

I-85 Traffic Study: A State-of-the-Practice Modeling of Freeway Traffic Operation

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Abstract

Two levels of efforts advance the world: theory and application. Their highest levels of development are called "the state of the art" and "the state of the practice", respectively, with the latter typically lags behind the former. This is particularly true with traffic simulation where applications are more concerned with reliability, operability, adaptability, and availability. The state-of-the-art traffic simulation theories and models have been documented comprehensively while literatures on the state-of-the-practice applications are relatively sparse. This paper illustrates the perspective that industry typically takes on how to conduct traffic simulation by means of an example application: I-85 traffic study. Background information is given first, which is followed by general considerations such as simulation software selection and data requirements. A step-by-step procedure of model development is next, together with issues encountered during the development of the base model and strategies of solving these issues.

INTRODUCTION

To define a new vision for Hartsfield-Jackson Atlanta International Airport (H-JAIA) for the next 20 years and beyond, as well as to accommodate the ever-growing demand of the aviation industry, a new Master Plan was developed at Hartsfield-Jackson. Key projects of the Master Plan include a fifth runway, a consolidated rental car facility (CONRAC), international passenger terminal, and south terminal. These envisioned expansions will have significant impacts on traffic patterns of both on-airport roadways and nearby Interstate freeways (I-75, I-85, and I-285). Identifying the current performance of these roadway systems serves as the starting point for future activity forecast and facility programming. This paper focuses on the development of the base conditions model for this study.

I-85 traffic study is a subtask of a larger project, I-85 Roadway Concept Study [1], which will recommend future roadway improvements in the I-85 corridor from Central

Avenue to I-285. These recommendations are based on the growth of traffic through the planning year 2026. The results of this project will be incorporated into the planning for the new CONRAC bridges over I-85. The basic methodology of the I-85 project is to recommend a technically preferred concept by going through the following procedure:

- Forecast Future Travel Demand
- Develop Alternative Concepts
- Simulate and Analyze Traffic Operations
- Check for Major Environmental Issues
- Estimate Project Implementation Costs
- Recommend Technically Preferred Concept

SIMULATION SOFTWARE SELECTION

The goal of this study is to build a base model that reflects existing traffic conditions, with emphasis on how and when congestion occurs as traffic demand varies. This necessitates detailed investigation of fleet composition, origin-destination (O-D) flow patterns, lane configurations, weaving sections, nearby arterials and signalized intersections, etc. Microscopic modeling was selected as the preferred approach. More specifically, the traffic simulation packages CORSIM and VISSIM [2] were solely considered because of their capabilities to simulate traffic operation and address congestion issue in complex networks and their previous use in related H-JAIA studies. A detailed comparison of CORSIM and VISSIM has been documented by Bloomberg L. and Dale J. [3]. After weighing their relative merits, VISSIM was chosen due primarily to the following reasons. First, VISSIM gives users more control over low level details such as signalized and unsignalized intersections, priority rules, speed decisions, route decisions, MOE collections, etc. Second, a major concern of this study is how weaving sections affect traffic operation because of the closely spaced interchanges. This is disadvantage of using CORSIM because O-D flows in CORSIM are eventually decomposed and represented by a series of nodal turning movements which, unfortunately, lose track of origin information - something one has to know when modeling a weaving section. VISSIM, on the

other hand, allows globally specified routes (i.e., O-D paths) and the corresponding relative flows. Traffic will follow the specified O-D paths, thereby making simulation of weaving section possible. However, calculating and coding traffic volumes in this manner requires significant effort if calculated outside the VISSIM environment. Third, VISSIM provides more user friendly animation and more options on high quality presentations, such as 3D graphics and video clips. Last (also maybe the least), a license of VISSIM was available to the HNTB project team where the study was conducted.

DESCRIPTION OF STUDY SITE

The study site is illustrated in Figure 1. Interstate 85 is the target route of this study and the section under investigation runs between Central Avenue (north end) and I-285 (south end). Three interchanges lie completely within the study site: Virginia Avenue, Airport/Camp Creek Parkway, and Riverdale Road. There are four on-ramps and six off-ramps in the southbound direction, while the northbound direction has five on-ramps and four off-ramps.

To account for the impact of arterial congestion on freeway traffic operations, the metering effect of signals on on-ramp traffic and the off-ramp queues were included in the model. This was done by incorporating parallel collector/distributor (CD) roads, and major intersecting (grade separated) arterial highways into the model. The boundary of the model is illustrated in Figure 1 by the dotted line. Trip origins and destinations were identified at the boundary, resulting in a total of 32 origins and 31 destinations, as shown in Table 1.

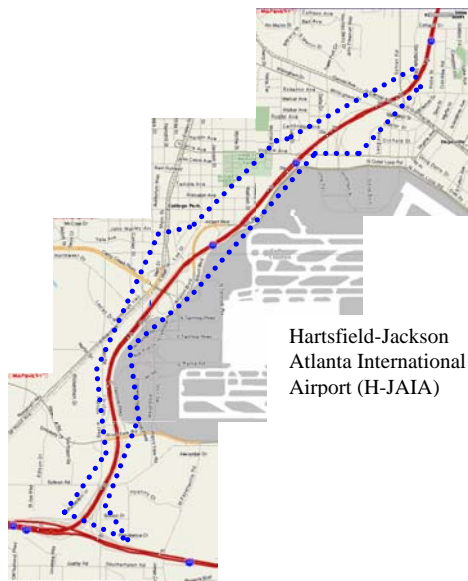


Figure 1. Map of Study Site

DATA NEEDS AND COLLECTION

Data collection is the fundamental part of traffic model development. Data needed in this study included a site map,

aerial photos, roadway geometry, traffic counts at key locations, free-flow speeds and travel times on each link.

Site Map

A site map was needed to identify model boundary as well as origins and destinations as discussed above. It was useful in developing the traffic count collection program.

Aerial Photos

The primary use of aerial photos was to clarify roadway geometry and guide coding of roadway network.

Roadway Geometry

This involved identifying nodes (i.e., decision points where two or more roadways intersect), links (a section of roadway between two adjacent nodes), link length, number of lanes, lane width, median type, etc. This information was obtained from field observation and aerial photos.

Traffic Counts

This was the most resource-consuming part of data collection. Key locations were identified for estimating O-D flows and turning movements. The traffic count collection program was then developed including detailed description of location, count type, data collection duration, and number of duplicated count stations. All the counts were recorded in 15-minute intervals and classified by vehicle types.

Intersection Data

Intersections are important to help understand the metering effect on entering traffic and serve as a penalty function in route choice. Intersection configuration (e.g., number of legs and lane distribution for each leg), signal coordination, and sequence of phases were the types of intersection data collected. This was done by field investigation as well as using aerial photos.

Free-Flow Speeds

Freeway links were the primary concern of this study, and their free-flow speeds were obtained by floating car study where test runs were made on the site such that the driver attempted to pass the same number of vehicles as he was passed by others. This worked as if the test car was floating in the traffic stream and experienced the average condition. The floating car test was run several times and the results were averaged to determine the free-flow speed for the section where the test runs were made. For all other roads, the free-flow speeds were assumed to be the posted speed limits wherever available. Otherwise, a predetermined scheme, described in section Network Coding, was used.

Actual Link Travel Times

Actual link travel times were used as to validate the model as a reality check and this data was collected simultaneously with floating car study.

MODEL DEVELOPMENT

Model development involved four steps: data analysis, network coding, model validation, and model revision.

Data Analysis

This step prepared the necessary input data to build the VISSIM model.

Determining Time Periods to Model

The goal of this study was stipulated that a "representative" day be used to build the base model. The "representative" day was determined as the day with the 30th highest hourly traffic volume in a year. Two scenarios were modeled: AM peak period and PM peak period. The duration of each scenario was three hours with one hour before and one hour after the peak hour. The following procedure was used to determine the AM and PM peak hours. First, all entrances (including upstream mainlines and on-ramps for both directions of I-85) were identified. Second, traffic volumes at these entrances were estimated from traffic counts collected at key stations. Third, traffic volumes for all entrances were summed and the sums were aggregated in 15-minute intervals, if necessary. Fourth, sliding a one-hour window through the sum, the peak hours for morning and afternoon were identified. Fifth, the AM peak period was set as the 3-hour period with one hour before and one hour after the AM peak hour, and the same for PM peak period.

Determining Vehicle Classes to Model

Combining the result of field data analysis regarding vehicle classification and the prior knowledge about the composition of traffic near the airport, all vehicles were classified into three groups: privately owned vehicles (POV), airport shuttles (STL), and heavy vehicles (HV).

Determining Intersection Delays

The objective of this analysis was to determine delay caused by signalized intersections. This information was used to estimate link travel time which, in turn, determined O-D paths. Intersection delay was obtained by running SYNCHRO [4], a traffic signal timing optimization software, for traffic signals at isolated and coordinated intersections. First, intersection turning movement volumes during peak periods were estimated. Next, a SYNCHRO model was built for each major arterial. The combination of arterials (i.e., Virginia Ave., Camp Creek Pkwy., and Riverdale Rd) and peak periods (AM and PM) resulted in six SYNCHRO models. For each SYNCHRO model, intersection turning movements were entered as input. Then SYNCHRO was run to calculate phase timings and delays. Phase timings were used as input to the VISSIM model as simulated intersection timing plans. Intersection delays consisted of approach delays which were weighted average delays of individual movements from the same approach.

Estimating Link Travel Times

The purpose of estimating link travel times was to provide the necessary information to determine route choice which, in turn, determined O-D paths. Link travel time was obtained by dividing a link's length by its free speed. As mentioned above, the free-flow speeds for freeway links were obtained from floating car study and the free speeds for other links were determined as the posted speed limits or from predetermined scheme.

O-D Estimation

O-D estimation was the critical part of data preparation because it prepared input traffic to the VISSIM model. Though many algorithms have been proposed to estimate O-F flows from link traffic counts, seldom have been advanced from the state-of-the-art to the state-of-the-practice. This study will follow a heuristic procedure, as widely adopted by the profession, to estimate O-D flows.

Constructing Weight Matrix

A weight matrix is an N by N table which consists of travel times from every node to every other node. If the travel time from node A to node B exists, the travel time is filled in cell (A, B). Otherwise, leave the cell blank. The travel times are called weights, to be consistent with terminology in Dijkstra's Algorithm later. Obviously, this weight matrix is actually a connectivity table where the linkage between two nodes is represented by its weight. No weight means no connection.

Determining O-D paths

An O-D path is a sequence of nodes, starting at an origin and ending at a destination, which defines the full route between the origin-destination (O-D) pair. Ideally, an O-D flow takes one O-D path. However, there might be multiple routes between a particular O-D pair and considering all the possibilities makes the problem too complicated to be practical. On the other hand, splitting an O-D flow among multiple O-D paths is the typical job of dynamic traffic assignment (DTA), a function that was not included in the version of VISSIM available to the study team. Therefore, it was determined that only one path was assigned to an O-D flow and the path was determined as the shortest one among the multiple options.

The shortest path problem was solved by Dijkstra's Algorithm and the O-D paths were then manually validated based on prior knowledge about the site. The paths were subject to modification, if necessary.

Constructing Turning Split Table

The purpose of this table is to provide a lookup table to determine the percent of entering flow (i.e., O-D split) that is assigned to an O-D path. For example, how much of the total flow entered at origin 1000 is bounded for destination 1951? The basic idea is to go through the path from the

origin to the destination and identify the split at each node (decision point). The overall O-D split of this O-D path is determined as the product of the turning splits identified along the path. Therefore, the lookup table to be constructed represents the decision to make at each node. The table consists of 4 columns: upstream node, this node, downstream node, and the associated turning split. For example, a row (1800, 1900, 1954, 0.88) means 88% of the traffic at node 1900 arrived from node 1800 will depart for node 1954.

Computing O-D Splits

This actually computes an N_O by N_D matrix where N_O is number origins and N_D is number of destinations. A cell in this matrix contains the relative flow, in percentage, from the indicated origin to the indicated destination. This relative flow is computed by sliding a 3-node (upstream node, this node, downstream node) window through the corresponding O-D path and multiplying all the turning splits identified along the way. It is interesting to note that each row of the matrix sums up to 1, meaning all the splits associated with this particular origin sums up to unity.

Balancing Origin and Destination Flows

Traffic balancing checks how entering flows match exiting flows and how realistic the O-D flow pattern is. This step was done for AM and PM scenarios separately. Each scenario consisted of 3 hours, so balancing was based on 3-hour flows. Flow balancing was performed at two levels. First, the network was decomposed into several sub-networks and flow balancing was performed for each sub-network. In this study, there were four sub-networks: the freeway sub-network and three arterial sub-networks. Next, a network-wide check was done by combining the results of sub-network analysis. After much comparison, computation, and adjustment, the balanced origin and destination flows were determined (see Table 1).

The table shows that the difference between the total of entering flow and the exiting flow is less than 1%, which is quite satisfactory.

Computing O-D Flows

With the entering flows and the matrix of O-D splits, O-D flows were obtained by multiplying each row of the matrix with the corresponding entering flow. This model had a total of $32 \times 31 = 992$ possible O-D paths, and it was too time-consuming to code all the paths into the VISSIM model. To improve efficiency yet still maintain sufficient accuracy, it was determined that the paths with less than 1 vehicle per hour would be eliminated. The eliminated flows were redistributed among other paths. This reduced the total O-D paths to 374. Converting percentage O-D splits to absolute O-D flows not only simplified coding relative flows later on but also provided the opportunity to do a reality check on the pattern of traffic distribution in the network.

Table 1. Balanced O-D flows (3-hour volume)

Origins	AM	PM	Destinations	AM	PM
N end of I-85 SB	10565	17334	Old National Hwy 1	239	776
Sylvan Rd. Ramp	364	691	CD Rd. to I-285 WB	58	854
Whipple Ave SB	330	300	Old National Hwy 2	815	4345
Delta St SB	646	1078	I-285 WB Exit 68	5743	13782
Dr. at Virginia Ave.	420	570	I-85 SB to 285 EB	317	728
Holliday Inn Dr. NB	82	129	Riverdale Rd. WB	1321	1338
Harrison Rd. SB	310	702	Riverdale Rd. EB	1508	3393
EB Virginia Ave.	741	950	Airport View SB	421	271
WB Virginia Ave.	1000	2247	Term. Pkwy NB	4069	2902
Toffie Ter. NB	979	900	E. Main St. SB	161	361
Virginia Ave. Ramp	164	535	Main St. SB	693	1521
Loop Rd. SB	756	2491	Camp Creek WB	2297	2837
Lee St. SB	115	743	Lee St. SB	183	484
Marta Access SB	152	884	Camp Creek EB	1333	1376
E Main St. SB	313	621	Airport Blvd SB	3188	2564
Main St. SB	969	2191	Main St. NB	1354	1155
Camp Creek Pkwy.	2439	2797	E. Main St. NB	1026	659
Camp Creek EB	343	231	Marta Access NB	869	208
Roosevelt Hwy. NB	1401	983	Lee St. NB	911	80
E. Main St. NB	582	281	Loop Rd. NB	2781	1024
Airport-Camp Creek	907	1399	Virginia Ave. WB	764	968
Airport Blvd. NB	160	462	Harrison Rd. NB	644	436
S Term. Pkwy. WB	535	1123	Holliday Inn Dr. SB	173	125
Airport Blvd. NB	2073	4668	Dr. at Virginia Ave.	480	660
Riverdale Rd. EB	997	1749	Toffie Ter. SB	712	1247
Airport Blvd. SB	971	1294	Delta St. NB	894	667
Airport View NB	89	86	Loop Rd. Ramp SB	1005	142
Riverdale Rd. WB	3139	2846	Virginia Ave. EB	1902	1280
S End of I-85 NB	9757	3655	Whipple Ave NB	1020	140
Riverdale Rd. Ramp	1197	705	Sylvan Rd Ramp NB	671	612
Old Nation Ramp	3592	1881	N End of I-85 NB	12612	12130
I-285 to I-85 Ramp	3695	2408			
Sum	49783	58934		50164	59065
Error	-381	-131			
%	0.77	0.22			

Note:

N- North, S-South, E-East, W-West, B-Bound, Rd.-Road, St.-Street, Ave.- Avenue, Dr.-Driveway, Pkwy.-Parkway, Blvd.-Boulevard, Ter.-Terrence, CD-Collector/Distributor, Hwy.-Highway, Term.-Terminal

Network Coding

This phase constructed the initial traffic model using VISSIM.

Defining Variables and Distributions

Before coding the network in VISSIM, some global variables and distributions were defined and these included vehicle types, vehicle class, vehicle compositions, speed distributions, acceleration profiles, etc. Vehicle type defines basic types of vehicles such as motorcycles, passenger cars, SUVs, etc. These vehicle types were grouped into the following three classes: privately owned vehicles (POV), airport shuttles (STL), and heavy vehicles (HV).

Vehicle distribution is location-specific and was determined by aggregating field observations based on the above three vehicle classes. The speed distribution scheme, based on uniform distribution, that was devised for this study is shown in Table 2. Since there were no available data to calibrate acceleration behaviors, acceleration profile for each vehicle type used default values.

Table 2. Speed distribution scheme

	Freeway	CD Rd	Ramp	Loop Ramp	Streets
POV	65-75	45-55	35-45	25-35	Speed limit
STL	60-70	40-50	30-40	20-30	Speed limit
HV	55-65	35-40	25-35	15-25	Speed limit

Coding Links and Connectors

One of the major differences between VISSIM and CORSIM is that the former uses link-connector architecture rather than link-node architecture. A link in VISSIM is the place where roadway geometry and traffic volume are specified. Coding roadway geometry for this study was guided by aerial photos as background image. Field observations were also important because they provided complementary information. Origin traffic volumes were specified at origins, i.e., entry links. The balanced origin flows in Table 1 are 3-hour totals, but time-varying traffic volumes were required to more accurately reflect future conditions. Global distributions were used to decompose the 3-hour flows into each individual hour. Global distributions were obtained by summing the 15-minute traffic counts over all origins, and the 15-minute sum were aggregated to 1-hour volumes. These hourly volumes were then used to generate the global distributions.

Connectors are typically used to connect two links with different geometric features (e.g., number of lanes) and are used extensively in coding intersections, speed zones, and priority rules.

Coding Intersections

Geometric features of an intersection were model by links and connectors. A controller was defined and associated with each signalized intersection. Traffic signal timing plans that were previously developed in SYNCHRO for these intersections were then entered into VISSIM. The current version of VISSIM (version 3.7) comes with a NEMA editor, an easy-to-use graphical user interface that simplified the coding of traffic signal timing plans. Signal heads from these controllers were placed in the appropriate lanes. Loop detectors are placed in proper lanes with corresponding phase selected.

Coding Speed Decisions and Zones

To ensure high quality simulation, vehicle speeds were specified as realistically as possible. Two options are available to assign vehicles speed: speed decision and speed zone. Speed decision is a point decision where predefined speed is assigned to the corresponding vehicle when it passes the point. A speed zone is a zone-based decision where vehicles temporarily accept the speed specified for that zone while traveling in that zone. In this study, speed decisions were placed at origins where vehicles enter the network and points where roadway type changes (e.g.,

freeway exits) to globally set vehicle speeds. Speed zones were placed mainly on right turn and left turn connectors where vehicles have to reduce their speeds to make the intended maneuvers.

Coding Route Decisions

Another major difference between VISSIM and CORSIM is that VISSIM supports route decisions which globally specify the path along which the specified fraction of vehicles is going to move through the network. One of the advantages of using route decisions is that origin-destination information can be preserved. This is necessary to accurately model weaving sections.

For this study, 374 O-D paths were modeled in VISSIM by route decisions for each of the AM and PM scenarios. Route decisions are also the locations where traffic volumes were specified. The internal processing of VISSIM summed all the traffic volume inputs at this origin and re-computed their percentage splits based on their contributions.

Coding Measures of Effectiveness

The final coding step was identifying locations of measures of effectiveness (MOE) data collection points, data collection time periods and types of data to be collected. Data collection points included freeway segments, freeway weave areas, ramps, arterial segments and intersections. The MOE data collection time periods were the calculated AM peak hour and the PM peak hour. The types of MOE data included density, delay, speed and maximum queue length.

Model Validation

In addition to the 2D animation that runs while computing, VISSIM also provides a realistic presentation in 3D animation. Though somewhat sluggish when graphics become complicated, the 3D animation does provide a realistic measure for modelers to check model performance and identify suspicious operation. A screenshot of the model is illustrated in Figure 4 where northbound traffic is approaching Camp Creek Parkway interchange.

In addition to visual inspection, the link travel times obtained during floating car study were compared against the simulated travel times. Discrepancies were analyzed and causes were traced. The results were then used to revise the model.

Model Revision

Based on the discrepancies observed and the causes of problem identified, the model was modified accordingly and the above process continued iteratively until the model was able to satisfactorily approximate existing conditions.

After the network coding was validated, each VISSIM model was run five times with different random seed numbers to introduce some variability into the model. The use of different seeds allowed volumes to vary by plus or

minus ten percent. The results of the five runs were averaged to produce composite results.



Figure 4. A screenshot of the 3D VISSIM animation

This concludes the development of base model which serves as the starting point of analyzing traffic operation under forecasted travel demand and testing the proposed improvement alternatives.

SUMMARY AND CONCLUSION

This paper documents the current state-of-the-practice approach of modeling freeway traffic operation based on an illustrative example - I-85 traffic study. The paper begins with background information related to this study. It then discusses some general considerations such as selection of simulation software and data needs and collection issues. This is followed by a step-by-step procedure, detailing how the base model was developed. Problems and difficulties encountered during model development are identified and strategies of overcoming these issues are presented.

Apparently, differences exist between state-of-the-art and state-of-the-practice traffic simulation. Applications are typically project-oriented and are aimed at solving real world problems. This stipulates that the methodology that the industry follows has to give more weight on the methodology's reliability, operability, adaptability, and availability. Therefore, given the many mathematically complicated methods, the industry is more likely to choose an approach that is simple, robust, and heuristic.

Applying traffic simulation theory to real world model is a challenging task. A real world traffic system may consist of so many working variables which may keep changing and escape observation. Frequently, simplifications and assumptions are necessary and trade-offs between the gain and the loss have to be made to render the modeling task feasible. For example, consider the time needed to manually enter nearly 1000 routes in VISSIM before simplification.

Finally, it is of great interest to clarify where the industry is regarding the state of the art and the state of the

practice, and develop effective strategies to advance both of them which, in turn, advances the simulation world.

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