons in the SW quadrant during the evening peak hour.

Table 4.8: P.M. Peak Hour VISSIM Volume Comparison Within the SW Quadrant

Location	VISSIM Volume	GEH	Source Volume
193: Loc 193: EB I-670	3734	1.65	3634
194: Loc 194: WB I-670	4096	8.14	4634
195: Loc 195: WB I-670 Off Ramp	316	2.66	365
196: Loc 196: NB I-35	5493	0.90	5560
197: Loc 197: SB I-35	5106	7.01	5619
199: Loc 199: SB I-35	5380	5.70	5806
202: Loc 202: NB I-35 Off Ramp	546	1.85	590
207: Loc 207: EB I-670 to SB I-35	402	5.10	511
208: Loc 208: SB I-35 to EB I-670	281	1.74	311
210: Loc 210: EB I-670 Off Ramp	148	3.59	195
213: Loc 213: SB I-35 On Ramp	889	8.87	1174
214: Loc 214: WB I-670 to NB I-35	460	13.92	206
215: Loc 215: NB I-35 Off Ramp	444	19.06	123
217: Loc 217: SB I-35 On Ramp	560	10.16	344
218: Loc 218: EB I-670	1979	0.27	1991
219: Loc 219: WB I-670	2721	6.06	2414
222: Loc 222: SB I-35 On Ramp	282	5.28	378
224: Loc 224: NB I-35	1934	9.79	2389
225: Loc 225: NB I-35 Off Ramp	273	3.58	217
226: Loc 226: SB I-35 Off Ramp	145	0.17	143
227: Loc 227: NB I-35 On Ramp	172	3.70	224

Three locations were found to result in a GEH value greater than 10.0 in the SW quadrant during the evening peak hour. These locations include on/off-ramps to I-35 and the WB I-670 to NB I-35 system to system ramp. Loc 214 was recorded to be approximately 200 vehicles higher than the recorded source volume and Loc 215 was recorded to be approximately 300 vehicles higher than the source. Loc 217 was recorded to be approximately 200 vehicles higher than the source volume. However, these discrepancies are primarily due to volume balancing to expected counts along I-35 and I-670. Figure 4.4 shows a visual representation of locations of volume count comparisons.

Figure 4.4: Locations of Data Collection Points Within the SW Quadrant

Some volume collection locations were found to have multiple sources detailing morning and evening peak hour traffic. For these locations the range of the minimum to maximum recorded volumes was compared to VISSIM output volumes. Table 4.9 shows VISSIM output volumes compared to the volume range during the morning peak hour and Table 4.10 shows VISSIM output volumes compared to the volumes range during the evening peak hour.

Table 4.9: VISSIM Volume Comparison to A.M. Peak Hour Minimum and Maximum Recorded Volumes

Location	VISSIM Volume	Source Volume Min	Source Volume Max
109: Loc 109: SB I-35	2593	1049	3092
110: Loc 110: NB I-35	1340	2076	2350
124: Loc 124: EB I-70	2553	2733	3045
125: Loc 125: WB I-70	3122	2656	3086
142: Loc 142: NB I-35	3466	3293	3737
143: Loc 143: SB I-35	4502	4435	5224
151: Loc 151: SB I-70	4377	3548	4486

Table 4.10: VISSIM Volume Comparison to P.M. Peak Hour Minimum and Maximum Recorded Volumes

Location	VISSIM Volume	Source Volume Min	Source Volume Max
Loc 109: SB I-35	2055	1419	2583
Loc 110: NB I-35	1824	1931	2573
Loc 124: EB I-70	2598	2586	3469
Loc 125: WB I-70	2808	2975	3033
Loc 142: NB I-35	4440	4136	5016
Loc 143: SB I-35	3964	3889	4096
Loc 151: SB I-70	4262	3518	4568

Morning and evening peak hour volumes recorded in VISISM are shown to fall within the measured range of recorded volumes with few exceptions. The exceptions fall outside of the expected volume range by less than 200 vehicles with one remaining outlier that falls approximately 600 vehicles less than the minimum measured volume during the morning peak hour. This located experienced a shortage of traffic volumes due to the wholistic approach of balancing anticipated traffic volumes along the Downtown Loop. Measured locations discussed earlier, located immediately north and south of Loc 110, were found be comparable with expected traffic volumes.

Vehicle speeds were collected through data collection points from the morning and evening existing condition VISSIM models for comparison.

Table 4.11 shows VISSIM output vehicle speeds alongside measured KC Scout speeds throughout the Downtown roadway network for the morning peak hour and Table 4.12 shows the same comparison for the evening peak hour. Figure 4.5 shows the physical locations of each speed comparison.

Table 4.11 A.M. Peak Hour Speed Comparisons

Location	VISSIM Speed	MoDOT Speeds
Loc 102: WB I-70	52.3	54.0
Loc 114: EB I-70	42.2	51.0
Loc 118: EB I-70 from EB 6th St	25.7	22.5
Loc 119: EB I-70	40.7	49.0
Loc 120: WB I-70	41.8	47.0
Loc 124: EB I-70	41.3	49.0
Loc 125: WB I-70	42.1	47.0
Loc 127: EB I-70 from EB 6th St	27.7	37.2
Loc 128: WB I-70 to Independence	28.9	34.4
Loc 131: EB I-70	42.2	39.0
Loc 132: WB I-70	42.2	53.0
Loc 133: SB Hwy 9 to EB I-70	23.7	28.3
Loc 134: Independence Approach	33.6	30.3
Loc 138: WB I-70	42.4	51.0
Loc 140: NB I-35 to WB I-70	33.4	58.0
Loc 153: SB I-70 Off Ramp	34.4	38.2
Loc 155: SB I-70	41.5	41.1
Loc 158: NB I-70 On Ramp	23.9	26.1
Loc 169: WB I-70	41.2	26.0
Loc 172: WB I-70	49.4	43.3
Loc 175: EB I-70	48.4	58.0
Loc 176: EB I-70	42.5	52.0
Loc 187: WB I-670	40.9	54.0
Loc 188: EB I-670	40.7	52.0
Loc 193: EB I-670	40.2	39.0
Loc 194: WB I-670	41.6	34.0
Loc 223: SB I-35	41.1	40.1

Table 4.12: P.M. Peak Hour Speed Comparisons

Location	VISSIM Speed	MoDOT Speeds
Loc 102: WB I-70	52.0	58.0
Loc 114: EB I-70	42.4	52.0
Loc 119: EB I-70	41.2	45.0
Loc 124: EB I-70	41.1	45.0
Loc 125: WB I-70	41.3	48.0
Loc 129: EB I-70 to EB 6th St	33.5	24.4
Loc 130: SB Hwy 9 to WB I-70	23.6	31.9
Loc 131: EB I-70	41.9	37.0
Loc 132: WB I-70	42.3	57.0
Loc 133: SB Hwy 9 to EB I-70	23.8	40.9
Loc 134: Independence Approach	33.7	23.0
Loc 138: WB I-70	42.3	54.0
Loc 140: NB I-35 to WB I-70	34.0	30.0
Loc 153: SB I-70 Off Ramp	32.9	40.2
Loc 154: SB I-70 On Ramp	34.8	39.5
Loc 157: NB I-70 On Ramp	17.1	25.9
Loc 169: WB I-70	41.9	44.0
Loc 172: WB I-70	52.1	46.8
Loc 175: EB I-70	47.6	62.0
Loc 176: EB I-70	42.2	48.0
Loc 187: WB I-670	40.6	55.0
Loc 188: EB I-670	34.4	45.0
Loc 193: EB I-670	38.9	31.0
Loc 194: WB I-670	41.7	36.0
Loc 223: SB I-35	40.2	42.6

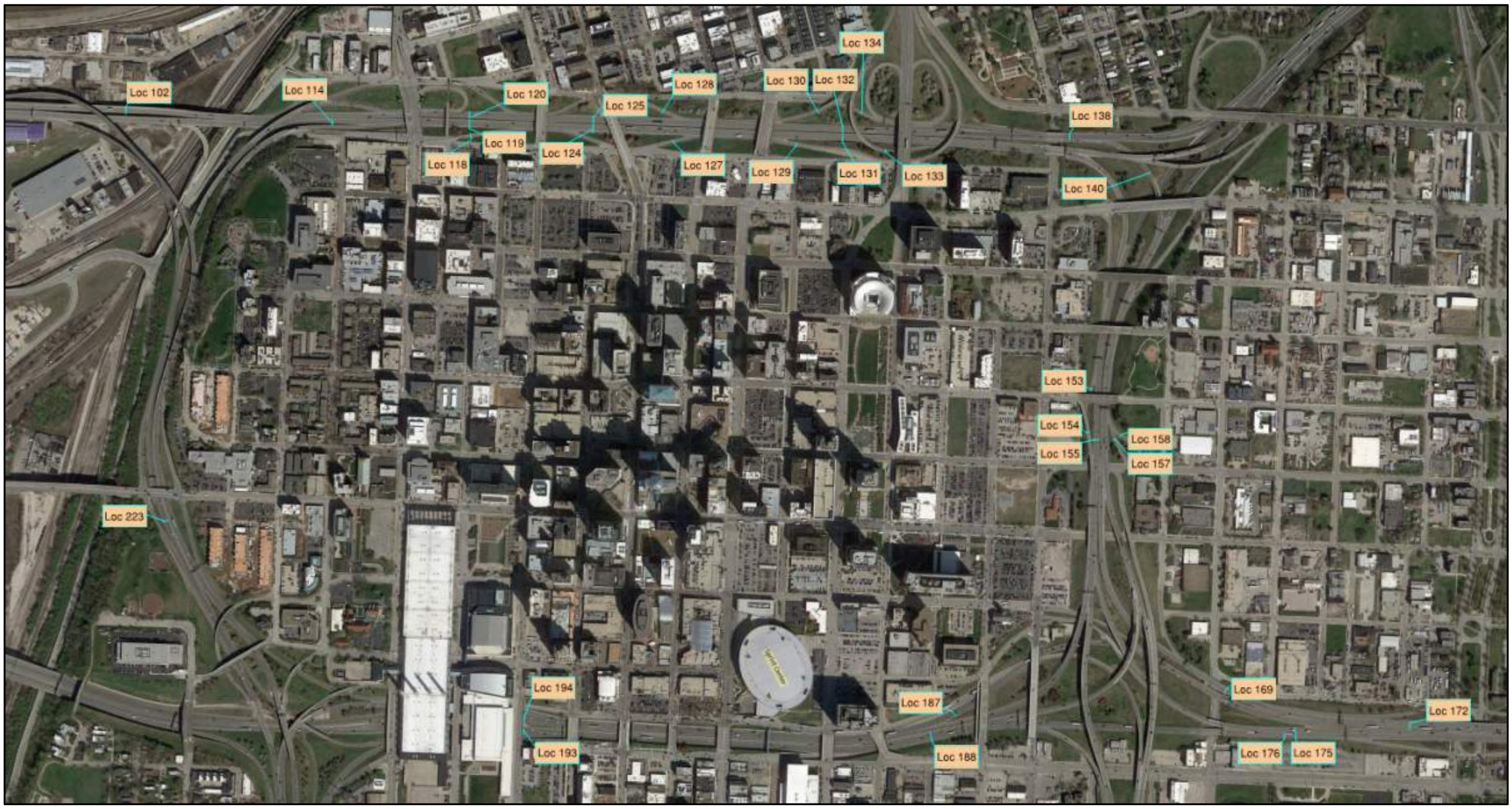


Figure 4.5: Speed Comparison Locations

Link Analyses

Link analyses were performed to visually assess VISSIM network performance for comparison purposes. Figure 4.6 shows posted speed limits through the Downtown Loop freeways.

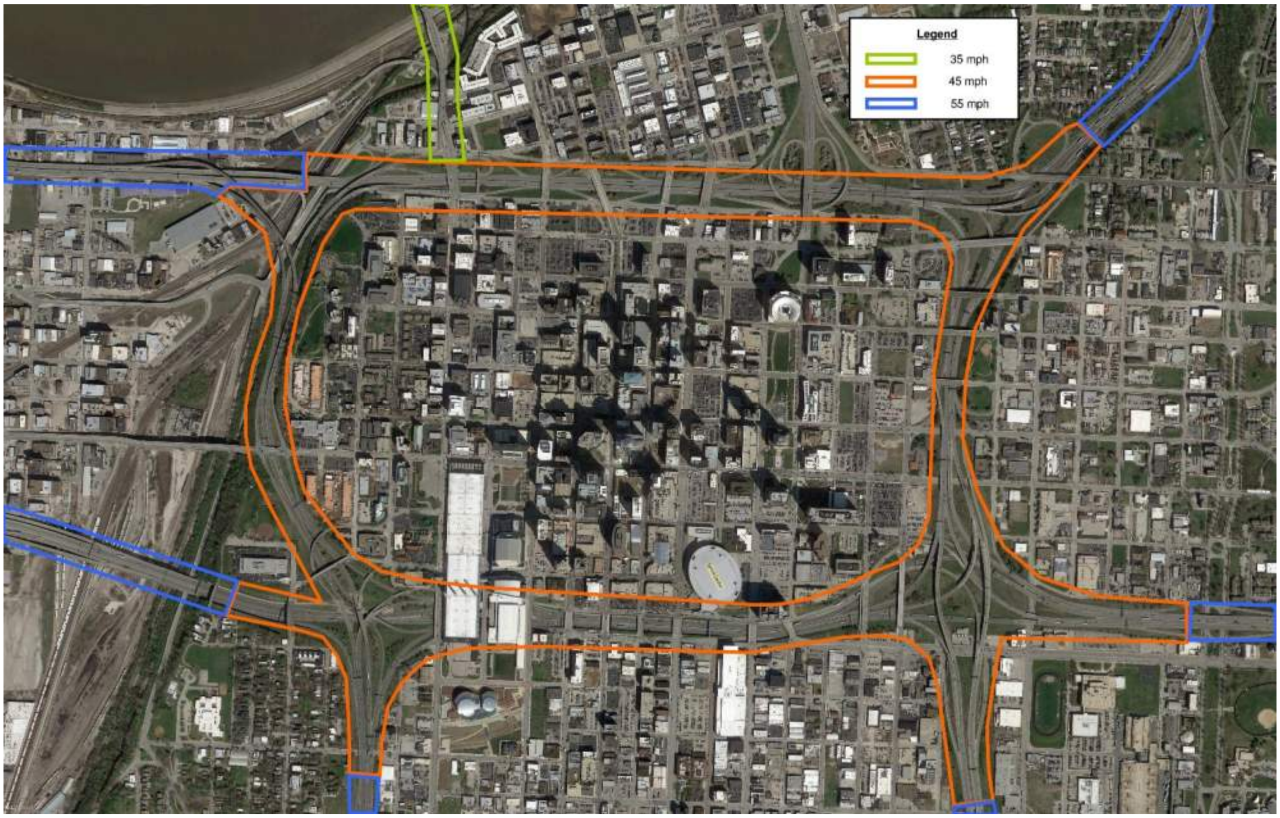


Figure 4.6 Downtown Loop Posted Speed Limits

Figure 4.7 below shows visual output measures from VISSIM minimum recorded speeds on a red-green scale with slower speeds indicated with red and faster speeds indicated with green.

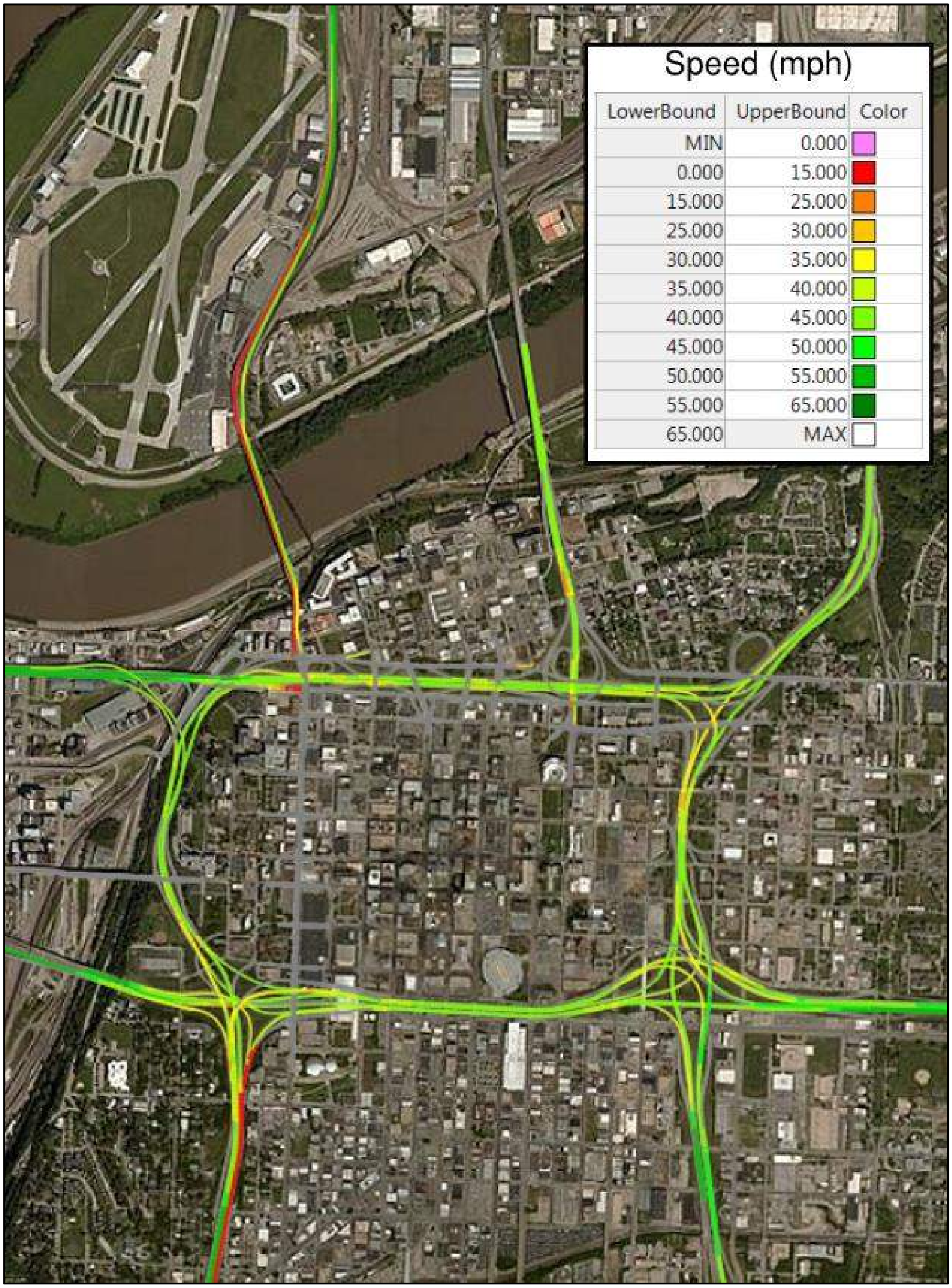


Figure 4.7 A.M. Peak Hour Minimum Travel Speed (mph)

In looking at Figure 4.7, the morning peak hour VISSIM model shows similar behaviors to the expected existing conditions. One limitation to a direct comparison to GoogleMaps relative speed maps is that the red-green scale is not provided for GoogleMaps and therefore cannot be fully replicated. Otherwise, queue lengths and vehicle slow-down locations are replicated in the VISSIM outputs with exception to the EB I-670 approach to Downtown in the southwest corner of the Loop. Similar to the morning peak hour, evening peak hour link analyses were performed to draw a like comparison. Figure 4.8 shows below shows visual output measures from VISSIM minimum recorded speeds on a red-green scale with slower speeds indicated with red and faster speeds indicated with green.

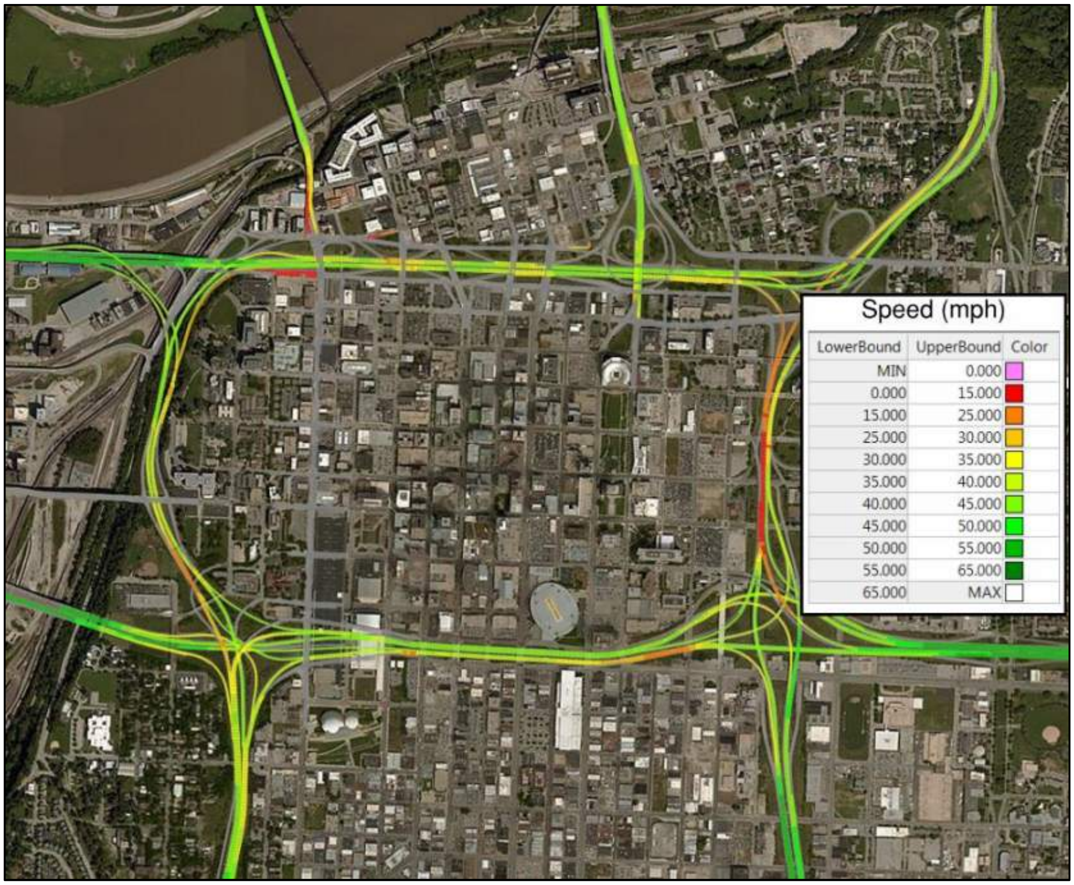


Figure 4.8: A.M. Peak Hour Minimum Travel Speed (mph)

In examining Figure 4.8, similar congestion characteristics are shown between the VISSIM model outputs and GoogleMaps typical day record. Vehicular slow-downs are experienced in the EB direction of the north Loop, SB I-70 queuing is seen along the east side of the Loop, and vehicular queues are found on NB I-35 on the west side of the Loop. As stated for the morning peak hour comparison, a limitation to a direct comparison to GoogleMaps relative speed maps exists since the red-green scale is not provided for GoogleMaps and therefore cannot be fully replicated.

Vehicle Network Performance

Total vehicle network performance metrics are widely usable for model validation but will serve a vital role in future alternative assessments. Table 4.13 shows network performance results for the morning and evening peak hour existing condition VISSIM models.

Table 4.13: Existing Conditions A.M./P.M. Peak Hour Network Performance Metrics

Existing Scenario	Total Vehicle Speed	Total Distance Traveled	Total Travel Time	Total Processed Volume
A.M. Peak Hour	34 mph	73,723 mi	2,175 hr	35,505 veh
P.M. Peak Hour	35 mph	74,832 mi	2,144 hr	36,971 veh

Vehicle Travel Times

The existing conditions VISSIM model was coded to measure travel times along the same travel paths as discussed in the data types portion of the report. Table 4.14 shows VISSIM recorded travel times along the Skycomp measured travel paths for the morning and evening peak hours.

Table 4.14: Existing Condition VISSIM A.M./P.M. Peak Hour Travel Times along Skycomp Paths

Collection Path	Travel Time	% Difference
Point 1 A.M. to 2	5:37	18%
Point 1 A.M. to 3	5:27	20%
Point 2 to 1 P.M.	1:30	24%
Point 3 to 1 P.M.	3:00	53%

Points 1 a.m. to 2 and 1 a.m. to 3 were both observed to be approximately one minute less than the travel time measured through Skycomp. Point 2 to 1 p.m. in the evening peak hour was found to result within 30 seconds of the expected Skycomp travel time. Point 3 to 1 p.m. in the evening peak hour was found to be approximately three minutes shorter than the measured Skycomp travel time. Table 4.15 shows VISSIM recorded travel times along the previously discussed GoogleMaps travel paths for the morning peak hour.

Table 4.15: Existing Condition VISSIM A.M. Peak Hour Travel Times Along GoogleMaps Paths

Destination

A.M. Peak Hour Travel Times	WB I-70 NW Corner	NB US 169	NB MO 9	NB I-29 NE Corner	EB I-70 SE Corner	SB US-71 SE Corner	SB I-35 SW Corner	WB I-670 SW Corner
EB I-70 NW Corner	X	05:09	03:56	03:23	04:16	04:05	06:15	05:59
SB US 169	07:10	X	10:44	09:09	09:59	09:39	08:16	*
SB MO 9	03:29	05:31	X	03:02	03:53	03:45	04:51	05:29
SB I-29 NE Corner	03:17	07:01	04:19	X	02:32	02:24	04:31	03:41
WB I-70 SE Corner	04:15	06:25	03:59	02:25	X	07:31	03:25	02:46
NB US-71 SE Corner	04:16	06:11	03:58	02:14	07:24	X	03:23	02:35
NB I-35 SW Corner	03:24	06:57	05:21	04:48	04:18	04:21	X	01:57
EB I-670 SW Corner	07:07	*	05:20	03:41	02:38	02:25	01:28	X

Origin

* Denotes that travel time was not recorded due to insufficient volume

Comparable travel times are found in comparing morning peak hour anticipated travel time ranges to the VISSIM morning peak hour existing conditions model travel time outputs. Table 4.16 shows VISSIM recorded travel times along the previously discussed GoogleMaps travel paths for the evening peak hour.

Table 4.16: Existing Condition VISSIM P.M. Peak Hour Travel Times Along GoogleMaps Paths

Destination

P.M. Peak Hour Travel Times	WB I-70 NW Corner	NB US 169	NB MO 9	NB I-29 NE Corner	EB I-70 SE Corner	SB US-71 SE Corner	SB I-35 SW Corner	WB I-670 SW Corner
EB I-70 NW Corner	X	05:31	04:02	03:23	05:16	04:28	03:21	*
SB US 169	04:36	X	06:54	07:39	08:25	07:45	05:52	*
SB MO 9	03:23	06:39	X	02:49	04:48	04:07	04:55	*
SB I-29 NE Corner	03:23	06:49	04:04	X	03:58	03:11	04:45	*
WB I-70 SE Corner	04:22	08:37	04:59	02:25	X	08:14	03:23	02:42
NB US-71 SE Corner	04:22	08:10	05:03	02:22	08:59	X	03:34	02:36
NB I-35 SW Corner	03:36	07:41	05:04	04:36	03:32	04:06	X	01:36
EB I-670 SW Corner	*	*	05:27	03:49	02:43	02:28	01:25	X

Origin

* Denotes that travel time was not recorded due to insufficient volume

Comparable travel times are found in comparing evening peak hour anticipated travel time ranges to the VISSIM evening peak hour existing conditions model travel time outputs.

5. Future Models and Travel Demand Model

Future travel demand model scenarios will be pivotal to the VISSIM modeling process of both future year and alternative scenarios. Travel demand model outputs of relative change from the existing conditions travel demand model will serve as the primary source for data trends in VISSIM model inputs. VISSIM inputs will be altered by the anticipated change from the existing conditions calibrated model to ensure validity of comparisons.

6. 2040 VISSIM Models

The 2040 VISSIM models were developed using the calibrated existing condition VISSIM model. The volumes were edited by applying the Cambridge DTA model percent difference found between the DTA existing to the 2040 alternative DTA models. The 2040 VISSIM models show spot analysis zones shown in the below figure. The VISSIM files are under the same name as below.

Figure 6.1: Spot Analysis Model Extents & Mitigation Locations

7. Model Comment Responses

Josh's Comments (PM model only)

1. 5th & Broadway
   1.1. SBR-Drivers to SB 35 generally drive straight to ramp-they do not weave.
   A connector was added directing vehicles from SB Hwy 169 to the SB-35 on-ramp.
   1.2. WB- (Limited observations) WBR queues in model should be longer. It seems WBT queues in model are a little long. – Volume balancing and PHF adjustments have resulted in larger queues in the WB direction. Queue lengths vary by simulation run but typically extend down the WB I-70 Off Ramp and sometimes on I-70 WB to the Main Street bridge.
   1.3. WB offramp-During most observed peak hours the WB offramp will queue to mainline I-70 and block lane 3 (outside lane) at least once. The queue will extend beyond the Main onramp.
   Volume balancing and PHF adjustments have resulted in larger queues in the WB direction. Queue lengths vary by simulation run but typically extend down the WB I-70 off-ramp and sometimes on I-70 WB to the Main Street bridge.
   Also edited the 5th/Broadway intersection WB approach by allowing RTOR, and changed conflict areas to priority rules on the WB off ramp.
2. 6th & Broadway
   2.1. SBL generally observed to stack in a single lane, frequently queuing past 5th St. Occasionally queues to 4th St, has been observed to queue as far as the south end of the river bridge. Most drivers drive directly into the left turn lane as they cross 5th, forcing drivers entering from underneath the bridge to yield.
   Updated lane change rules to eliminate described behavior.
   2.2. EBL in model does not queue enough. During the entire peak hour the observed queue will extend to between the 35 split and the WB 70 split. Occasionally, the queue will extend back to 12th St - Volume balancing and PHF adjustments have resulted in larger queues in the EB direction. Queue lengths vary by simulation run but sporadically extend down the NB I-35 off-ramp to the 12th St overpass. The behavior has been observed to vary by simulation run seed.
3. WB Main onramp
   3.1. Vehicles that are unable to find a gap are usually observed to stop near the yield sign, not under the Wyandotte overpass. Editing the "emergency stop" distance on connector 20430 resulted in desired yield location but had adverse impacts to WB I-70 weaving. Therefore, the "emergency stop" distance was returned to the default setting. As mentioned in previous responses, volume balancing and PHF adjustments have resulted in

increased queuing observations and queues are seen to sporadically extend up the WB I-70 on-ramp. This behavior varies by simulation run seed.

3.2. A short queue is frequently observed on this offramp – See previous response

4. EB Broadway onramp

4.1. (Limited observations) There seems to be a lot of difficulty in this weaving section that has not been observed in the field. – Driver behavior settings were adjusted to the "Aggressive Weave" setting so that vehicles merge onto the freeway more aggressively. See the Calibration Document for further details on driver behavior adjustments.

5. Mo 9/Main Weave (Limited observations)

5.1. There seems to be a lot of difficulty in this weaving section that has not been observed in the field. – See previous response

6. EB 70-NE corner

6.1. Lane 1 (inside lane) observed queues usually past Walnut, sometimes past Broadway. May be related to congestion on NB 29/35 north of the NE corner of the loop. – Added queuing has been observed in the southernmost EB lane sporadically through volume balancing and PHF adjustments. Some added congestion has been observed along the northernmost EB lane but major impacts are thought to be due to interactions outside of the study model limits.

6.2. Lane 3 (outside lane) (Limited observations) has been observed to be congested. Congestion at this location is a relatively new concern. The cause and extent is not known. See previous response

7. NB 35-North of NE corner

7.1. Is usually observed to be congested from NE corner to the N limits of the model for the entire peak hour. – NB I-35 congestion in the NE corner is thought to be due to interactions outside of the study model (for example – perhaps due to the NB I-35 / Paseo merge).

8. SB 70-SE corner

8.1. (Limited observations) It appears too many vehicles in model are stopping at the 2-1 lane drop Links and connectors along the SB I-70 2-1 lane drop have been updated to the "Aggressive Weave" driver behavior. This resulting in more aggressive merging operations and a reduction in vehicle stopping at the merge.

9. EB 70-East of SE corner

9.1. Is often observed to be congested from Prospect to Paseo, sometimes backing up into the South side of the loop. Lane 4 (Outside lane) appears to be over-utilized in the model. – EB I-70 congestion in the SE corner is thought to be due to interactions outside of the study model.

10. NB 71-South of SE corner
    10.1. Lane 2 (Middle lane) is usually observed to be congested starting at the point where the lane splits into a single lane to go to the East side of the loop. This congestion occasionally extends back to 23rd St. This congestion appears to be unrelated to the congestion on NB I-35 at the NE corner – Volume balancing and PHF adjustment updates have resulted in some added congestion along NB 71 but existing condition queues are not shown in the model. Some interaction effects are thought to be due to the Hwy 71 weaving segment just south of study area and discrepancies in lane choice approaching each ramp.
11. Truman & Broadway (Limited observations)
    11.1. SBL observed to usually spill out of the turn bay. The queue is known to extend beyond 14th St (not known if this occurs occasionally or frequently).
    Volume balancing and PHF adjustment updated have resulted in more realistic vehicular operations through the Broadway Boulevard corridor. The focus of results metrics will be on the freeway and ramp system across the existing conditions and alternative condition scenarios.
    11.2. NBL observed to frequently spill out of turn bay (length and frequency is unknown)
    See previous response
    11.3. In the model, have the WBL at 14th St turn directly to the right lane if they are going to SB 35
    See previous response
12. NB 35-South of SW corner
    12.1. Lane 2 (Center-left lane) does not appear to be over-utilized as has been observed in the field –Adjustments were made via lane change distance settings and routing updates
13. EB 670 to SB 35 onramp
    13.1. Entering drivers generally do not stop in observations – Merging segment geometry has been added to allow for more realistic merging operations.
    13.2. Lane 5 (Exit lane to 20th)(Limited observations) Observed drivers usually do not stop at the exit point. – Increased lane change distances and weaving driver behaviors have resulted in more desirable merging behavior.
14. NB 35 at NW corner
    14.1. Lane 1 (inside lane) is often observed to be congested. While the congestion is not as consistent as the congestion in lane 2, the queue can be longer. The queue has been observed to reach 12th Street to I-670. Not certain if the congestion is due to lane volume or due to late lane changes. - Volume balancing and PHF adjustments have resulted in larger queues in the EB 6th Street direction. Queue lengths vary by simulation

run but sporadically extend down the NB I-35 off-ramp and occasionally to the 12th St overpass. The behavior has been observed to vary by simulation run seed.

Ryan's Comments

15. What calibration methods will be used? Speed? Throughput? – A Calibration Document been created to add further detail.
16. Is it necessary to have two different weaving driver behaviors? – A Calibration Document been created to add further detail.
17. Some static routing decisions are shown as volumes and some are shown as ratios. Please change all to volumes for quick checks/etc. – Static routing decisions have been updated to match the 15-minute PHF adjustment vehicle inputs.
18. WBR at Broadway/5th should allow RTOR. – The WBR at 5th Street has been updated to fully allow RTOR.
19. SBL at Broadway/6th are blocking the left through lane. Is this realistic? Consider adding a connector upstream so these vehicles are in the correct lane. – Lane change rules have been updated to result in merging behaviors similar to existing conditions.
20. On the east end of the model shouldn't EB I-70 include the off-ramp to Prospect? (vehicles will not be using the rightmost lane as much as shown in the model) Note the routing does not include the Brooklyn off-ramp. – Some added congestion has been observed along EB I-70 in the SE corner but major impacts are thought to be due to interactions outside of the study model limits.
21. Lane Change Distances:
    21.1. Some of the freeway diverges seem to use 5000' as a default LCD, however this isn't consistent (some use 3000', others use 1656', and still more are left at the default of 656'). Is there a pattern with these distances?
    Lane change distances were primarily used for calibration of queue lengths. Several connectors were updated from default settings in previously submitted model, however, some are left to default distances due to upstream or downstream routing decisions.
    21.2. SB I-35 mainline at 20th Street off-ramp (connector 10001) is still at default. This should be increased. (this should also help the ramps coming from EB I-670 and 13th St as the right lane will have fewer vehicles) – Connector lane change distance has been increased.
    21.3. NB I-35 exit to 14th Street (connector 20375) is still at default. This should be increased. - Connector lane change distance has been increased.
    21.4. SB I-35 exit to EB I-70 (connector 20251) is still at default. This should be increased. - Connector lane change distance has been increased.
    21.5. SB I-35 exit to WB I-70 (connector 21289) is still at default. This should be increased. - Connector lane change distance has been increased.
22. I believe PTV suggests including the length of the taper for ramps. Perhaps this would result in more realistic merging compared to the conflict areas at the gores? This would also change merging behavior at some locations (for instance SB I-35 to EB I-70 where it drops

from two to one lane)
Lane geometries have been updated to allow for more realistic merging behaviors.

23. (AM) I'm surprised to see a lack of congestion on SB I-35 (NE corner of the loop) – Adjusted model volumes based on additional field data comparisons and PHF adjustments have resulted in some added congestion in the NE Corner. This congestion appears to vary by simulation run seed.
24. (AM) I'm surprised to see a lack of congestion on EB I-670 within the loop and extending upstream into the west bottoms – Volume balancing and PHF adjustments have resulted in added congestion through EB I-670, however, queues extending to the West Bottoms have not been observed in the models.
25. (PM) I'm surprised to see so much congestion WB on Truman (N) at Broadway. Is this typical?
    25.1. Notice how hesitant the WBR is here (even with green signal) due to the conflict area. I prefer priority rules (but understand it would be a huge undertaking to change all intersections). Volume balancing and PHF adjustments have resulted in improved operations along WB Truman Road.

APPENDIX A - SKYCOMP DATA COLLECTION METHODOLOGY

SURVEY METHODOLOGY SUMMARY

Downtown Kansas City Freeway Loop
Origin-Destination, Route and Travel Time Patterns
Kansas City, Missouri

Surveys conducted in October / November 2016

Prepared by Skycomp
in association with Burns & McDonnell

INTRODUCTION

The scope of services for the survey conducted by Skycomp in Kansas City, Missouri included the use of time-lapse aerial photography (TLAP) and INRIX data in order to obtain traffic flow parameters for transportation planning activities.

The TLAP assignments were to record and extract second-by-second traffic movements on vehicles that used the downtown Kansas City Loop. The primary task was to produce peak period morning and evening origin-destination (O-D) tables. An additional task was volume counts at designated locations in the survey area. Skycomp's TLAP work was divided into two tasks: *Task 1* related to acquisition and alignment of the TLAP imagery; *Task 2* related to post-flight data extraction.

Four weeks of INRIX *Trip Records* data were analyzed in order to produce 24-hour origin-destination tables for the EMME model area. Additionally, two areas (West Bottoms and Fairfax) were selected for medium/heavy vehicle analysis from 9:00 AM to 3:00 PM. *Task 3* related to creating O-D tables for the EMME model area; *Task 4* related to the medium/heavy vehicle analysis of selected regions.

TLAP TASK ONE – SURVEY EXECUTION AND PHOTO ALIGNMENT

Using a hovering helicopter in a fixed position approximately one mile above the ground, Skycomp executed two 2-hour survey flights to acquire continuous photographic coverage of the study area. These surveys were conducted on the following dates:

Tuesday, October 18, 2016 (4:00-6:00 p.m.)
Tuesday, November 15, 2016 (7:00-9:00 a.m.)

SURVEY AREA

The assigned survey area is shown on the next page in *Figure 1*. This survey area was imaged using a three-camera wide-area video "WAV" system. Images were recorded at a rate of one frame per second. Resolution was set so that it would be possible later to trace individual vehicles between origins and destinations across the survey area, and to obtain queue profiles at designated intersections.

AERIAL CAMERAS

Skycomp prepared a camera coverage plan such that the entire survey area could be viewed by one of three high-resolution digital cameras mounted aboard one helicopter hovering about one mile above the ground. This "wide-area video" (WAV) camera systems captured all visible vehicle flows continuously at a one-second frame rate, for approximately 120-minute periods. The aerial camera plan is shown in *Figure 2*.

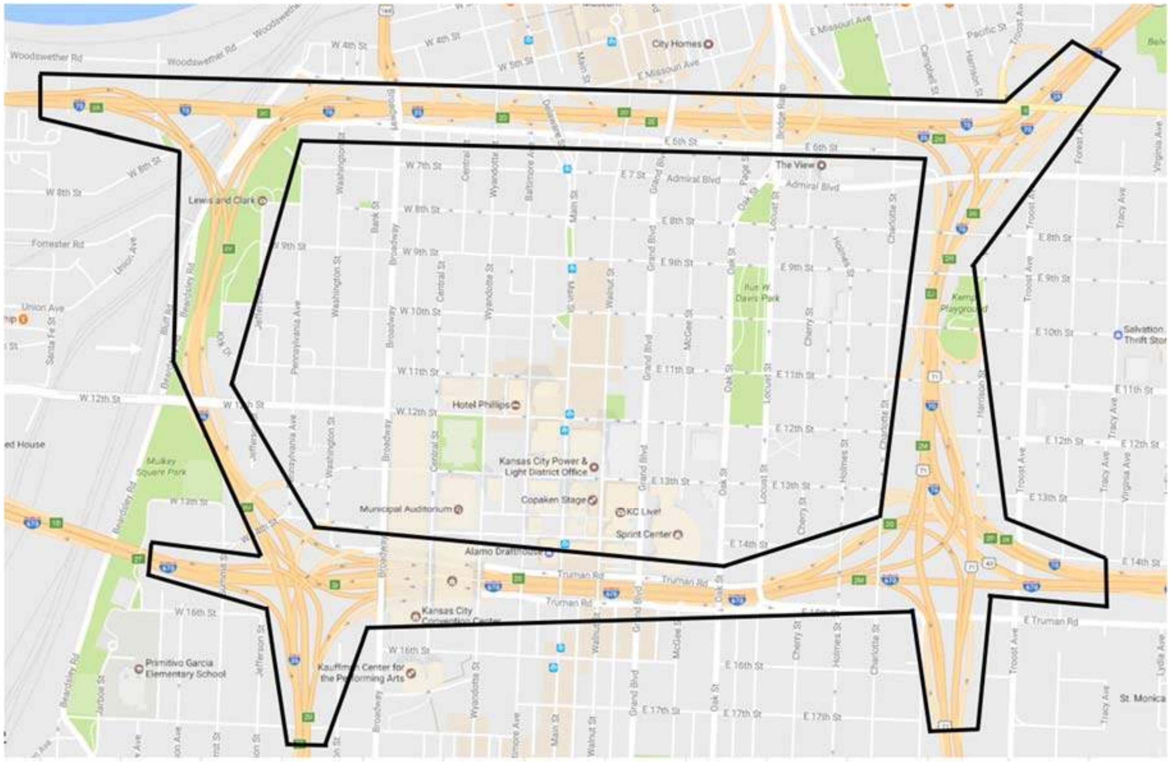


Figure 1: The survey area is outlined in black above; tracing was done along the primary highways comprising the loop to determine vehicle routes and overall traffic O-D percentages between specified locations.

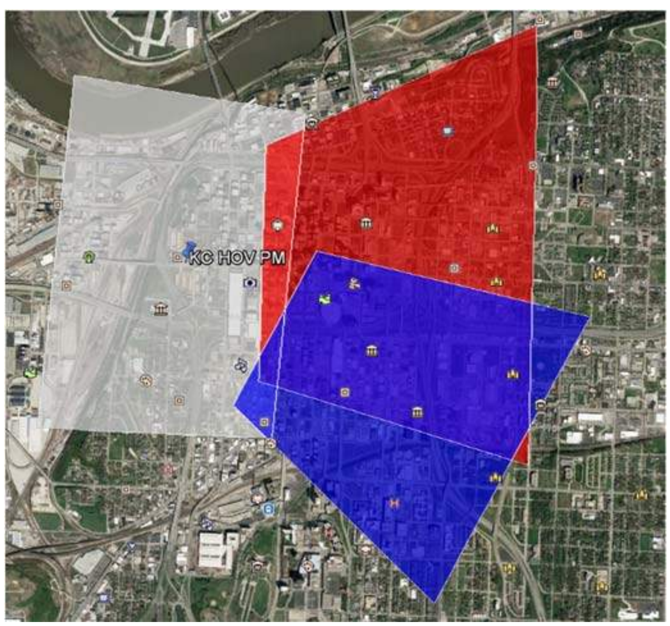


Figure 2: One helicopter with a three-camera cluster was used to image the study area during the evening period (shown above). Each colored polygon is the approximate field-of-view of one high-resolution digital camera. The hover point of the helicopter is depicted by a by a yellow pin left of center. A fourth camera was added to the cluster for the morning survey to enhance resolution in certain locations of the survey area.

SURVEY METHODOLOGIES

Aerial Survey – As described above, Skycomp deployed one helicopter to record all visible highway traffic flow within the aerial survey area. Using one Skycomp "Wide-Area Video" (WAV) digital imaging systems in the multi-camera configurations described above, the surveyors produced image archives suitable for the extraction of the metrics described below. Digital images were captured at one-second intervals.

Aerial Photo alignment –First, all associated imagery sets were tightly-aligned by camera to compose a permanent photographic record of highway traffic conditions. One image taken at the same instant by each of the survey cameras were then pasted onto a single digital "photoboard"; one such photoboard was produced for each second of each survey period. Tight alignment was maintained of all pasted images so that the background would not move when a user advanced from one board to the next. A transparent overlay was then created and applied over each photoboard; the overlay contains codes and colored lines to control recording of the data. These aligned photoboards were then used for the extraction of data.

Figure 3: This is a sample photoboard from the evening survey. Each of the three photographs were acquired at the same instant, combined onto a single image (photoboard) that shows the entire survey area at once.

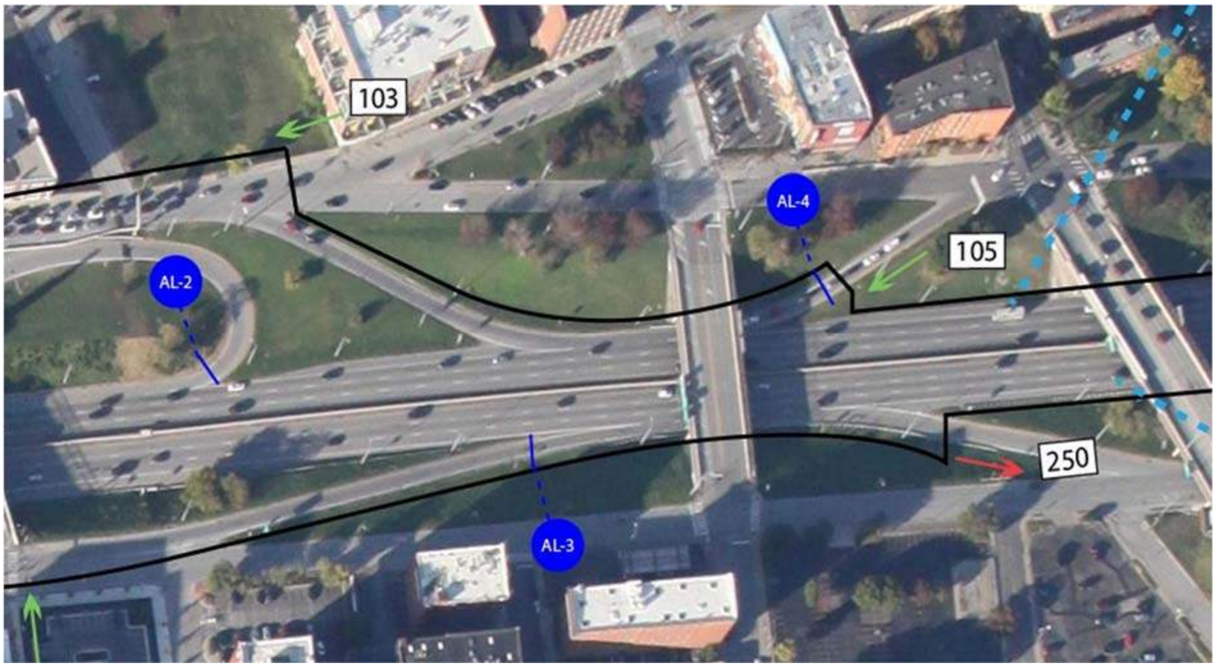


Figure 4: This full-resolution image was cropped from the evening photoboard, and shows the data reduction codes. The blue dots indicate where sampled vehicles were selected for tracing; the numbers (103, 105, 250) serve as origin and destination codes.

TLAP TASK TWO – DATA EXTRACTION, COMPILATION AND DELIVERY

Origin-Destination Data – Virtual *assignment lines* (AL's) were used to define where vehicles would be selected for tracing. A sampled number of vehicles that crossed each AL were traced backward to their origins and forward to their destinations. AL's were drawn as close to the designated origins as possible. In some cases, obstructions in the aerial imagery (overpasses) required that assignment lines be moved to where vehicles could most effectively be traced; volume counts were obtained to supplement O-D compilation in these instances. Vehicles were traced as needed until leaving the survey area across a black boundary line. For this survey, 10% of the vehicles crossing each AL for the 90-minute loading period were selected for tracing; for the high volume AL's, a maximum of 300 vehicles were selected. At some of the low volume AL's (freeway ramps), more than 10% of traffic flow was sampled. Due to a traffic incident later in the evening survey period (potentially impacting O-D behavior), only 60 minutes were sampled at some of the assignment lines. Additionally, at some locations where the origin and destination were known, volume counts were used in lieu of traced samples.

LIST OF ASSIGNMENT LINES

AL-1	Mainline – SB US 169
AL-2	Ramp - NB Broadway Blvd to WB I-70
AL-3	Ramp - EB W 6th St / Broadway Blvd to EB I-70
AL-4	Ramp - WB W Independence Ave / Delaware St to WB I-70
AL-5	Ramp - EB E 6th St / Deleware St to EB I-70
AL-6	Ramp - SB SR 9 to EB / WB I-70
AL-7	Ramp - NB SR 9 to WB I-70
AL-8	Ramp - EB / WB Independence Ave to WB I-70
AL-9	Mainline - SB I-29
AL-10	Ramp - EB / WB Admiral Blvd to SB I-70

AL-12A Ramp - WB 10th St to NB I-70
AL-12B Ramp - WB 11th St to NB I-70
AL-14/15 Mainline - WB I-70
AL-16 Mainline - NB US 71
AL-18 Ramp - E Truman Rd to EB I-670
AL-19 Mainline - NB I-35
AL-20A Ramp - EB I-670 to SB I-35
AL-20B Mainline - EB I-670
AL-22 Ramp - EB / WB W 12th St to SB I-35
AL-23 Ramp - EB / WB W 12th St to NB I-35
AL-24A Mainline - EB I-70
AL-24B Ramp - EB I-70 to SB I-35

Vehicle tracing O-D master database creation - Based on the sampling rate, vehicles were selected for tracing as they crossed each AL, and then traced backwards and forward until crossing a boundary of the survey area (black lines in the overlay graphic, as shown in Figures 4). Tags were applied manually to these selected vehicles as they moved between origins and destinations using a computerized imagery tagging tool; that tool accumulated the tagging information into a master vehicle trajectory database for each survey period. This included fields for time-stamped crossing of AL's and origin and destination boundary lines. This master database is comprised of two types of files: the "A" files which contain one record for each traced vehicle to include the origin, destination, class (car, truck, tractor-trailer or bus), travel time and the time that the trace began. The "B" files contain one record for each tag applied to each traced vehicle. Each such record contains a unique vehicle ID number to correlate it to the "A" file, the precise time that each tag was applied, and the pixel (x,y) location of the vehicle's tag on the photoboard (this provides trajectory information to be extracted later if needed).

'ID'	Type	Total Time (sec)	Symbol	Origin	Destination	Notes
101	Car	65	1	200	120	71608 B
102	Bus	112	2	200	120	71654 W BUS
103	Car	119	3	200	300	71714 B CAR
104	Car	175	4	200	340	71757 B CAR
105	Car	56	5	200	120	71904 G CAR UI
106	Car	149	6	200	120	71949 W CAR
107	Car	175	7	200	125	72036 B CAR UI
108	Car	71	8	200	205	72130 G CAR
109	Truck	90	9	200	120	72235 W TRUCI
110	Car	163	10	200	310	72344 W CAR

Figure 5: This is a sample from the "A" file from the morning period. Each record represents one traced vehicle.

'ID'	Origin	Destinatic	Lane	Photo	X	Y	Field 1	Field 2
921	200			r_02a_20160921-081758.ecw	12092	3991		
921	200			r_02a_20160921-081800.ecw	12036	4000		
921	200			r_02a_20160921-081802.ecw	11986	3999	AL-1	
921	200			r_02a_20160921-081806.ecw	11896	3956		
921	200			r_02a_20160921-081810.ecw	11837	3875		
921	200			r_02a_20160921-081812.ecw	11834	3820		
921	200			r_02a_20160921-081816.ecw	11856	3720		
921	200			r_02a_20160921-081820.ecw	11914	3666		
921	200			r_02a_20160921-081824.ecw	11977	3663		
921	200			r_02a_20160921-081828.ecw	12026	3670		
921	200			r_02a_20160921-081832.ecw	12067	3699		
921	200			r_02a_20160921-081837.ecw	12063	3795		
921	200			r_02a_20160921-081841.ecw	12051	3899		
921	200			r_02a_20160921-081842.ecw	12045	3929		
921	200			r_02a_20160921-081843.ecw	12041	3960		
921	200			r_02a_20160921-081910.ecw	11992	4189		
921	200			r_02a_20160921-081911.ecw	11989	4205		
921	200			r_02a_20160921-081914.ecw	11970	4287		
921	200			r_02a_20160921-081918.ecw	11947	4417		
921	200			r_02a_20160921-081922.ecw	11928	4530		
921	200	120		r_02a_20160921-081928.ecw	11880	4646		

Figure 6 (above): This is a sample from the "B" file from the morning period, for Vehicle ID 921. Each record represents one vehicle tag placed on succeeding photoboards; the x,y fields track the movement of each vehicle across the photoboard. The filename includes the time to the nearest second, allowing the exporting of detailed travel times using the route markers in Field 1.

Next, O-D data was compiled into summary tables by survey period. Hourly volumes were applied to the raw tallies of the tracing results in order to create balanced tables. Each "Table 1" displays these balanced tables; each "Table 2" displays the data from Table 1 converted to percentages.

TABLE 1: Origin-Destination Table with Applied Hourly Volumes										
	Hourly	Destinations								
Origins	Balanced Volume	100	104	105	107	110	111	120	125	130
100	**1385**	0	78	16	47	10	0	8	0	0
101	**20**	0	0	0	0	0	0	0	0	0
103	**1**	0	0	0	0	0	0	0	0	0
105	**490**	10	0	0	0	0	0	0	0	0
110	**726**	0	0	7	0	0	0	13	26	0
112	**66**	0	0	0	0	0	0	0	0	0
113	**33**	0	0	0	0	0	0	0	0	0
115	**211**	7	0	13	0	7	0	0	0	0
120	**3588**	0	0	70	0	35	26	0	0	0
135	**130**	0	0	3	0	0	0	80	0	6
137	**118**	4	0	0	0	0	0	97	0	11
150	**331**	19	0	28	0	9	0	132	9	9
155	**3340**	68	0	107	0	27	10	358	10	87
170	**3451**	110	0	50	0	35	0	1509	0	120

Figure 7: Partial Table 1, evening survey period.

TABLE 2: Origin-Destination Overall Percentages Table (Based on Table 1)										
	Total	Destinations								
Origins	Origin Percentages	100	104	105	107	110	111	120	125	130
100	**5.4%**	0%	0%	0%	0%	0%	0%	0%	0%	0%
101	**0.1%**	0%	0%	0%	0%	0%	0%	0%	0%	0%
103	**0.0%**	0%	0%	0%	0%	0%	0%	0%	0%	0%
105	**1.9%**	0%	0%	0%	0%	0%	0%	0%	0%	0%
110	**2.8%**	0%	0%	0%	0%	0%	0%	0%	0%	0%
112	**0.3%**	0%	0%	0%	0%	0%	0%	0%	0%	0%
113	**0.1%**	0%	0%	0%	0%	0%	0%	0%	0%	0%
115	**0.8%**	0%	0%	0%	0%	0%	0%	0%	0%	0%
120	**14.0%**	0%	0%	0%	0%	0%	0%	0%	0%	0%
135	**0.5%**	0%	0%	0%	0%	0%	0%	0%	0%	0%
137	**0.5%**	0%	0%	0%	0%	0%	0%	0%	0%	0%
150	**1.3%**	0%	0%	0%	0%	0%	0%	1%	0%	0%
155	**13.0%**	0%	0%	0%	0%	0%	0%	1%	0%	0%
170	**13.4%**	0%	0%	0%	0%	0%	0%	6%	0%	0%

Figure 8: Partial Table 2, evening survey period.

Travel Times - The client designated 4 routes where travel times were to be obtained using the aerial imagery. AM routes were southbound from 1 to 2 and 1 to 3. PM routes were northbound from 2 to 1 and 3 to 1 (see *Figure 9* below).

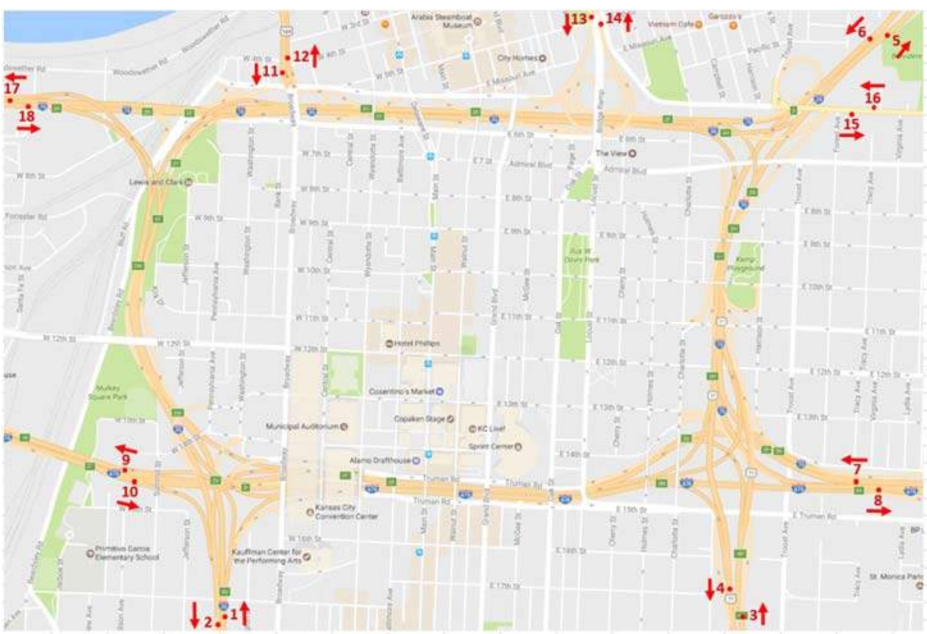
Figure 9: Travel time routes (AM: 1-2, 1-3; PM: 2-1, 3-1)

Travel time results were provided in excel workbooks (see *Figure 10* below).

Date:		Tuesday, November 15, 2016		
Route:		(1) vicinity of airport interchange to (3) I-35 / 12th St Interchange		
Direction:		Southbound		
Distance (miles):		1.9		
Sample	Time (PM)	Travel Time (seconds)	Travel Time (mins:secs)	Speed (mph)
1	700-715	334	5:34	20
2	700-715	347	5:47	20
3	715-730	430	7:10	16
4	715-730	391	6:31	17
5	715-730	442	7:22	15
6	730-745	356	5:56	19
7	730-745	415	6:55	16
8	745-800	485	8:05	14

Figure 10: Partial travel time table

Volume Counts - The client specified 18 mainline locations for 2-hour volume counts (for each time period). See map and list of count locations in *Figure 11* below. Volume counts were provided in 15-minute sets; in these tables, vehicles were also classified as trucks, tractor-trailers, buses or autos/other small vehicles (pick-up trucks, vans, etc.). See sample table in *Figure 10* below.



Volume #	Location
1	Northbound I-35
2	Southbound I-35
3	Northbound US-71
4	Southbound US-71
5	Northbound I-29
6	Southbound I-29
7	Westbound I-70
8	Eastbound I-70
9	Westbound I-670
10	Eastbound I-670
11	Southbound US-169
12	Northbound US-169
13	Southbound SR-9
14	Northbound SR-9
15	Westbound Independence Ave
16	Eastbound Independence Ave
17	Westbound I-70
18	Eastbound I-70

Figure 11: Volume count locations are depicted above.

Project:	Downtown Kansas City Freeway Loop
Assignment:	1
Location:	Northbound I-35
Date:	Tuesday, November 15, 2016
Time:	7:00-9:00 AM

VOLUME COUNT SUMMARY

TIME PERIOD	VEHICLE CLASS.	NB
7:00 AM	Total Vehicles	1166
	Passenger Car	1141
	Truck	8
	Tractor-Trailer	9
7:15 AM	Bus	8
7:15 AM	Total Vehicles	1475
	Passenger Car	1441
	Truck	16
	Tractor-Trailer	13
7:30 AM	Bus	5
7:30 AM	Total Vehicles	1595
	Passenger Car	1567
	Truck	11
	Tractor-Trailer	5
7:45 AM	Bus	12
7:45 AM	Total Vehicles	1744
	Passenger Car	1705

Figure 10: The partial table above depicts AM volume counts for northbound I-35 approaching the downtown Kansas City loop.

<u>TLAP Deliverables - </u>Skycomp has produced the following deliverables:

1. Summary of the survey methodologies in a written report;
2. Origin-destination tables (Tables 1 and 2 per above);
3. Travel times on designated routes;
4. Volume counts.

INRIX TASK THREE – DATA EXTRACTION, COMPILATION AND DELIVERY

The INRIX Trips database is comprised of GPS "ping" trails (lat/longs) of individual trips; each trip has a unique Trip ID number. Furthermore, each trip is associated with a specific device, so that if a vehicle makes multiple trips in one day, it is possible to understand that the trips are related. Several other fields are provided including the time that each trip began and ended; the coordinates of its beginning and ending points (origins and destinations); and the coordinates of all route pings which are contained in the database, with precise time stamps. The ping rates vary widely from one trip to the next, ranging from one ping per second to around five minutes per ping (latter is rare). Most vehicles ping at a rate between 30 seconds and two minutes.

To perform this study, INRIX provided Skycomp with a database that included all trips aggregated by INRIX for the month of March 2016 for which at least one ping was generated within the study area.

The general processing steps were as follows:
1. Because the INRIX Trips database contains three types of vehicle classification (light, medium and heavy vehicles), all vehicle records were segregated and retained for analysis.

2. The next step was to create subsets of the trips database, each of which contained only the trips within a specific time period. The analysis periods are listed below. Trips from typical, non-holiday, Tuesday-Thursdays were included.

AM Peak – 6:00 AM to 9:00 AM
Midday - 9:00 AM to 3:00 PM
PM Peak – 3:00 PM to 7:00 PM
Overnight - 7:00 PM to 6:00 AM

3. The lat/long coordinates of each start and end point for each trip is part of the trip's information. These points were plotted against the traffic analysis zone (TAZ) map provided by the client, so that the origin and destination codes in the database could be appended with the client's TAZ code names.

3. The origins and destinations of the vehicles were then compiled into O-D Counts tables by vehicle class (light, medium, heavy) and time period. O-D Percentages tables were then created based on the O-D Counts tables. These O-D matrices were then provided to the client.

INRIX TASK FOUR – DATA EXTRACTION, COMPILATION AND DELIVERY

Using the INRIX Tripstats data from *Task Three*, Skycomp performed analyses on two industrial sites; West Bottoms, Kansas City, MO; and Fairfax, Kansas City, KS. For each of these studies, vehicles classified as heavy or medium were analyzed from 9:00 am to 3:00 pm. Trips from typical, non-holiday, Tuesday-Thursdays were included.

The general processing steps for the INRIX OD analysis of medium/heavy vehicles in the West Bottoms and Fairfax areas differ from the *Task Three* steps in that points had to be plotted against customized polygons rather than the TAZ map provided.

Questions - If there are any questions about the methodologies described above, please direct them to Billie Barnett at Skycomp, at *barnett@skycomp.com*.