



Louisville - Southern Indiana Ohio River Bridges Project

Technical Memorandum: Microsimulation

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LSIORB

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Introduction

This memo documents the development and application of microsimulation models for the Louisville-Southern Indiana Ohio River Bridges (LSIORB) Project for the Supplemental Environmental Impact Statement (SEIS) and the Interchange Justification Study (IJS). The CORSIM model was used in support of the development of the *SEIS*. This memo focuses on the CORSIM model development and analyses.

Purpose and Use of Microsimulation

Microsimulation is the modeling of individual vehicle movements on a second or subsecond basis for the purpose of assessing the traffic performance of highway and street systems, transit, and pedestrians. Microsimulation was chosen for this project because of its ability to model complex systems under congested conditions. It has the ability to model the interaction of vehicles throughout the downtown area. This way, the effects of operational difficulties in one segment can be observed on the upstream and downstream segments.

Microsimulation was used on this project because of its ability to model complex traffic operations on a systemwide basis. The Kennedy Interchange is a complex set of closely-spaced ramps in a dense, urban area. Therefore, it was important to analyze the freeway system, not only on a segment-by-segment basis, but also on a systemwide basis. The Highway Capacity Manual analyses are fixed on one, independent segment of the freeway (i.e., it does not take into consideration (for the most part) the effects of operations in upstream and downstream segments). Microsimulation was used to complement the HCS analysis performed in the Kennedy Interchange. It was used primarily to generate freeway operations performance measures in order to evaluate freeway operations under different design alternatives. Some arterials are modeled, but the focus of the model is operations on the freeway segments. Specific performance measures were calculated for use in the SEIS and are explained further below.

CORSIM is a corridor simulation tool that operates within the Traffic Software Integration System (TSIS). CORSIM was used in order to remain consistent with the LSIORB Final Environmental Impact Statement (FEIS). The original *FEIS* model was built and calibrated using CORSIM version 5. The model for this study was re-calibrated and run in CORSIM version 6.1.

The Kennedy Interchange CORSIM model was originally built as part of the 2003 *FEIS* and subsequently updated in 2007 for an *IJS* addendum. The model was updated as part of the *SEIS* project to aid in the development of Kennedy Interchange geometric alternatives as well as the development of the *SEIS*.

Model Extents

The Kennedy Interchange CORSIM model includes the proposed construction limits¹ and beyond. The model limits were chosen in order to capture the adjacent interchanges within a reasonable area of influence. The model extents capture the next adjacent interchange including I-64 at 3rd Street on the west, I-65 at Broadway (including Chestnut Street ramp) on the south, I-64 east of the Mellwood Avenue ramps on the southeast. The next adjacent interchange to the east (Zorn Avenue) is over 1.5 miles away

¹ See Figure 3.2-3A of the SEIS for an illustration of the Kennedy Interchange construction limits.

and was not included. The next adjacent interchange to the north (Court Avenue) is over one half mile away across the Ohio River in Indiana. It was not included in the Kennedy Interchange CORSIM model. The CORSIM model extents are shown in Figure 1.

Figure 1 – CORSIM Model Extents



Traffic Volumes

Volumes and truck percentages used in the CORSIM model were taken from the post-processed results of the SEIS time-of-day travel demand forecasting model. Volume forecasts were developed for each alternative. The volumes and the documentation of their derivation can be found in the *LSIORB Traffic Forecast* document.

Model Times

The peak hours were determined from 2010 traffic counts. The AM peak hour is 7:00 AM to 8:00 AM. The PM peak hour is 4:00 PM to 5:00 PM. These were the peak hours modeled with CORSIM. The

simulation was set to run for 60 minutes² with 60-minute flow rates used as input. This period was chosen based on the traffic data available. Statistics were calculated for the peak hour.

Selection of Measures of Effectiveness

The measures of effectiveness to be examined were chosen with the LSIORB SEIS project objectives in mind. The Purpose and Need of the LSIORB SEIS lists the following need: Traffic congestion on the Kennedy Bridge and within the Kennedy Interchange. The following measures of effectiveness from CORSIM output are the system performance statistics that best characterize the degree to which a particular alternative meets the project objectives as they pertain to the Kennedy Interchange operations:

- Average Peak-Hour Speed – system measure
- Total Vehicle Hours of Delay (VHD) – system measure
- Throughput as a Percent of Demand – system measure
- Average Link Density – link measure

The first three measures focus primarily on systemwide measures while the fourth measure reflects operations on individual links. These measures may all be used as relative indicators of congestion in the Kennedy Interchange and allow the alternatives to be compared. Each of these measures is described in more detail below. These measures of effectiveness were used in the *2003 LSIORB FEIS* and retained for consistency for the *SEIS*.

Average Peak-Hour Speed

The Average Peak-Hour Speed (miles per hour) was chosen as a measure of effectiveness to evaluate the overall system performance. The Average Peak-Hour Speed is calculated by dividing the sum of travel time of all vehicles by the sum of the travel distance of all vehicles during the peak hour. This yields an average speed over the entire network. A lower average speed for one alternative as compared to another alternative indicates more congestion under that alternative.

Total Vehicle Hours of Delay

The system Total Vehicle Hours of Delay (hours) was chosen as another measure of effectiveness to evaluate the overall system performance. The Total Vehicle Hours of Delay is calculated by summing the peak-hour cumulative delay time for each link in the network. Higher values of delay for an alternative indicate a greater amount of congestion under that alternative.

Throughput as a Percent of Demand

Throughput as a Percent of Demand was chosen as another measure of effectiveness to evaluate the overall system performance and must be viewed in tandem with Average Peak-Hour Speed and Total Vehicle Hours of Delay. If simulation alternatives are severely congested and queues build back upstream to the entry link of the model, CORSIM may be unable to load additional vehicles onto the network. Some vehicles may be blocked from entering the network on these entry links. These blocked

² This does not include a “warm-up” period as CORSIM automatically has an initialization period, immediately preceding the 60-minute data simulation period, in which the network is populated and an equilibrium is reached.

vehicles will not be included in the travel time or delay statistics for the model run. Therefore, the delay and speed measures of effectiveness are underestimated so the number of vehicles that are blocked from the network must be taken into consideration when examining network speed and delay.

CORSIM records the excess queues that back up outside the network and reports them as “VEHICLES BACKED UP BEHIND NODE N”, where N is the entry node behind which the vehicles are backed up. Throughput as a Percent of Demand is calculated by summing the total number of vehicles blocked behind entry nodes during the peak hour (as reported by CORSIM) and subtracting it from the total demand of vehicles coded to enter the system. This yields the total number of vehicles that were able to enter the system. This number was then divided by sum of all entry demands (vehicles) during the peak hour to yield throughput as a percent of demand.

If a simulation alternative has a lower percentage of Throughput as a Percent of Demand, then it can be concluded that the average network speed is overestimated and the network delay is underestimated.

Average Link Density

Average Link Density (vehicles per mile per lane) was chosen as a measure of effectiveness that provides an indication of operations on individual links. Average Link Density is calculated on a per-link basis by dividing the average vehicle content of that link during the peak hour by the sum of the lengths of the lanes on the links. Higher values of density on a link indicate greater congestion.

Model Application

Due to the stochastic nature of CORSIM, each model was run 10 times³ with a different random number seed set each time. The MOEs were averaged over the 10 runs and the average for each of the MOEs was reported. Within each set, there are three random number seeds that influence different aspects of the model. The first influences vehicle entry headways. The second influences vehicle entry headways on the NETSIM (arterial) network. The third influences individual vehicles' responses to traffic choices (e.g. accepting gaps in traffic).

Calibration

Calibration is the adjustment of model parameters to improve the model's ability to reproduce local driver behavior and traffic performance characteristics⁴. The idea is to adjust the model so that it most accurately portrays existing local conditions and is able to predict travel conditions under future scenarios. The objective is to find a set of calibration parameters that accomplishes this.

³ Ten runs were determined to be adequate based on the guidance provided in Section 5.4.1 in *Traffic Analysis Toolbox Volume IV: Guidelines for Applying CORSIM Microsimulation Modeling Software*, Publication No. FHWA-HOP-07-079, p. 124-125.

⁴ *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software*, Publication No. FHWA-HRT-04-040, July 2004, p. 53.

In order to test CORSIM calibration parameters, a base model of existing 2010 conditions was used. For this study, the existing CORSIM model network from the previous *FEIS* and *IJS* was used as a base. 2010 volumes were coded into this existing model network.

Field Observations of Existing Conditions

Field observations were conducted in order to gain an understanding of the existing traffic conditions and operations in the Kennedy Interchange area.

Traffic Data Collection

Traffic counts were taken in the downtown area in fall 2010 and spring 2011. These were 24-hour classification counts on freeway ramps in the Kennedy Interchange area and beyond. More details regarding this data collection and the results can be found in the *LSIORB Traffic Forecast* report.

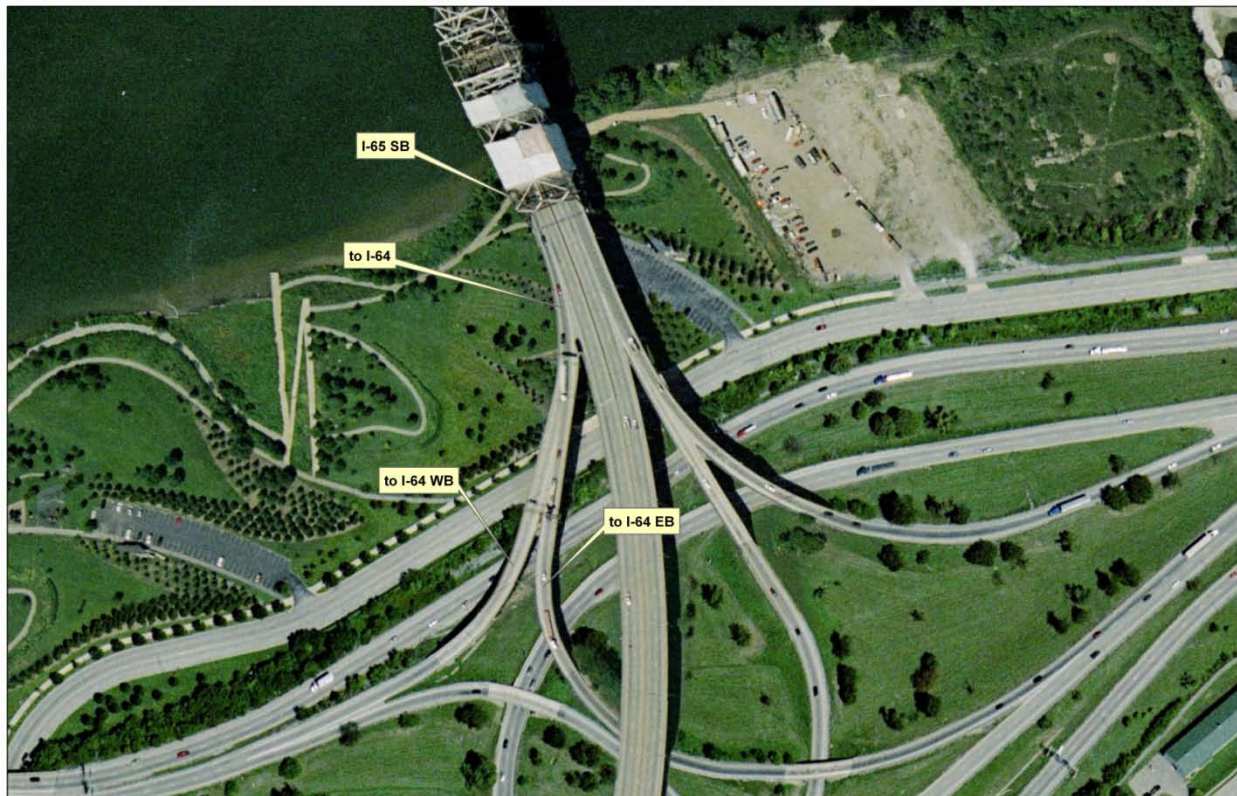
Field Observations

Field observations were conducted in order to assess typical traffic patterns during the AM and PM peak hours. The Traffic Response and Incident Management Assisting the River Cities (TRIMARC) website is a very useful tool for observing daily traffic operations in the Kennedy Interchange area. The website displays images from traffic cameras that show real-time traffic conditions online⁵. There are nearly a dozen cameras in the Kennedy Interchange study area that provide real-time images of traffic in the area. The website also reports incidents (including location and duration) so that it can be determined whether traffic observations are being affected. The cameras were observed daily during the AM and PM peak periods to identify queuing and bottleneck patterns.

Two locations were selected as key bottleneck and queuing locations to be used in the calibration process. I-65 SB between Court Street (Indiana) and the ramps to I-64 just south of the Kennedy Bridge is an area of major congestion. Southbound traffic routinely queues across the bridge, especially in the right lane. This lane feeds the single-lane off-ramp that serves the two ramps to I-64. It is a diverge section followed closely by another diverge section. See Figure 2 for a photo of the location.

⁵ http://www.trimarc.org/perl/map_form.pl

Figure 2 – I-65 SB Kennedy Bridge Bottleneck Area



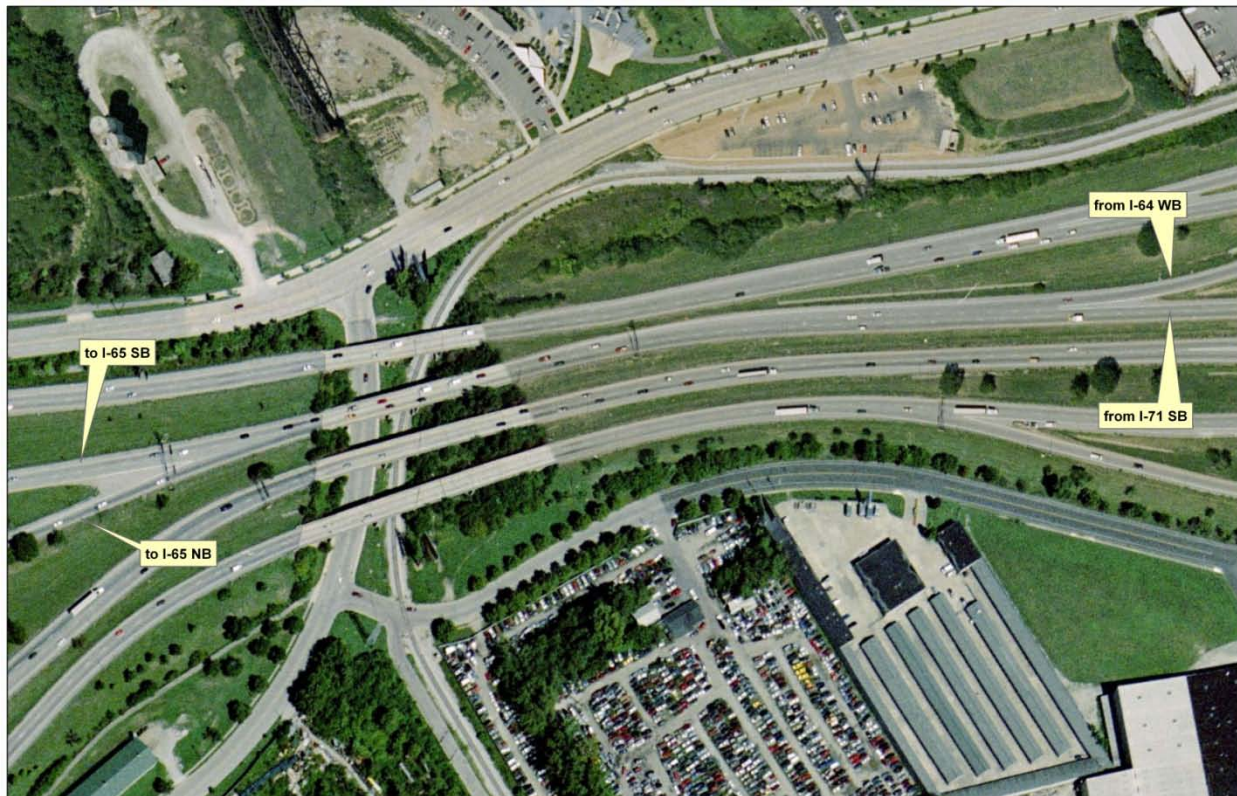
The other key bottleneck location is the I-64 WB/I-71 SB weave to I-65 SB and I-65 NB. This section includes a right-hand merge (I-64 WB traffic) followed by a weaving section to I-65 NB. Because of the high proportion of I-64 WB to I-65 NB traffic in the section (especially in the PM peak hour), recurring congestion and queuing occurs here. See Figure 3 for a photo of the location.

Because these two particular bottleneck locations routinely operate at oversaturated conditions during the peak hour, an accurate estimate of the demand was not recorded. The peak-hour traffic volumes were collected by tubes during the peak hour while queues were formed. Therefore, counts in the area do not fully capture the demand during the peak hour. During the calibration process, additional demand was assigned to I-64 WB and I-65 SB at these locations in order to more accurately demonstrate both the correct upstream and downstream throughput as well as queue formation.

Calibration Approach

As suggested in the *Traffic Analysis Toolbox Volume III*, calibration was approached on two levels: global and local. Two main calibration measures were examined when testing the adjustment of calibration parameters: the ability of the model to accurately model the capacity of key bottlenecks and its ability to replicate recurring congestion and queuing at the key locations. Both measures were examined in tandem to achieve calibration adjustments that would provide the best fit on both a systemwide and local level.

Figure 3 – I-64 WB/I-71 SB to I-65 Weaving Area



The following calibration parameters were chosen as candidates for adjustment in the calibration process:

- Car Following Sensitivity Factors (CFSF)
- Car Following Sensitivity Multiplier
- Warning Sign Placement

The first parameter is a global parameter while the second two are applied locally.

Calibrate Bottleneck Capacity

The first step of the process was to calibrate the capacity of key bottlenecks. The two aforementioned bottlenecks were examined. The complexity of the Kennedy Interchange, with its closely spaced ramps and freeway-to-freeway connections, makes it difficult to calculate exact capacities to use to check the calibration of individual bottlenecks in CORSIM. An example is the I-64 WB and I-71 SB merge and weave to I-65 NB and I-65 SB. The area includes a ramp merge on the right followed closely by a left-hand off-ramp that forms a weaving section. Such a scenario cannot be exactly evaluated using Highway Capacity Manual methodologies. However, because the two key bottlenecks being examined are both operating at saturated conditions during the peak hour, the observed traffic counts on the exit links are pretty good indications of the actual bottleneck capacity. Therefore, throughput (measured by

comparing modeled versus base volumes as noted above) was used as the main criterion to evaluate the successful representation of the key recurring bottlenecks and queuing.

A GEH⁶ statistic was calculated for volumes at the key links. The volumes produced by calibration run output were compared to the traffic volume/count at that particular location. The GEH statistic was chosen because of its non-linear nature and its ease of comparison across wide ranges of volumes. The global CFSF parameters were chosen to be adjusted to attempt to produce bottleneck capacities with a GEH < 5.0.

The first scenario tested was with the CFSF parameters used in the previous *FEIS* and *IIS*. Due to different traffic conditions and a newer version of the CORSIM software, the FEIS CFSF parameters actually showed too much throughput downstream of the bottlenecks. The model produced GEH factors of 7.3 and 11.9 when compared to the observed capacities for the I-64 WB/I-71 SB and I-65 SB Kennedy Bridge bottlenecks respectively. See Figure 3. Therefore, the next scenario tested the FEIS CFSFs increased by 1/10th of a second each. This yielded lower volumes and corresponding GEHs of 3.4 and 8.7. The CFSFs were eventually increased by 3/10th of a second each and this yielded acceptable GEHs of 1.3 and 3.3. Table 1 shows the original CFSF set from the *FEIS* and the final set achieved during calibration for the *SEIS*.

Figure 3 – Capacity Calibration at Key Bottlenecks

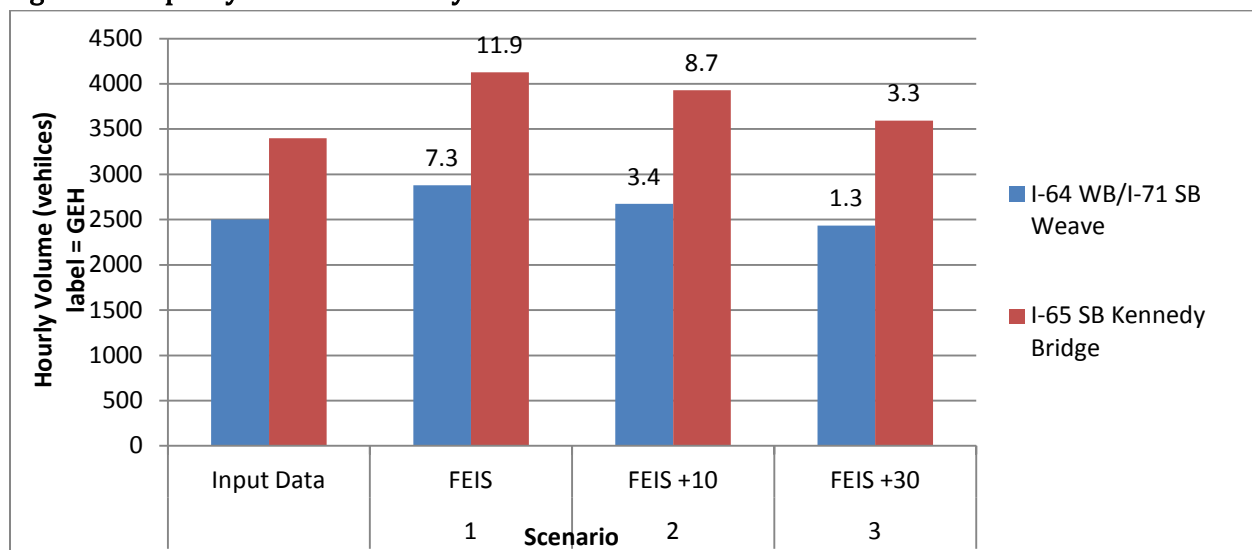


TABLE 1 – Adjustment of Car Following Sensitivity Factors

Case	Driver Type									
	1	2	3	4	5	6	7	8	9	10
FEIS	1.20	1.10	1.00	0.90	0.80	0.75	0.70	0.65	0.60	0.55
SEIS	1.50	1.40	1.30	1.20	1.10	1.05	1.00	0.95	0.90	0.85

⁶ *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software*, Publication No. FHWA-HRT-04-040, July 2004, p. 64.

Calibrate Recurring Congestion and Queuing

After running a model scenario in CORSIM, the model animation of the network was viewed in TRAFVU (a dynamic animation tool within the TSIS suite that provides visual representation of the simulation) to compare to the recurring queues observed in the field. The CFSF multiplier and warning sign location parameters were used as calibration parameters. If the congestion and queuing were not satisfactorily replicated, the calibration parameter(s) were adjusted again and the iterative process was continued. Generally, the congestion and queuing from the model reasonably matched the queuing observed from the field as part of the global CFSF calibration step. Minor, local adjustments were made to warning signs if necessary in order to reduce warning messages during the CORSIM run. The local CFSF multipliers were left unchanged from the *FEIS* parameters. Overall, these factors needed very little adjustment. Figure 5 and Figure 6 show the modeled congestion and queuing at the I-64 WB/I-71 SB weaving section and the I-65 SB Kennedy Bridge bottleneck respectively.

Figure 5 – I-64 WB/I-71 SB Bottleneck and Queuing During PM Peak Hour

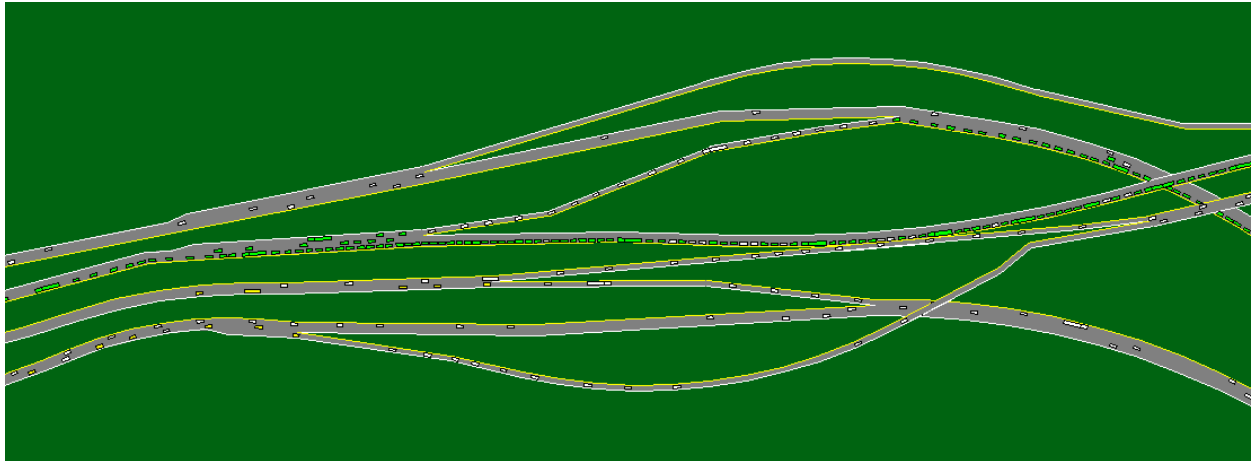


Figure 6 – I-65 SB Kennedy Bridge Bottleneck and Queuing During AM Peak Hour



Model Results

The CORSIM models were run using the new calibration parameters and volume and truck data provided by the *Traffic Forecast* report. The following scenarios were simulated in CORSIM:

- 2010 Existing
- 2030 No-Action
- 2030 FEIS Selected
- 2030 Modified Selected

Each of the measures of effectiveness was calculated for AM and PM peak hours in the scenarios above. Table 2 and Table 3 show the network measures of effectiveness (Average Speed, Vehicle Hours of Delay, and Percent Throughput) for the Kennedy Interchange. Figure 7 and Figure 8 depict the average link density plots for the Kennedy Interchange under the 2010 Existing/2030 No-Action and the 2030 FEIS Selected/2030 Modified Selected respectively.

TABLE 2 – Kennedy Interchange Model Network Output

Alternative	Average Speed (mph)		Vehicle Hours of Delay (hours)		Percent Throughput	
	AM	PM	AM	PM	AM	PM
2010 Existing	40	30	313	664	93%	91%
2030 No-Action	38	23	406	1,115	84%	80%
2030 FEIS Selected	44	49	303	172	99%	99%
2030 Modified Selected	50	46	131	237	99%	97%

Source: CORSIM model output averaged over 10 seed runs.

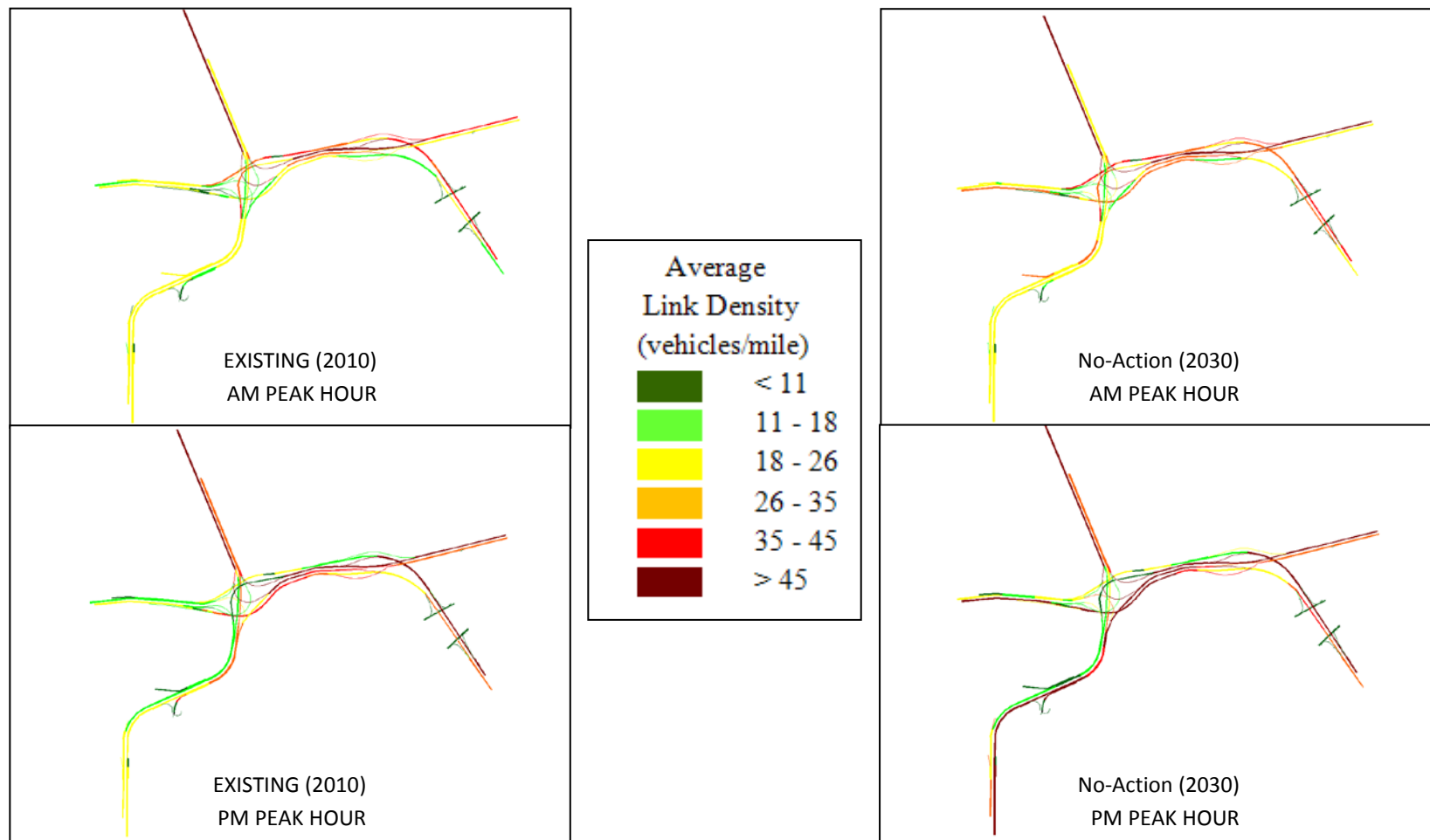


Figure 7 – Kennedy Interchange Average Link Density – Existing (2010) and No-Action Alternative

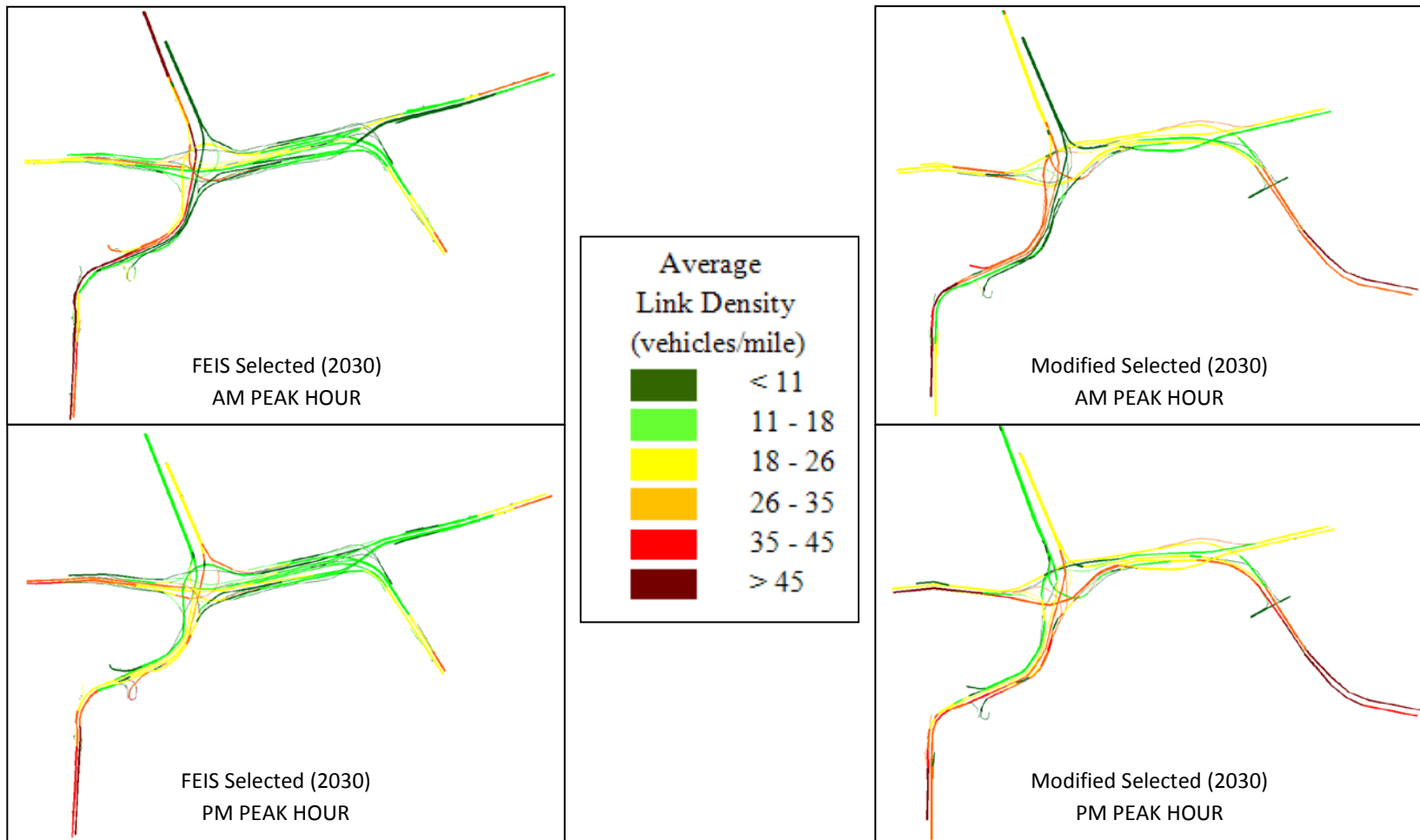


Figure 8 – Kennedy Interchange Average Link Density – 2030 FEIS Selected and Modified Selected Alternatives

Documents Referenced

Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software,
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