LINCOLN TUNNEL CORRIDOR STUDY: TRAFFIC MICRO-SIMULATION

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Abstract: The paper discusses a case study of the Lincoln Tunnel, which is one of three Hudson River crossings between northern New Jersey and Manhattan operated by the Port Authority of New York and New Jersey. The study considered traffic management strategies such as highway speed electronic tolling lanes, toll plaza reconfiguration, occupancy priority lane(s), high occupancy toll lane(s), and the implementation of a second exclusive bus lane for the Lincoln Tunnel facility. The study was unique: it contained three distinct traffic areas each with different characteristics, urban arterial, urban streets, and toll plaza. Therefore, the VISSIM micro-simulation software provided the most effective tool to analyze and evaluate the traffic management schemes. The project area covers a 2.5-mile corridor extending from the western approach roads to the tunnel, including the New Jersey Turnpike, New Jersey State Routes 3 and 495, and was inclusive of all entry and exit points along the corridor.

The study required a particularly complex data collection program that involved approximately 200 surveyors for each of the data collection days. The data collected included vehicle classification, occupancy, and payment type by approach. To determine the origin-destination patterns, license plate data was collected and matched at all entry and exit points to the study network. Finally, standard manual turning movement counts and queue counts were performed throughout the corridor to develop balanced traffic volumes and provide calibration references. The paper explains the complexity of the data collection program and the planning and organization that was involved including data conversion techniques for use in the VISSIM micro-simulation model.

The VISSIM model was created within a 3D urban environment using 3D studio to create the landscape and buildings that enable easier understanding of the model for multiple stakeholders.

INTRODUCTION

The Port Authority of New York & New Jersey (PANYNJ) is a bi-state agency that operates six tunnel and bridge crossings that connect New York and New Jersey. One of the PANYNJ's major crossing facilities is the Lincoln Tunnel, which connects northern New Jersey and Midtown Manhattan, New York. The Lincoln Tunnel has a number of approach roadways that combined make up the Lincoln Tunnel corridor. The Lincoln Tunnel corridor, approximately 2.5 miles in length, consists of the New Jersey Turnpike, New Jersey State Route 3, US Route 1&9, and New Jersey State Route 495 that continues through the Lincoln Tunnel toll plaza, and into the tunnel (refer to Figure 1).

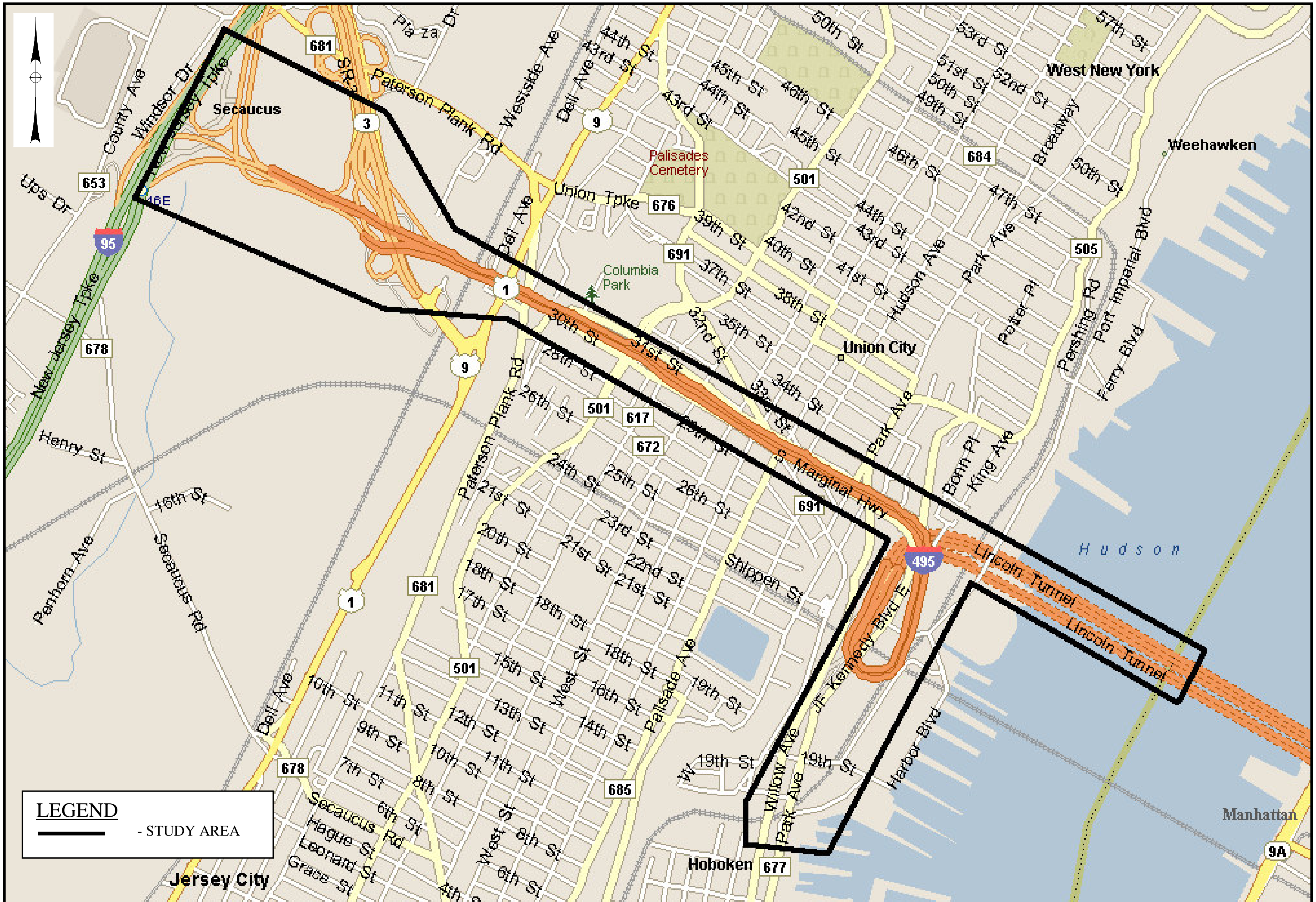


Figure 1: Geographical Limits of the Study Area

The Lincoln Tunnel facility consists of three tunnels (tubes) that are designated the center, north and south tubes and were completed in 1937, 1945, and 1957, respectively. Each tube has two travel lanes. The center tube operates inbound to Manhattan or outbound from Manhattan or two way depending on peak period demand. In 2003, the three tubes carried over 42,156,000 vehicles with a 50 percent directional split. In 1992 the Lincoln Tunnel facility experienced an average daily traffic volume of 129,511 vehicles. The Lincoln Tunnel facility is tolled in the eastbound direction using 13 toll lanes that utilize a combination of electronic toll collection (E-*ZPass*) and E-*ZPass*/manual toll collection strategies. During the morning peak period, the PANYNJ employs an Exclusive Bus Lane (XBL) strategy, which reserves the left-lane of the westbound New Jersey State Route 495 (in a contra-flow direction) for buses only. The XBL operates between the hours of 6:15 AM and 10:00 AM and carries approximately 419,000 buses and 15 Million passengers annually or 1,700 buses and 60,000 commuters daily.

The Lincoln Tunnel corridor simulation study was commissioned by the PANYNJ to develop an existing conditions corridor simulation to evaluate potential geometric and operational strategies for the Lincoln Tunnel corridor. The operational strategies include highway speed E-*ZPass* lanes, toll plaza operations and reconfiguration, occupancy priority lane(s), high occupancy toll (HOT) lane(s), and a second XBL lane. The subsequent paper describes the process of developing the existing conditions simulation which required the completion of the following tasks: data collection planning, collection and reduction, developing the existing conditions simulation model, and model calibration.

DATA COLLECTION PROGRAM

The Lincoln Tunnel corridor simulation was developed to evaluate both geometric and operational strategies aimed at maximizing the throughput and minimizing the delay to the traveling public. In the initial model planning process, it was determined that the peak period for the Lincoln Tunnel corridor was 5:30 AM to 10:00 AM and that data collection tasks would encompass the entire peak period. During the data collection planning phase, it was determined that the simulation model had to be capable of evaluating operational strategies based on vehicle classification, payment type and occupancy by individual corridor approach. Therefore, individual vehicle (classification, occupancy, and payment type) data was collected in conjunction with an origin-destination (O-D) survey.

The data collection program was conducted on two days, the first during the month of October 2002 and the second during the month of November of 2002 and consisted of the following tasks:

- Vehicle classification, occupancy and payment type counts (by individual vehicle)
- O-D survey through license plate collection (both video and audio)
- Manual classified turning movement counts

- Vehicle classification counts
- Automatic traffic recorders counts
- Vehicle queue surveys
- Toll transaction times and truck inspection times surveys
- Travel time surveys

Due to the data requirements, the data collection program was designed as a closed system where all of the entry and exit points were counted simultaneously on the same day. The data collection program required over 200 surveyors at one time for each day of data collection.

While most traffic counts require the data to be classified by vehicle type, as stated above, the data for this study had to be collected regarding a specific vehicle type. The following are the stratifications collected for eastbound traffic:

Vehicle Classification stratified into the following classifications:
- Passenger car (including passenger van)
- Commercial van (commercial lettering and/or no windows)
- Small truck (2 axles with up to 6 tires and 3 axles)
- Large trucks (4 axles or more)
- Buses

Vehicle Occupancy (excluding trucks and buses) stratified into the following classifications:
- One Occupant
- Two Occupants
- Three Occupants
- Four + Occupants

Payment Type stratified into the following classifications:
- E-ZPass payment
- Manual (Cash) payment

Simultaneously, a sample license plate survey was conducted for all eastbound traffic at each entry and exit point using audiocassette recorders and video cameras.

DATA REDUCTION

The data collection tasks resulted in a large quantity of data that ultimately was reduced into hourly balanced traffic volumes for incorporation and use into a micro-simulation model. As the westbound alternatives were not based on individual vehicle characteristics (occupancy and payment type), but rather vehicle classification, the westbound traffic data reduction task resulted in hourly balanced traffic volumes by vehicle classification only.

The eastbound traffic data reduction task resulted in hourly balanced traffic volumes by an individual vehicle's class, occupancy, payment type and origin. The eastbound vehicle classes are summarized in Figure 2. In addition, there are two additional vehicle classes within the model that are not represented in Figure 2. These include vehicles not bound for the Lincoln Tunnel (local traffic) and over-height vehicles bound for the Lincoln Tunnel but turned away from the Tunnel because of physical limitations.

The processes to derive the final hourly balanced traffic volumes by class are shown in Figure 3 and described in the following text.

Derivation of Original Balanced Volumes

The original balanced volumes (OBV) were derived and balanced for each hour based upon the automated traffic recorders, manual turning movement counts, and vehicle classification, occupancy, and payment type counts. All of the data were tabulated and placed on stick volume diagrams for easier comparison. The OBV represent total vehicles only and were utilized as the target numbers for the summation of all individual vehicle classes in the balancing process.

Derivation of The Final Balanced Volumes

The final balanced volumes (FBV) consist of a combination of eastbound traffic destined for the tunnel, local traffic not destined for the tunnel, and westbound traffic from the tunnel and local streets.

The eastbound final balanced volumes were derived using a combination of the OBV and the O-D license plate data. The eastbound license plate data represent a sample of entry and exit patterns within the Lincoln Tunnel corridor. The license plate data was inputted into the "MicroMatch" license plate matching software to develop matrices that represent a sample of the total vehicle origin-destination movements.

To determine the individual 22-vehicle classes' O-D patterns by hour, the "Furness" process was utilized to balance the movements. The "Furness" two-dimensional matrix balancing method was developed in 1970 and has been widely used to balance matrices. The process takes the given matrix (containing synthetic friction factors or "prior" matrix data) and "factors up (or down)" to fit or "balance" a given set of O-D totals. The total entry and exit volumes from the OBV were

Figure 2: Vehicle Class Definition

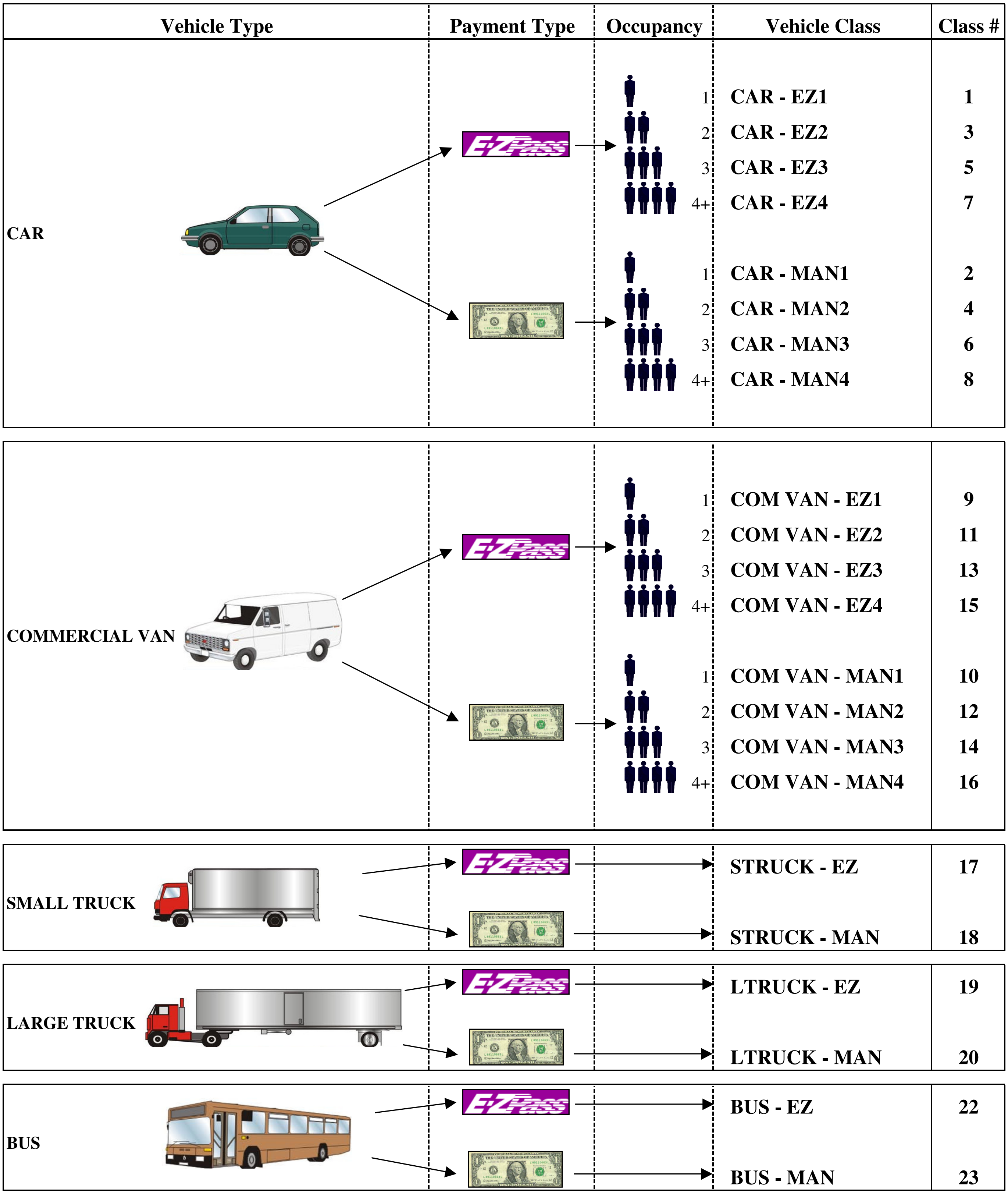
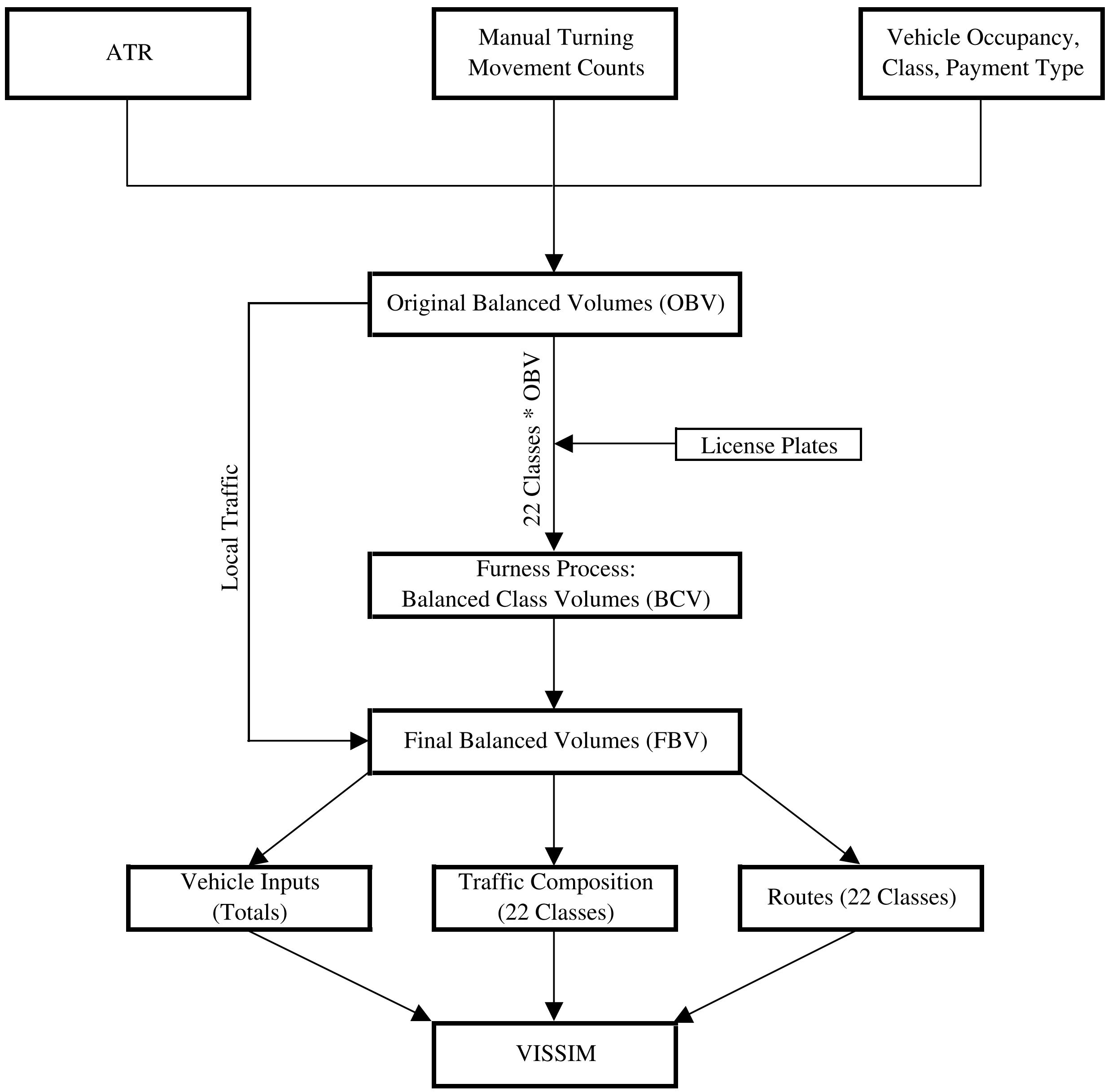


Figure 3: Process to Derive Final Balanced Volumes



disaggregated into the 22 classes by the vehicle classification, occupancy, and payment type proportions at the appropriate location to determine the entry and exit target volumes. The total license plate matches were utilized as the seed cell values for each individual class matrix. The Furness process then balanced these cell values to match the origin and destination target volumes to calibrate for each of the 22 classes by hour to either the entry or exit volumes.

The results of the eastbound traffic data reduction process were hourly balanced traffic volumes for each of the vehicle classes defined in Figure 2.

SIMULATUION MODEL DEVELOPMENT AND IMPLEMENTATION

Model Selection

The VISSIM micro-simulation model was used for the Lincoln Tunnel Corridor simulation study. VISSIM is a European microscopic traffic flow simulation model based on car following and lane change logic. The software can analyze vehicular traffic including transit, pedestrian and bicycle operations under constraints such as lane configuration, traffic composition, traffic signals, and transit stops. In addition, the software does not follow the conventional link/node modeling system, but utilizes a link/connector system that allows complex geometry to be modeled. The link/connector system also permits different traffic control (signal, yield or stop) to be utilized anywhere in the model. Therefore, it was determined that VISSIM would be the ideal tool for the evaluation of the combination of complex geometry, traffic controls and toll plaza operations that exist within the study area.

Model Development

In general, VISSIM models are comprised of five basic components: (1) roadway network (links and connectors in 3D with elevation); (2) traffic control systems (signal, stop and yield control); (3) vehicle compositions; (4) vehicle inputs; and (5) vehicle routes.

The roadway network was constructed first in a 2D environment, and then converted into a 3D environment by supplementing the links and connectors with elevation data. Next, the traffic control systems were coded to reflect the adaptive and fixed time traffic signal controllers, stop signs, and yield signs throughout the corridor. Next, the total volume inputs were coded at the entry links and then further stratified into the 22 vehicle classes by percentage through the use of the traffic composition function within VISSIM (Refer to Figure 2). The Lincoln Tunnel Corridor has 22 vehicle classes defined by vehicle classification, occupancy, and payment type plus two additional classes that represent local traffic not bound for the tunnel, and over-height trucks bound for the tunnel, but denied entry to the tunnel for a total of 24 vehicle classes. Finally, the 24 classes are assigned to specific routes that represent a vehicles path from its origin to its destination (over 21,000 possible routes).

Toll Plaza Portal Traffic – Dynamic Routing

In the morning peak period, there are 13 toll lanes that service the two eastbound portals. However, toll lanes number five through eight are positioned centrally within the toll plaza and have a fairly equal distance to each of the downstream tubes. Therefore, it was assumed that when one portal was congested all traffic within these lanes would divert to the other portal and vice versa. To achieve this, the Vehicle Actuated Programming (VAP) module within VISSIM was implemented to permit vehicles from toll lanes five through eight to be dynamically routed to a less congested portal based on pre-determined lane occupancy rates.

Simulation Model Outputs

As the VISSIM micro-simulation model is stochastic, the model results differ depending on the random seed assigned to each run. Therefore, a methodology was developed that required that the model be simulated 20 times using different random number seeds and then remove five runs closest to and the five runs farthest from replicating the input volumes. The statistics from the remaining ten simulations were the averaged to produce summary output results.

Model Calibration

Once the initial model was developed to incorporate all of the data, the project team initiated the model calibration phase. To calibrate the Lincoln Tunnel Corridor simulation model, the model inputs (traffic volumes) were compared to model outputs that included traffic volumes at select locations, turning movements, toll plaza volumes by lane, queues, travel times, and speeds. The calibration process was based on adjusting and enhancing the model to more accurately reflect field conditions that included roadway geometry, general traffic operations, traffic signal timing, yield/stop signs, driver behavior characteristics, vehicle characteristics, and toll processing times (manual/E-ZPass). The calibration process used the following priority system: toll plaza / portal volumes/operations, queuing at the toll plaza and approach ramps/roadways, intersection operations, and overall system operations.

Some overall peak period network operations Measures of Effectiveness (MOEs) included the following:

- Total Number of Vehicles
- Total Distance Traveled (miles)
- Total Travel Time (hours)
- Total Network Delay (hours)
- Average Travel Time (minutes)
- Average Delay Time (minutes)
- Average Network Speed (mph)

The network operations MOEs also included hourly statistics for the individual 22 vehicle classes (Refer to Figure 2) by route. Therefore, the simulation model is capable of evaluating alternatives by any of the individual vehicle classes (e.g., HOT lanes for vehicles using electronic toll tags with 2 occupants).

The model calibration process resulted in a 2002 Existing Conditions model that will serve as the base model to be utilized for evaluating geometrical and operational strategies.

LESSONS LEARNED

Data Collection/Reduction

- The objectives of the model should be defined prior to the planning of the data collection program.
- Obtaining counting authority from all jurisdictions affected by the traffic count program is important in the post 9/11 environment.
- Data collection planning and survey training is paramount to obtaining good data.
- Obtaining license plate data using video techniques is more efficient than voice recorders with respect to data reduction and additional field observations.
- Supplement the data collection program with video data for record purposes and to aid in the calibration process.
- While data reduction through excel spreadsheets has become a necessity due to data quantity and size, the spreadsheets must be thoroughly reviewed.

Model Development/Calibration

- As part of the initial model planning/development phase, design the model for the pending implementation of the alternates.
- Ensure that outside influences (beyond the scope of the model network) such as major traffic generators and traffic signals are represented within the model.
- The calibration process should be well defined prior to initiating calibration with respect to

Measures of Effectiveness and comparison statistics.
- Prior to initiating the calibration process, the project team should determine the calibration priorities with respect to locations as well as statistics.
- The calibration target with respect to statistics as well as point of diminishing returns should be defined prior to initiating the calibration.
- Maintain accurate and up-to-date calibration logs as well as electronic copies of all necessary files.

Compute Hardware and Software

- For large-scale models that require vast input data and produce vast output data, it is recommended that Excel 2003 be utilized.
- For large-scale models that incorporate 3D models, it is recommended that 128MB or higher graphics/video cards be utilized.

REFERENCES

Port Authority of New York and New Jersey (2004) – "Lincoln Tunnel Internet Site." New York, New York.
New York City Department of Transportation (2003) – "New York City Bridge Traffic Volumes 2002." New York, New York.

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