DEVELOPING MICROSCOPIC TOLL PLAZA MODEL USING PARAMICS

by

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ABSTRACT

Simulation modeling is the most cost-effective way of studying real life transportation problems, either existing or anticipated, without disturbing the balance of the transportation system. There is a vast suite of simulation models available in market, ready to choose from macroscopic, mesoscopic, or microscopic in nature, to study different transportation system elements like freeways, highways, signalized and un-signalized intersections. However, most of these network simulation models, like PARAMICS, VISSIM, CORSIM … etc, do not come readily available with built in toll plaza models.

On the other hand, many researchers have independently developed toll plaza models, which can only model an isolated toll plaza without the road network. These toll plaza models, which are based on queuing theory (and some are macroscopic in nature), do not take into account headway, gap acceptance, or inter-vehicle interaction to follow a lead car or to perform lane changing maneuvers. Vehicles just upstream of the toll plaza are assigned to one of the toll lanes, solely based on the payment method (manual, automatic coin machine, or electronic toll collection) and queue lengths at the toll lanes. For instance, if a vehicle is traveling in the leftmost lane and the rightmost toll lane has the shortest queue length, then the queuing model will assign this vehicle to the rightmost lane, and the vehicle will do unrealistic maneuvering to reach to the assigned toll lane instantly.

Microscopic network simulation models simulate the vehicular movements based on lane-changing and car-following rules. If such a model could be customized to serve the purpose of the toll plaza simulation, it will simulate the vehicular movements just upstream and downstream of the toll plaza more realistically. Being a network simulation model, it can also model the road

network integrated with the plaza, which can be used to study the entire toll road corridor, unlike the isolated toll plaza models.

In addition to being a microscopic network simulation model, PARAMICS has many simulation tools, which can be customized to develop a network model with enhanced toll plaza simulation capabilities. PARAMICS also provides the flexibility of using an aerial picture of the toll plaza and upstream/downstream sections of the road as overlay, to ensure that the toll plaza model operates under similar geometric conditions as the real plaza. Using an overlay, exact details of the transition area can be fed into the model. In real life, there is a smooth transition (in terms of the number of lanes and the width of the roadway) from the uniform free-flowing section of the roadway to the toll plaza. Detailed representation of the transition area, in terms of geometry and curb of the roadway along with the number of lanes, is essential for a realistic toll plaza simulation. This kind of detail is not available in a queuing model.

As the roadway approaches the toll plaza, it contains more lanes compared to its upstream segments. However, in a simulation model vehicles have a tendency to maintain the same old lanes, and the newly added lanes remain unoccupied by the vehicles. Next-lane Allocation feature in PARAMICS can be used to map upstream lanes onto downstream lanes, preventing this unrealistic behavior from occurring in the simulation model. It tells the vehicles in a particular upstream lane to choose from one or more of the downstream lanes as per the settings. Next-lane allocation can be used in such a manner that all the downstream lanes are utilized. PARAMICS has several other tools such as Restrictions Manager, Vehicle Type Manager, Lane-choices Rules, HOV Lanes, and Vehicle Actuated (VA) Signals which can be used in combination to build a toll plaza model.

A microscopic ‘Holland East Plaza - SR408’ network model has been developed using PARAMICS V5.1. This model contains the plaza and the downstream section of SR 408 Westbound till I-4 interchange in downtown Orlando. This model has been successfully calibrated and validated for the mainline toll plaza and ramp volumes for year 2004.

Several hypothetical incident scenarios were simulated to study an entire corridor from the toll plaza to Interstate 4. It was found that the volumes on I-4 off-ramp and SR 408 mainline were affected the most under incident conditions. Volumes for other ramps were not affected in the same proportions. An incident on mainline toll road affected the throughput of the plaza significantly, but the same is not true for an incident on an off-ramp. Travel times to I-4 off-ramps and SR 408 thru lanes were the most sensitive in each of the incident scenarios. In case of the elimination of tolls during the hurricane evacuation, the throughput of the plaza increased significantly. Travel times for the vehicles coming through the plaza and going to different destinations decreased significantly, while it increased for vehicles using on-ramps, because of their inability to merge in the mainline traffic due to the increased toll road volume. The developed model in this thesis has the potential of transportation network wide applications with multiple toll plazas.

Dedicated to

Muhammad (peace be upon him), the Messenger of God

the seal of the Prophethood, the mercy to the Worlds, the best of creation,

the greatest and the most compassionate among teachers

for showing the path to the Truth,

for guiding the humanity out of darkness of disbelief to the light of Faith.

> *But ye prefer the life of the world*
>
> *Although the Hereafter is better and more lasting*
>
> *Lo! This is in the former scrolls*
>
> *The Books of Abraham and Moses*
>
> [Qur'an: 87: 16-19]

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LIST OF ACRONYMS

AAWT	Average Annual Weekday Traffic
ACM	Automatic Coin Machine
API	Application Programming Interface
AVI	Automatic Vehicle Identification
ETC	Electronic Toll Collection
HCM	Highway Capacity Manual
HEP	Holland East Plaza
HOT	High Occupancy Toll
HOV	High Occupancy Vehicle
LOS	Level of Service
MB	Manual Booth
OOCEA	Orlando-Orange County Expressway Authority
ORT	Open Road Tolling
SAIC	Science Application and International Corporation
TPASS	Toll Plaza Animation/Simulation System
UCF	University of Central Florida
VMT	Vehicle Miles Traveled

1. INTRODUCTION

The Orlando Metropolitan Area, which consists of Orange, Osceola and Seminole Counties, is one of the fastest growing metropolitan areas in the country. In recent years, the economy of this area has largely been based on tourism due to the location in the area of such major tourist attractions as Walt Disney World, Universal Studios, and Sea World, as well as many other smaller attractions. In addition, the high tech industry has a substantial presence in the Orlando Metropolitan Area, and includes such major employers as Lockheed Martin and AT&T. Other major employers in the area include the University of Central Florida and the Orlando International Airport. It is estimated that around 1,643,114 persons lived in Orlando in 2004 *(1)*.

From 2000 to 2004, the population of the Orlando Metropolitan Area (Orange, Osceola and Seminole Counties) increased by 14.6 percent. During the same time period, the number of registered vehicles increased by 16.6 percent and the number of vehicle miles traveled (VMT) increased by 35.2 percent *(1)*.

Traffic volume in the region is anticipated to grow continuously and the ability of the road network to meet the demand will continue to decline. There is a growing need to augment the transportation infrastructure of the city, and this is evident with the start of several projects involving addition of express ETC lanes at toll plazas, widening of I-4 and other toll roads and extensions of several roads in the area.

I-4 and toll facilities SR408, SR417, SR528 and Florida’s Turnpike are major roadways serving Orlando area.

2. PROBLEM STATEMENT

The East-West Expressway (SR408) is a toll road facility connecting east Orlando to the downtown area. This road serves to heavy traffic commuting to and from downtown area during peak hours. It directly connects downtown Orlando to the University of Central Florida (UCF) to the east, and the Florida Turnpike to the west. UCF is one of the major traffic generators in the area with more than 45,000 students. Tolls are collected at Dean and Holland East mainline toll plazas on SR408 between downtown Orlando and UCF. Both plazas have several dedicated ETC lanes along with automatic coin machine and manual lanes. This road served 82, 870 vehicles daily in 2004, which is the highest figure for any road in the city, excluding I-4, for that year. During 2000 to 2004, the number of E-PASS transponders in use on the toll roads in the area increased by 80.4%. SR408 recorded more than 127 million toll transactions and collected $80.4 million in toll revenues during the year 2004-05 (*1*). This further adds to deteriorating traffic conditions on SR408, which is manifested clearly during peak hours. During peak hours, vehicles queuing in automatic coin machine and manual lanes back up several miles upstream of the Holland East Mainline toll plaza and block the path for E-PASS vehicles, causing them delay. Ideally, E-PASS vehicles are expected to experience zero delay across toll plazas, but instead they end up suffering congestion and delay because of road blockage. This decreases the service level at the plaza dramatically, and also results in decreased throughput. Moreover, E-PASS vehicles have to decelerate near plaza for safety reasons and this increases travel time and reduces capacity. Traffic on SR408 comes to standstill at several locations during peak hours. In the present setup, benefit of ETC lanes is not being fully exploited.

The Orlando-Orange County Expressway Authority (OOCEA) operates eleven mainline toll plazas in the Central Florida region. Holland East is the largest toll plaza with 14 lanes, including both directions. Expressway Authority started installing Electronic Toll Collection-Automatic Vehicle Identification System (E-PASS) on mainline toll plazas and tolled ramps in 1994. By December 2003, all the mainline toll plazas had dedicated ETC only lanes. OOCEA converted University Mainline toll plaza on SR417 to open road tolling with two express lanes in each direction by summer 2003, and plans to do the same for all mainline plazas on SR417 and SR408 by 2007. OOCEA found that E-PASS usage reached more than 65% at all mainline toll plazas during peak hours by December 2004. Since E-PASS patronage has risen to a significant level, it makes sense to provide them with better service. With the addition of three Express ETC lanes in each direction and widening of SR408, traffic conditions are expected to improve significantly. ETC vehicles will continue to move across toll plazas at posted highway speed without any obstruction.

In order to perform the cost-benefit analysis of investing in express lanes, benefits of improvements need to be compared against the cost of construction. Benefits can be assessed in the form of increased throughput, reduced delays and free flow traffic movements near the toll plazas and converted to monetary value. Collecting real life data to assess benefits takes more time and is costly. Moreover, results can only be obtained after the construction is complete. In order to make decision whether express lanes should be installed or not, benefits of express lanes should be estimated before hand. Simulation modeling is the cheapest and fastest tool to achieve such results. A microscopic toll plaza model can be used to study the Holland East Plaza under different traffic conditions. It can simulate various hypothetical scenarios like traffic incidents, addition of lanes, lane closures, and lifting of tolls during hurricane evacuation.

However, a microscopic toll plaza model is not available with any of the widely used and popular microscopic traffic simulation models. Although standard microscopic models do not have a readily available built-in toll plaza model, there are many traffic flow algorithms and other features/tools available in such microscopic models, which can be used to create a microscopic toll plaza model and embed it in the overall microscopic model. A toll plaza model has been developed in this thesis by using tools available in PARAMICS. Such a model will be based on traffic flow algorithms used and tested by researchers (*24, 25, 26, 27, 28, 29, 30, and 31*). This model can be replicated and used by practitioners and researchers.

3. RESEARCH OBJECTIVES

The objectives of this research are to:

1. Develop an isolated microscopic toll plaza model by customizing traffic maneuvering mechanisms and simulation tolls present in PARAMICS.
2. Model and calibrate an isolated Holland East Plaza (HEP) for year 1995 configuration, because of the availability of extensive lane wise volume data for that year.
3. Using ramp data available for year 1998 and key calibration parameters obtained in step 2, develop and calibrate the HEP and downstream segment of SR408. Ramp data is available for 1998 year only.
4. Validate this model for year 2004 data (the most recent data available) and plaza configuration, and test the performance of the model for hypothetical scenarios, like during an incident, lane closures, or lifting of tolls during hurricane evacuation.

4. LITERATURE REVIEW

This literature review covers two aspects of toll plaza modeling. At first, a discussion on some of the earlier toll plaza models is provided. Most of the toll plaza models are found to be isolated models, which can only model the plaza without the toll road network. After that, focus has been shifted towards finding a suitable microscopic network simulator, which will help develop a network model with enhanced toll plaza simulation capabilities.

4.1. Toll Plaza Models

Toll Plaza Animation/Simulation System (TPASS) is a discrete-event toll plaza model developed by Science Application and International Corporation (SAIC). It can determine queuing, wait times and toll revenues for different configurations of toll plazas *(2)*. It is one of first models to provide animation along with simulation.

TPSIM is a stochastic, object oriented, discrete-event microscopic simulation model that was coded using Microsoft Visual Basic 6.0 and interfaces with Windows98/NT/XP. TPSIM was used to simulate Holland East plaza (HEP) for different number and configuration of ETC lanes *(3, 15, 23, 34, and 39)*.

SHAKER and TPModel are hybrid queuing models which utilize both macroscopic and microscopic variables. SHAKER tries to maximize throughput of a toll plaza by assigning vehicles to different toll lanes depending upon existing queue lengths in each lane *(4, 5, and 6)*.

Toll Plaza Simulation (TPS) is a stochastic, microscopic simulator developed for capacity analysis under the sponsorship of the Institute of Transportation, Ministry of Transportation and Communications in Taiwan *(7)*.

TOLLSIM is a toll plaza model developed by Wilbur Smith Associates. It estimates the traffic operation conditions at a toll plaza for every 15 minute period in terms of queues, average delay time and vehicles processed by vehicle class and payment type *(8)*.

FDOT's State Traffic Engineering Office developed a dynamic toll plaza queuing analysis program (D-QUEUE TOLLSIM) to evaluate traffic delays at toll facilities. This program simulates traffic volumes, service rates, weaving maneuvers, facility layouts, and types of operation. D-QUEUE TOLLSIM calculates delay, queue size, queue length, and level of service *(9)*.

ANATOLL is another toll plaza simulation model which predicts queues at toll booths. ANATOLL is developed with the help of Centre d'Etudes Techniques de l'Equipement, France. It works by using text files, and has no graphic interface and cannot present the simulation dynamically *(10)*.

KLD Associates, developer of WATSIM, have developed generic toll plaza simulation model (GENTOPS), but it is not available to end users along with standard WATSIM model (*40*).

4.2. Toll Plaza Studies

Foote suggested that non-stop toll collection could increase the capacity of toll plazas from 600 to 1800 veh per hour per lane *(11)*. Automatic vehicle identification (AVI) lane will decrease construction, maintenance and operating costs of tollbooths and motorists will see benefit in time, fuel and convenience. Vehicles will be able to move at posted highway speed, and the capacity of each AVI lane would approach that of a regular traffic lane.

Pietrzyk enlisted capacities of different types of toll as *(12)*:

- Manned – 350 veh/hr
- Automatic – 500 veh/hr
- Mixed AVI – 700 veh/hr
- Dedicated AVI – 1200 veh/hr
- Express AVI – 1800 veh/hr

Although, in real life higher values have been observed at the Holland East Plaza (*see Table 2*).

Al-Deek et al. performed before and after analysis of Holland East plaza on SR408 to assess benefits of ETC lanes *(13 and 14)*. The authors concluded the following benefits of adding dedicated AVI lanes:

- Measured throughput of dedicated ETC lanes increased by 160%.
- Service time decreased by an average of five seconds per vehicle.
- Average queuing delay decreased by more than one minute per vehicle.
- Maximum queuing delay decreased by 2.5-3 minutes per vehicle.
- Total queuing delay decreased by 8.5-9.5 vehicle-hours per peak hour per ETC lane.

Al-Deek et al. concluded that for all plaza configurations simulated with manual lanes operating over capacity, the total plaza queuing delay can be reduced in half, the average queuing delay per vehicle can be reduced by more than 90 seconds, and the plaza throughput (vehicle per hour) can increase by more than 20%, if only as little as 10% of the users can switch from manual to ETC lanes *(15)*.

Extensive data was collected for Holland East Plaza and several customer groups and their processing rates at toll plaza were identified *(16)*. This is summarized below:

1. (M) Manual service, can process 8.3±0.8 veh/min.
2. (ACM) Automatic Coin-Machine Service lanes (no semi-trucks permitted and no gate present), can process 10.3±0.5 veh/min.
3. (T) Manual service consisting of drivers of semi-Trucks, can process 2.3±1.3 veh/min.
4. (E15) ETC Service using AVI technology to automatically record the toll amount and drivers are limited to speed limits of 15 mph, can process 15.0±2.0 veh/min.
5. (E35) ETC with drivers limited to speed limits of 35 mph, can process 23.0±2.0 veh/min.
6. (E55) ETC with drivers limited to speed limits of 55 mph, can process 32.0±2.0 veh/min.

Klodzinski and Al-Deek used TPSIM to study Dean Mainline toll plaza and in the process also assessed the transferability of the simulation model *(17 and 34)*. The model was validated using data from three separate days. Several traffic and driver characteristics parameters of the simulation model, such as mean reaction time and mean headway, were adjusted to match the output of the simulation with real life observed traffic data.

The Highway Capacity Manual (HCM) 2000 talks about level of service (LOS) criteria for free flow sections of highways as well as signalized intersections. The HCM does not provide similar criteria for LOS of toll plazas, which cannot be classified as either of the above mentioned two facilities. Klodzinski and Al-Deek came up with a new methodology for defining level of service at toll plazas based on 85th percentile delay experienced by vehicles. *(18)*.

Level of Service	85th percentile delay (sec/veh)
A	≤ 14
B	14 – 28
C	28 – 29
D	49 – 77
E	77 – 112
F	≥ 112

Several structural and geometrical design improvements were done at University Mainline toll plaza on SR417 during 2002-2003. It included addition of toll lanes and conversion of ETC lanes to express lanes. Express lanes are like normal open road sections, and vehicles do not have to slow down near toll plaza unlike ETC lanes. When a vehicle equipped with E-PASS transponder passes through toll plaza, the tag reader reads the vehicle information and deducts appropriate amount of toll from the corresponding E-PASS account. Usually, toll plazas have dedicated ETC lanes which only an E-PASS vehicle can use. In addition, E-PASS vehicles can use any toll lane at a toll plaza, because all the lanes are equipped with E-PASS tag reader facility.

Klodzinski et al. collected real life data to perform before and after analysis of University Mainline toll plaza to study the benefits due to introduction of express lanes and other improvements *(19)*. It was found that throughput for ETC lanes in PM peak direction increased by 18%. In AM peak direction, throughput for automatic coin machine and manual lanes decreased by 20.4% and 4.5% respectively. This happened because E-PASS vehicles preferred express lanes, and there was a decrease in mixed-use of automatic coin machine and manual lanes by E-PASS vehicles. With the introduction of express lanes, average delays decreased by 75.5% in automatic coin machine lanes and 60.2% in manual lanes. It was also found that speeds in the express ETC lanes (after study) were significantly higher than speed in dedicated ETC lane (before study).

Due to conversion of dedicated ETC lanes with express lanes, capacity increased form 2016 to 2314 vph and speed increased from 31 mph to 65 mph (which is also posted speed).

4.3. Traffic Simulation Models

Traditionally, traffic simulation models were developed independently for different facilities (e.g. freeways, urban streets, arterials, etc.). A wide variety of simulation models exist for various applications. Simulation models may be classified according to the level of detail with which they represent the system to be studied: Microscopic (high fidelity), Mesoscopic (mixed fidelity), and Macroscopic (low fidelity).

A microscopic model describes both the system entities and their interactions at a high level of detail. A mesoscopic model generally represents most entities at a high level of detail but describes their activities and interactions at a much lower level of detail than would a microscopic model. A macroscopic model describes entities and their activities and interactions at a low level of detail.

Another classification addresses the processes represented by the model: (i) Deterministic; and (ii) Stochastic. Deterministic models have no random variables; all entity interactions are defined by exact relationships (mathematical, statistical, or logical). Stochastic models have processes, which include probability functions.

Traffic simulation models have taken many forms depending on their anticipated uses. While Federal Highway Administration (FHWA) funded the development of facility specific simulation software (NETSIM, ROADSIM, FRESIM, etc), these software have limited applications when it comes to generalized networks with Intelligent Transportation Systems (ITS) applications in general, and toll plaza modeling in particular. A new generation of traffic simulation models has been developed for ITS applications. Examples are AUTOS, METROPOLIS, *PARAMICS*, VISSIM, DYNASMART, DYNAMIT, INTEGRATION, THOREAU, and AIMSUN2.

4.4. Applications of Simulation Models

Applications like user's route choice dynamics in the case of lane closures was studied in a simulation environment by Mahmassani and Jayakrishnan (*20*). The results showed that providing real time in-vehicle information to users could lead the network to reach a steady state at a faster rate than under the no-information case.

Modeling traffic flows in networks involving advanced traffic control and route guidance systems by Yang and Koutsopoulos using MITSIM (MIcroscopic Traffic SIMulator) on the A10 beltway in Amsterdam, the Netherlands network with non-recurrent congestion caused by a 20-minute incident, the case study demonstrated that on average 2-4% of travel time savings is achieved when real-time traffic information is provided to 30% of drivers (*21*). For drivers having viable alternative routes, real time route guidance is very effective, creating travel time savings of up to 18%.

Korve Engineers employed the WATSIM simulation model to evaluate alternative scenarios for increasing capacity and improving traffic flow on a freeway connection, SR242 in California and ensuring a balanced design relative to freeway SR4 on the north and I-680 to the south (*22*). Design alternatives considered for three future periods (years 2000, 2010, 2020) included geometric changes, widening, HOV lanes and ramp metering. This study illustrated the use of simulation as an element of the design process with the capability of analyzing candidate designs of large-scale highway systems in a manner that lied beyond the capabilities of a straight-forward HCM analysis.

Gardes et al. calibrated PARAMICS and used it to evaluate Interstate 680 freeway improvement strategies in the San Francisco Bay Area (*24*). A major section of the study was devoted to describing a procedure that was developed to calibrate two critical driver behavior parameters: the mean target headway and the mean reaction time. A two-dimension process to calibrate these two parameters against target speeds and volumes was successfully applied. Shaw and Nam concluded that in an integrated project selection process, output data from micro simulation could serve as input for engineering economic analysis, which in turn provides an objective basis for selection of projects implementing the freeway reconstruction (*25*). The context was the Southeast Wisconsin Freeway System Operational Assessment (FSOA), a detailed examination of the safety and operational performance of the Metropolitan Milwaukee freeway system. As the project and software technology evolved, micro simulation emerged as the basis of an ongoing process for analyzing system wide freeway operations. The need to integrate FSOA with other studies and the District's project selection process became clear. Only the most advanced micro simulation software has the power necessary to accomplish a task of this complexity. PARAMICS and VISSIM packages were evaluated. Both offer significant advantages compared to CORSIM, and PARAMICS was recommended as the basis for further simulation work.

Liu et al. addressed the use of Application Programming Interface (API) to change the underlying simulation model used in PARAMICS (*26*). The authors explained how to override the simulator default models such as car following, lane changing, route choices, etc. The paper explained the procedure for coding the signalized intersections in PARAMICS. Complete details of coding Actuated signals, Signal Coordination and Ramp control using API were illustrated. The authors concluded that API allows researchers to override the simulator's default models such as car following, route choice models, lane changing, and interface complementary modules (any ITS application) such as signal optimization, adaptive ramp metering, incident detection, etc.).

Lee et al. described the importance of calibrating the PARAMICS model for local traffic conditions. The authors simulated a one-mile segment of Interstate 5 in Orange County, California (*27*). Real-time loop detector data and two field data sets were collected and used in both calibration and validation processes. The authors stated that the two key parameters used in the study were mean target headway and mean reaction time. The authors found that these calibrated parameter values indicated differences between California drivers' behavior and the default values in PARAMICS.

Stewart developed a model using PARAMICS to study the effects of ramp metering on Motorway 8 (M8) and its neighboring surface streets in Scotland (28). A model was calibrated and validated with respect to the base model by comparing observed link count data, journey time data, automatic traffic count data and video count data over the sections of M8. The study revealed an acceptable correlation of the simulation results with observed statistics for ramp signal frequencies, cycle times and platoon sizes. The author was able to test different scenarios to illustrate the potential of ramp metering; based on his observations he concluded that PARAMICS can be used to replicate the traffic conditions and the driver behavior reasonably.

Abdulhai et al. used PARAMICS to study the impacts of the High Occupancy Vehicle (HOV) lane implementation for Highway 401 in Toronto, Canada (*29*). A model was developed to evaluate a set of various improvement options of Highway 401 by considering three different scenarios: converting one of the existing lanes into HOV lanes, addition of an HOV lane, and addition of a general purpose lane. All these scenarios were conducted under “All-or-nothing” traffic assignment option available in PARAMICS. The traffic parameters of flow, speed and delay for different sections of Highway 401 were used to compare the results from different scenarios. Application of PARAMICS to evaluate the various HOV lane improvement options for Highway 401 in Toronto was successful in meeting the primary research objectives, primarily to develop an HOV lane treatment plan. Also, visual inspection during micro-simulation runs identified potential problem areas with regards to ingress/egress locations.

Chu et al. used PARAMICS to evaluate the effectiveness of the ramp metering technology on a section of I-405 using three ramp-metering algorithms ALINEA, BOTTLENECK and ZONE (*30*). This study revealed the use of calibration in simulation modeling. Some of the points that came into light during the study were:

Accurate geometry of network and smooth coding of links, are important since drivers’ behavior in PARAMICS is very sensitive to the network geometry. The signposting setting for links, which is used for defining locations of weaving area are crucial. Driver behavior factors in car-following and lane-changing models; including the mean target headway and mean driver's reaction time are important.

Lee et al. applied PARAMICS to explore the potential employment of real-time information for the efficient management of city logistics operations (*31*). Simulation results suggested that the diversion strategies examined usually resulted in reduced travel times, which improved the efficiency of commercial vehicle operations (CVO).

Boxill and Yu conducted a two-step evaluation study of simulation models: initial screening and in-depth evaluation (*32*). Criteria for initial screening were developed in order to eliminate models with no potential for use with ITS applications. In-depth evaluation attempts to identify more specific features and limitations of models selected from the initial screening process. Nine models were assessed in terms of ITS features modeled. These models were AIMSUN 2, CONTRAM, CORFLO, CORSIM, FLEXYT II, HUTSIM, INTEGRATION, PARAMICS and VISSIM. It is found that PARAMICS appears to be the leading model for real time simulation of hundreds of vehicles. It also appears to be the comprehensive visualization system and provides intelligent route guidance capabilities.

For the work presented in this thesis, PARAMICS was chosen as the microscopic network simulator to develop a network model with enhanced toll plaza simulation capabilities.

5. TOLL PLAZA MODEL

Since a built-in toll plaza model is not available for use with any of the widely used microsimulation models (i.e., PARAMICS, VISSIM, CORSIM … etc), almost every researcher independently develops a model using some programming language (VB, Java etc.) and customizes it for his or her study. Many researchers have developed isolated toll plaza models for their studies which do not contain toll road network (2, *3, 5, 7, 8, 9, and 10*). Some of these models work independently of the actual geometry on ground, and vehicular movements in the transition area are not simulated microscopically. A vehicle is directly assigned to one of the toll lanes from the uniform toll road segment based upon payment type (manual, automatic coin machine, or electronic toll) and queue lengths at toll booths (*see Figure 1*).

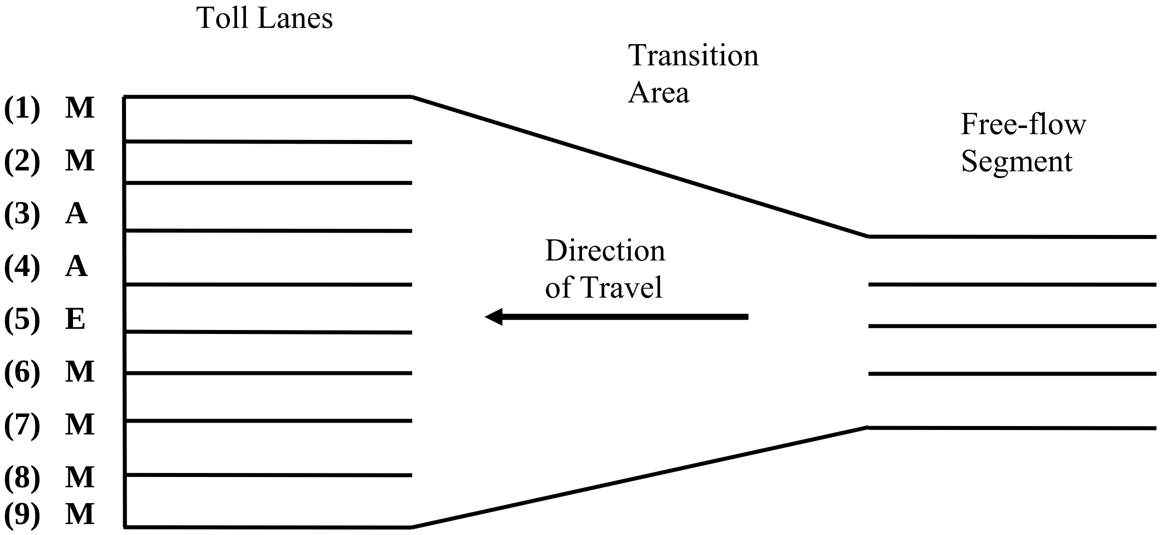


Figure 1: Holland East Toll Plaza Configuration in 1995 – Queuing Model

(M – Manual payment, A – Automatic coin machine, E – Electronic toll collection)

Electronic toll collection (ETC) vehicles can use any lane.

If a vehicle is traveling in the leftmost lane and the rightmost toll lane has the shortest queue length, then the queuing model will assign this vehicle to the rightmost lane, and the vehicle will do unrealistic maneuvering to reach to the assigned toll lane instantly. In a queuing model, vehicles do not take into account headway, gap acceptance, or inter-vehicle interaction to follow a lead car or to perform lane changing maneuvers. For queuing models, ensuring equal queue lengths at all the toll booths and processing the queued vehicles at a defined rate are the primary mechanisms which account for the toll plaza simulation. They do not simulate vehicular movements just upstream and downstream of the toll plaza microscopically.

PARAMICS employs car-following and lane-changing models to simulate the movement of individual driver vehicle units (DVU). A DVU is a combined representation of the behavior of driver and the physical characteristics of a vehicle. Each DVU contains a set of static and dynamic parameters. Dynamic parameters are updated during each time-step of the simulation (*33*).

Static parameters of a DVU:

- Type, age of vehicle
- Origin – Destination
- Aggressiveness, awareness

The "type" parameter denotes one of the pre-defined types of the vehicles, which is further associated with following set of physical parameters:

- Color (for display)
- Weight

- Length, width, height
- Maximum speed, maximum acceleration, maximum deceleration
- Mode, demand information, familiarity, perturbation

Dynamic parameters of a DVU:

- Position (lane and distance from stop line)
- Speed
- Acceleration
- Next turn intention, target lane range, target lane on next link
- Exit index (on roundabout)
- Time stopped on journey, time stopped on link
- Travel time on journey, travel time on link

Using the car-following model, a DVU changes its speed according to its perception of the speed and acceleration of the DVU in front. It also adjusts its speed after seeing brake lights of the DVU immediately ahead. Lane changing in PARAMICS is done when a suitable gap in target lane is available. Acceptable gap is based on the target headway, which is again linked with the car-following model. Target headway for a DVU varies around the specified mean target headway and depends upon other parameters. For example, a high aggression value will cause a DVU to accept a smaller headway and hence smaller gap. The very nature of the car-following and lane-changing models in PARAMICS V5.1 and their application in simulating vehicular movements around toll plaza ensures that this model works in accordance with traffic flow theory.

An aerial picture of the Holland East plaza was used as an overlay to create the toll plaza model (*see Figure 2*). Using the aerial picture ensures that the toll plaza operates under similar geometric conditions as the real plaza. Geometry of a toll plaza can have profound effect on the vehicular movements near the plaza. At a toll plaza with inadequate length of transition area, vehicles may face difficulty in changing lanes to reach the correct toll payment lane. Using an overlay, exact details of the transition area can be fed into the model. In real life, there is a smooth transition (in terms of number of lanes and width of the roadway) from the uniform free-flowing section of the roadway and to the toll plaza. In the present case, free-flowing section of the roadway approaching Holland East plaza has four lanes. After going certain distance towards the plaza, width of the roadway increases and it accommodates five lanes of vehicles. As the roadway approaches the plaza, its width increases to accommodate six lanes of vehicles, until it reaches the plaza where it has nine designated lanes. This kind of detail is not available in a queuing model (*see Figure 1*). Behavior of a vehicle in traffic stream is directly affected by the presence of other vehicles in its front and sides. A detailed representation of the geometry and curb of the roadway is vital for a realistic simulation of the traffic.

Figure 2: Holland East Toll Plaza – PARAMICS Model

(Source: www.terraserver-usa.com)

Note: Numbers shown in the figure represent node numbers.

After the geometry is completed, the primary tasks are to:

a) Instill a tendency in the vehicles to smoothly move towards one of the appropriate payment lanes as they approach the toll plaza.

b) Process only valid vehicle types through toll lanes. For example, automatic coin machine (ACM) lane will process only ACM vehicles and ETC vehicles, but it will bar manual payment vehicles.

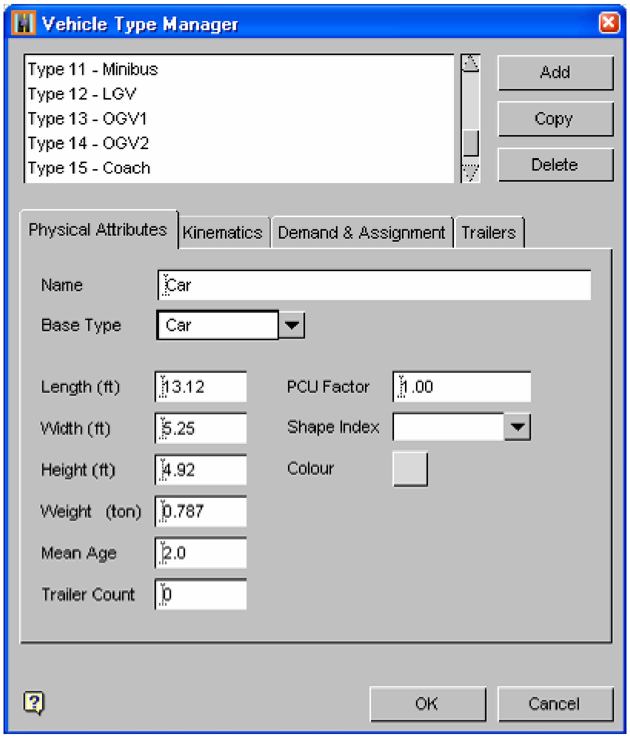
c) Assign appropriate stop time (time duration for which vehicles remain stationary at booth to pay toll) for manual payment and ACM vehicles to pay toll.

The development of a microscopic toll plaza model based on the capabilities of PARAMICS is discussed in this thesis. Important tools of PARAMICS required to complete these tasks are discussed next.

5.1. Tools of PARAMICS Required for Toll Plaza Model

5.1.1. Vehicle Type Manager

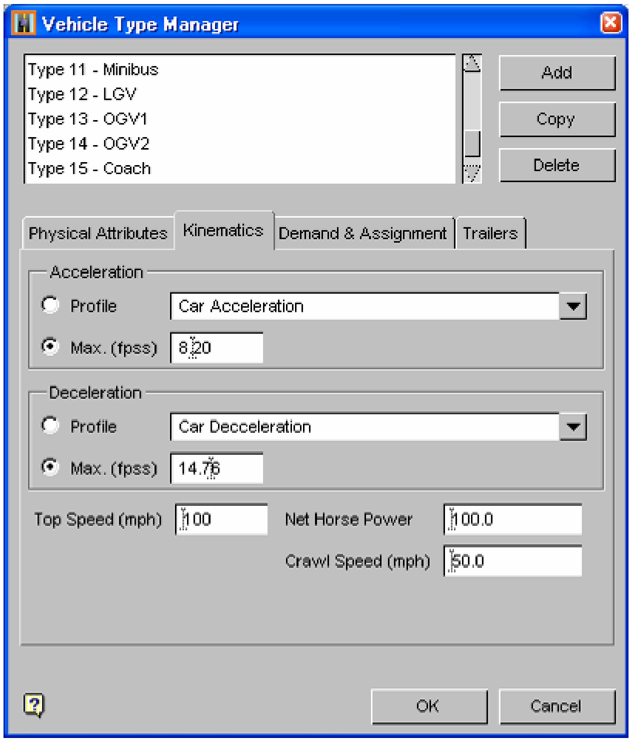
Vehicle type manager allows users to define vehicle type as per the requirement of the modeling. Vehicles types may be either one of the default types, or user defined customized vehicle types. There are seven base vehicle types available *(see Figure 3)*: Car, LGV (light goods vehicle), OGV1 (ordinary goods vehicle class 1), OGV2 (ordinary goods vehicle class 2), Coach, Bus and Minibus *(33)*. Vehicle Type Manager defines physical attributes and assigns acceleration and deceleration profiles for each type. User can create a vehicle type by using one of the base vehicle types, or customize a new vehicle type. Top speed and maximum acceleration/deceleration values for each vehicle can also be fixed (*see Figure 4)*. Vehicle type manager also defines the proportion of a particular vehicle type in the traffic stream.



Type 11 - Minibus
Type 12 - LGV
Type 13 - OGV1
Type 14 - OGV2
Type 15 - Coach

Name: Car
Base Type: Car
Length (ft): 13.12
Width (ft): 5.25
Height (ft): 4.92
Weight (ton): 0.787
Mean Age: 2.0
Trailer Count: 0
PCU Factor: 1.00
Shape Index:

Figure 3: Vehicle Type Manager - Physical Attributes



Type 11 - Minibus
Type 12 - LGV
Type 13 - OGV1
Type 14 - OGV2
Type 15 - Coach

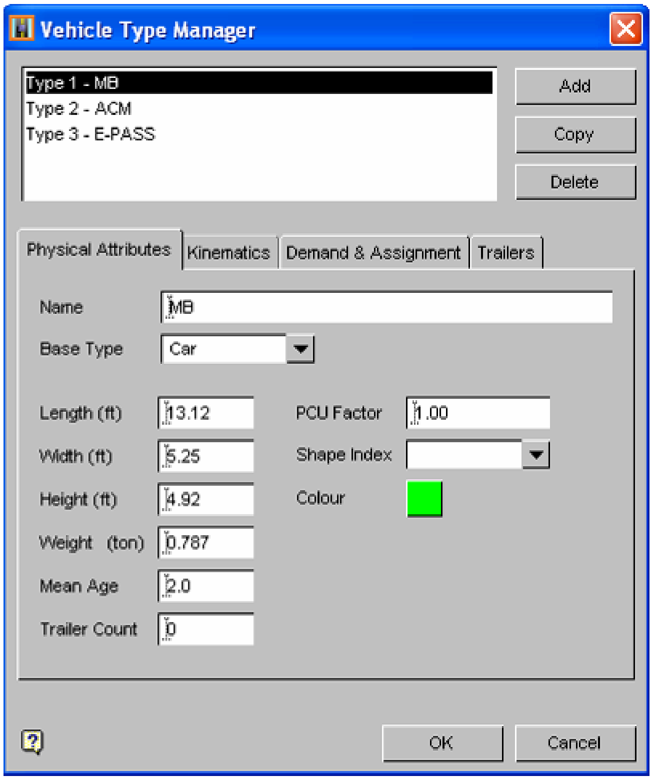
Acceleration
○ Profile: Car Acceleration
● Max. (fpss): 8.20

Deceleration
○ Profile: Car Decceleration
● Max. (fpss): 14.76

Top Speed (mph): 100
Net Horse Power: 100.0
Crawl Speed (mph): 50.0

Figure 4: Vehicle Type Manger - Kinematics

From the operational point of view of a toll plaza, vehicles have been classified into three categories *(see Figure 5)* depending upon their mode of toll payment: vehicles using manual payment lane, automatic coin machine (ACM) lane, and electronic toll collection (ETC) lane.



Type 1 - MB
Type 2 - ACM
Type 3 - E-PASS

Name: MB
Base Type: Car
Length (ft): 13.12
Width (ft): 5.25
Height (ft): 4.92
Weight (ton): 0.787
Mean Age: 2.0
Trailer Count: 0
PCU Factor: 1.00
Shape Index:
Colour: 🟩

Figure 5: Toll Plaza Vehicles - MB, ACM and E-PASS

MB: This vehicle type pays toll by using manual booth (MB).

ACM: This vehicle type pays toll by using automatic coin machine lanes.

E-PASS: This vehicle type pays toll by using electronic transponder, and can use any lane at a toll plaza.

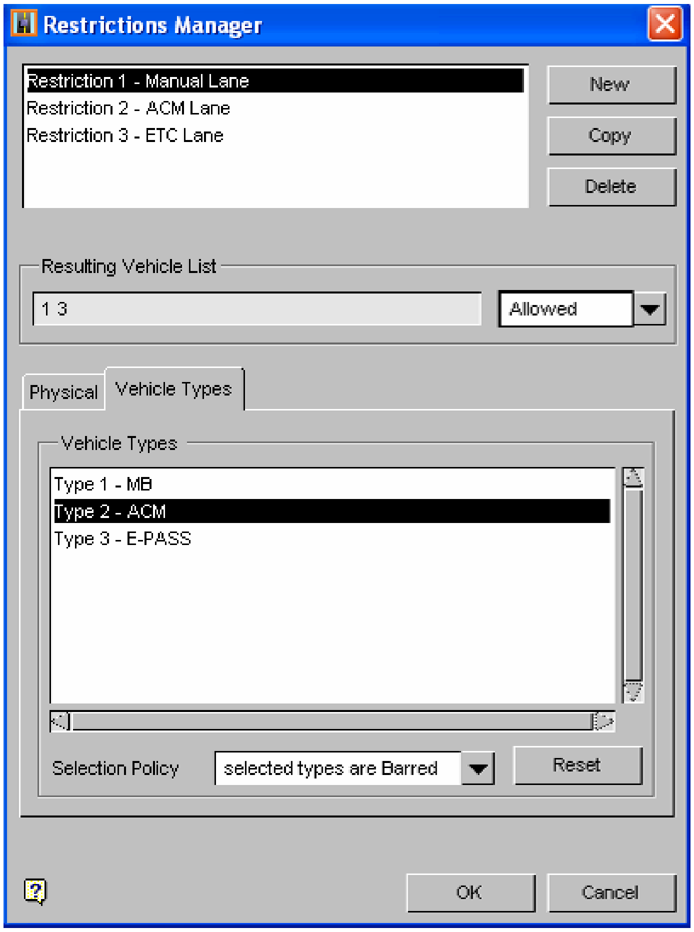
These vehicle types were assigned different colors so that they can be easily identified during the toll plaza simulation runs: MB- Green, ACM- Blue and E-PASS- White.

Vehicle Type Manager can also be used to define the proportion of a particular vehicle type in the O-D matrix and their familiarity with the network.

5.1.2. Restrictions Manager

Restrictions Manager can be used to define restrictions on different types of vehicles. A restriction can be based on physical dimension and type of the vehicle. Once a restriction is defined, it can be applied to a particular lane of any road segment in the network. Vehicles falling into that restriction will not be allowed to enter the restricted lane.

Here, it is used to define three types of restrictions to represent different toll payment lanes at a toll plaza *(see Figure 6).*



Restriction 1 - Manual Lane
Restriction 2 - ACM Lane
Restriction 3 - ETC Lane

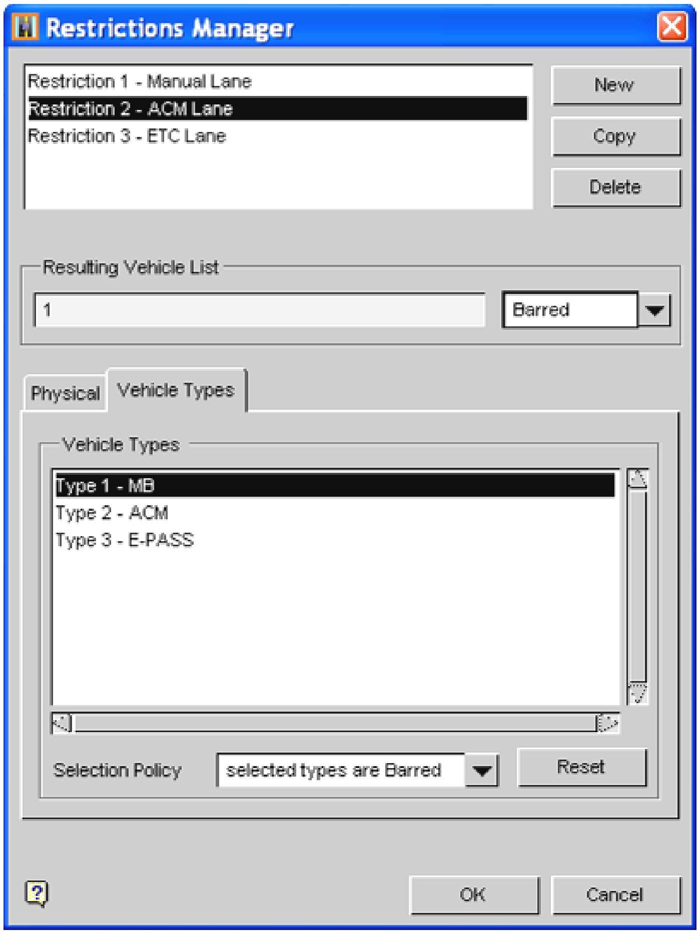
Resulting Vehicle List: 1 3 — Allowed

Vehicle Types
Type 1 - MB
Type 2 - ACM
Type 3 - E-PASS

Selection Policy: selected types are Barred

Figure 6: Toll Plaza Payment Lanes – Manual Lane

Manual Lane: This type of restriction represents manned booth payment lanes at toll plazas. It allows MB and E-PASS vehicles to pass through the lane and bars ACM vehicles *(see Figure 6).*



Restriction 1 - Manual Lane
Restriction 2 - ACM Lane
Restriction 3 - ETC Lane

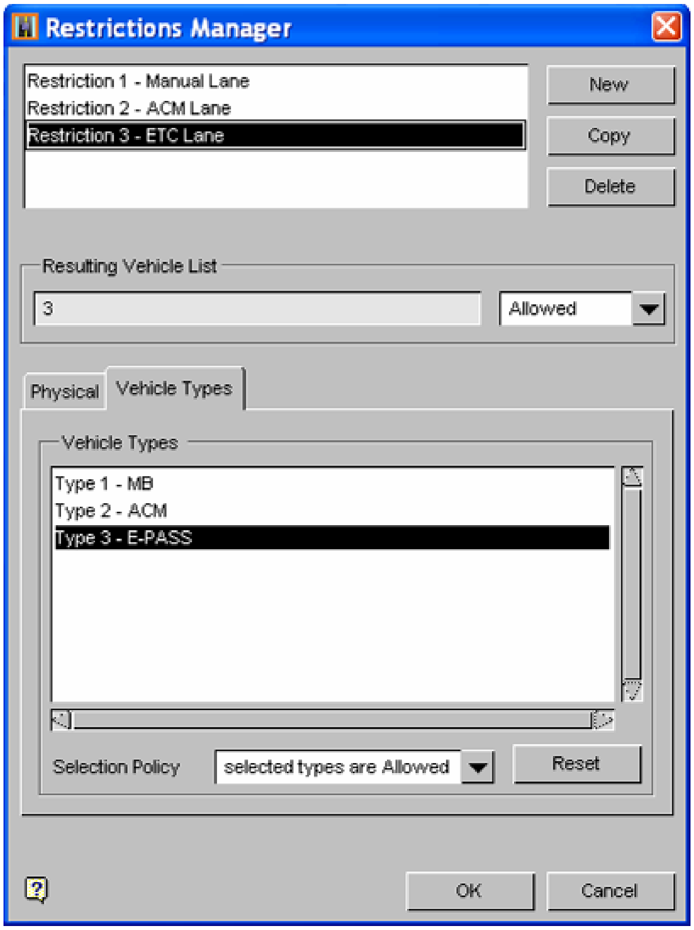
Resulting Vehicle List: 1 — Barred

Vehicle Types:
Type 1 - MB
Type 2 - ACM
Type 3 - E-PASS

Selection Policy: selected types are Barred

Figure 7: Toll Plaza Payment Lanes - ACM Lane

ACM Lane: This type of restriction represents automatic coin machine payment lanes at toll plazas. It allows ACM and E-PASS vehicles to pass through the lane and bars MB vehicles *(see Figure 7).*



Restrictions Manager

Restriction 1 - Manual Lane
Restriction 2 - ACM Lane
Restriction 3 - ETC Lane

Resulting Vehicle List: 3 | Allowed

Vehicle Types
Type 1 - MB
Type 2 - ACM
Type 3 - E-PASS

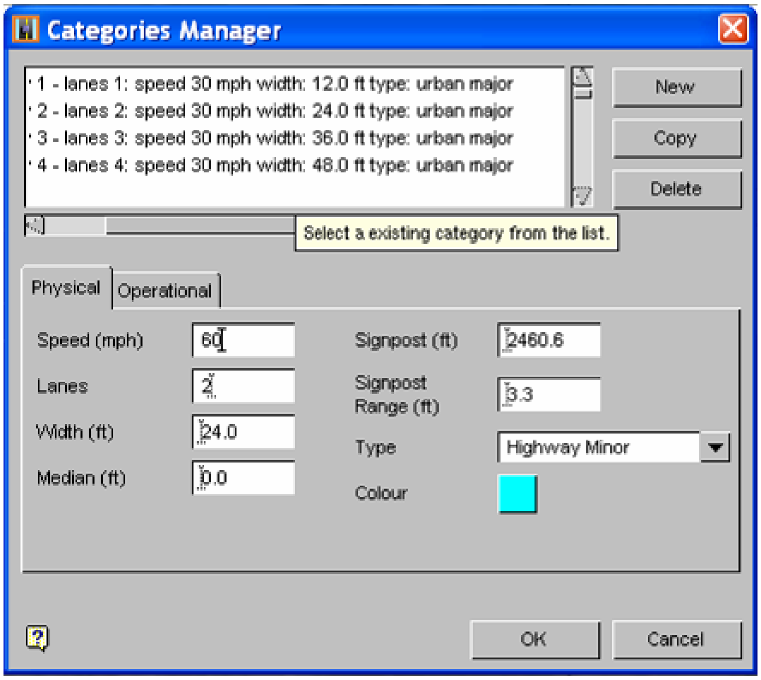
Selection Policy: selected types are Allowed

Figure 8: Toll Plaza Payment Lanes - ETC Lane

ETC Lane: This type of restriction represents electronic toll collection lanes at toll plazas. It allows only E-PASS vehicles to pass through the lane and bars MB and ACM vehicles *(see Figure 8).* However, E-PASS vehicles are also allowed to use lanes other than the dedicated ETC lanes.

5.1.3. Categories Manager

Categories manager defines different types of road segment based on geometric characteristics and their classifications. PARAMICS defines different types of road segments with up to five lanes in each direction *(see Figure 9).*



Categories Manager

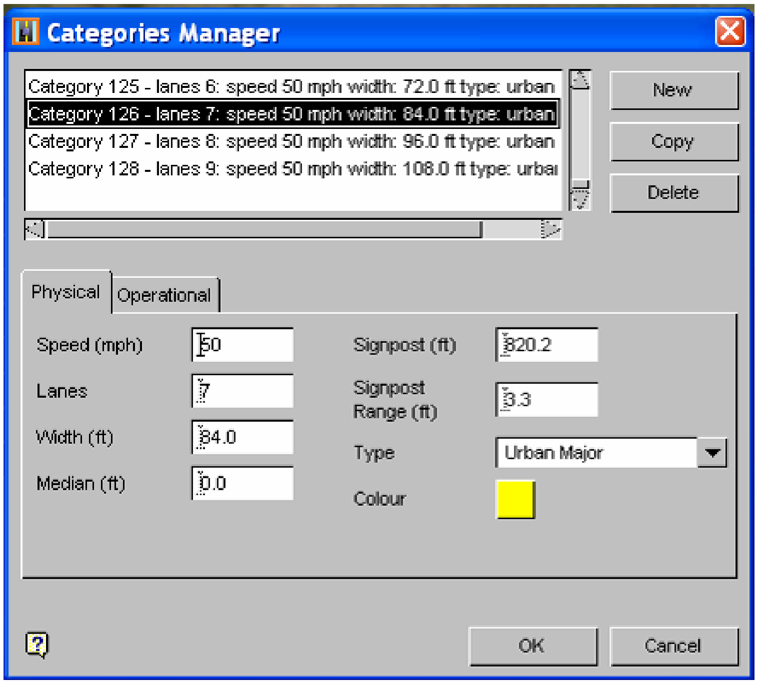
1 - lanes 1: speed 30 mph width: 12.0 ft type: urban major
2 - lanes 2: speed 30 mph width: 24.0 ft type: urban major
3 - lanes 3: speed 30 mph width: 36.0 ft type: urban major
4 - lanes 4: speed 30 mph width: 48.0 ft type: urban major

Select a existing category from the list.

Speed (mph): 60
Lanes: 2
Width (ft): 24.0
Median (ft): 0.0
Signpost (ft): 2460.6
Signpost Range (ft): 3.3
Type: Highway Minor
Colour:

Figure 9: Categories manager

However, the number of lanes at the Holland East Plaza can be seven or more depending upon the time and demand.



Category 125 - lanes 6: speed 50 mph width: 72.0 ft type: urban
Category 126 - lanes 7: speed 50 mph width: 84.0 ft type: urban
Category 127 - lanes 8: speed 50 mph width: 96.0 ft type: urban
Category 128 - lanes 9: speed 50 mph width: 108.0 ft type: urba

Speed (mph) 50
Lanes 7
Width (ft) 84.0
Median (ft) 0.0
Signpost (ft) 820.2
Signpost Range (ft) 3.3
Type Urban Major
Colour 🟨

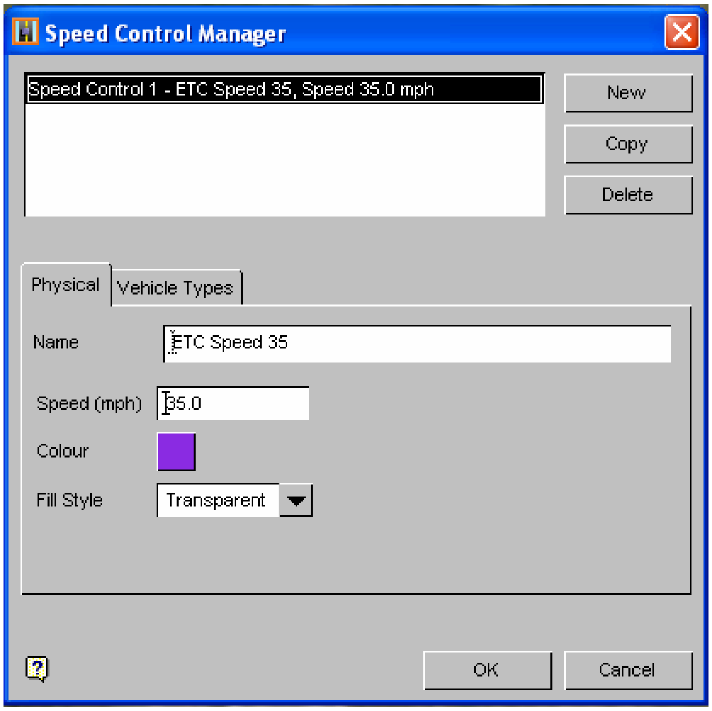
Figure 10: Categories manger - customized road segments

Categories manager provides flexibility to define road type as per the requirement. Road segments with 6, 7, 8 and 9 lanes have been defined for the purpose of this study *(see Figure 10)*.

5.1.4. Speed Control Manager

Speed control manager can be used to define any kind of restrictions in speed for a particular vehicle type. Once speed controls are defined, they can be applied to a particular lane. Speed control overrides the speed limit for that lane for designated vehicle types.

Speed control was used to assign a particular speed to E-PASS vehicles when crossing the toll plaza, while other vehicles stop to pay the toll *(see Figure 11)*.



Speed Control 1 - ETC Speed 35, Speed 35.0 mph

Name: ETC Speed 35

Speed (mph): 35.0

Fill Style: Transparent

Figure 11: Speed control manager

5.1.5. Next-lane Allocation

There are several different kinds of network restrictions which can be applied for links, lanes and turns. Lane allocation is primarily used to specify lane behavior at priority and signalized junctions/intersections. It is used to allocate a range of lanes on an incoming link at an intersection which will be used by vehicles to turn from the incoming link onto the out-going link. Next-lane can be used to override the default lane mapping feature. The number of turning lanes will affect the number of next-lanes available. It can override the default range and specify the exact lanes on the next lane link for each lane on the current link. In this manner, it can be used to implement forced lane changes which might be required at some intersections. For example, sometimes vehicles taking left turn from a single left-turning approach lane at an intersection choose from among two or more departure lanes (if available) in the destination link. By doing this, left-turning vehicles occupy two or more lanes just after clearing the intersection, although they were all coming from a single lane. It might prevent other vehicles, which are on the opposite approach lane, from taking free right turns. If it is desired that the right-turning vehicles from other direction should be able to take free right turns (because of the availability of more than one lane in the destination link), then left-turning vehicles can be forced to stick to one lane while clearing the intersection. Extending this feature, left-turning vehicles can also be made to choose a lane from any two pre-specified lanes in the destination link. This capability of next-lane allocation feature can be used to regulate the behavior of vehicles just upstream of the toll plaza.

Road segment near toll plaza is wider and has more lanes compared to upstream section of the same road. As a road segment approaches the toll plaza, smooth transition is provided to accommodate more and more lanes. Lanes are added to the roadway as it approaches the toll plaza. When a new lane is added to a link in the toll plaza simulation model, vehicles have a tendency to occupy old lanes and newly added lane remains empty. For example, if a link in the model has five lanes, then one more lane is added to the downstream link so that it has six lanes *(see Figure 12).* Lanes are numbered from right to left as per the current convention in PARAMICS. So, the right-most lanes in the links upstream and downstream of node '8' are numbered '1'. On the other hand, the left-most lane in the link upstream of node '8' is numbered '5', while it is numbered '6' for the downstream link. Vehicles stick to the same 'lane number' while traveling across a node onto the downstream link. So, vehicles occupy only the five rightmost lanes in the downstream link and the leftmost lane remains empty (*see Figure 12*). Next-lane Allocation feature in PARAMICS can be used to map upstream lanes onto downstream lanes preventing this unrealistic behavior from occurring in simulation models.

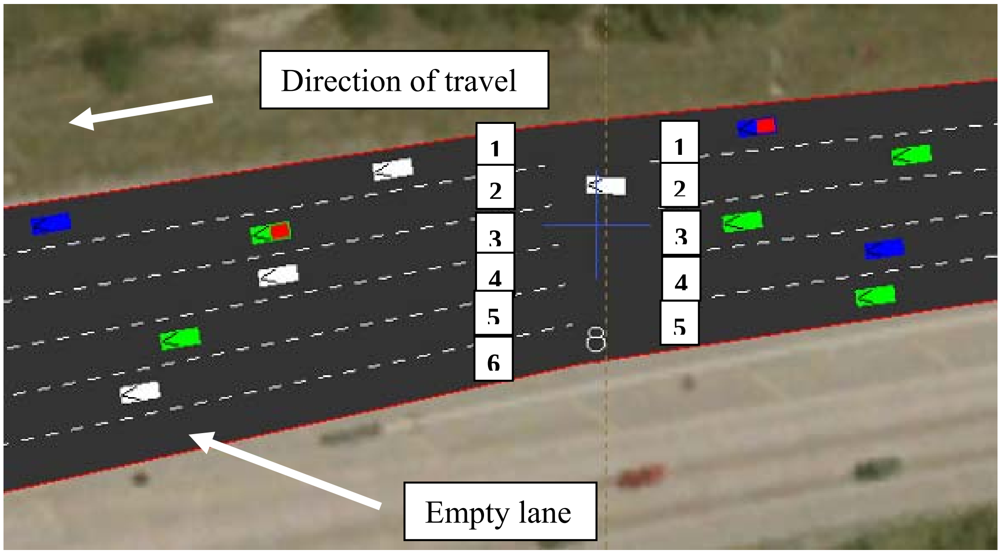


Figure 12: Lane usage before Next-lane Allocation

It tells the vehicles in a particular upstream lane to choose from one or more of the downstream lanes as per the settings. Next-lane allocation can be used in such a manner that all the downstream lanes are utilized.

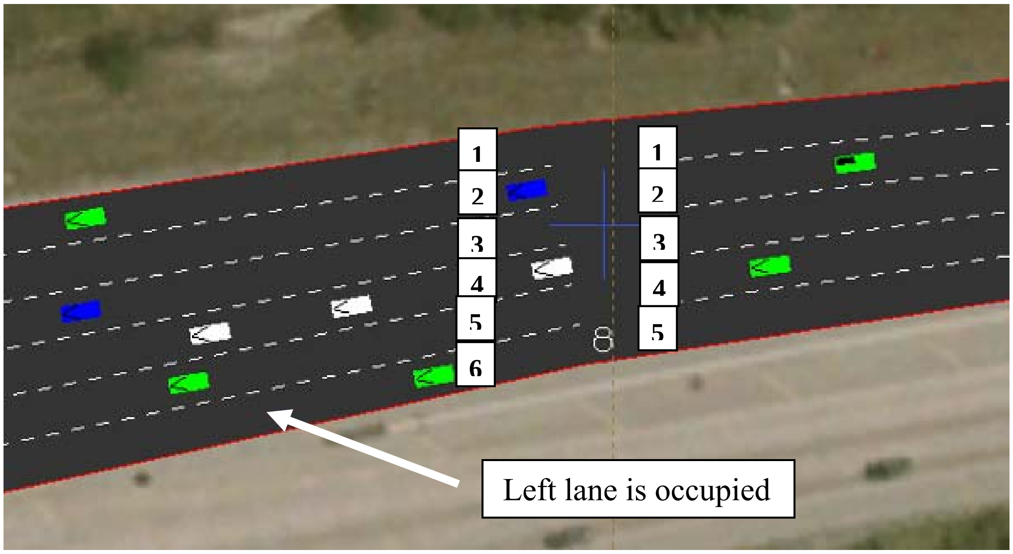


Figure 13: Lane usage after Next-lane Allocation

Before next-lane allocation, leftmost lane in downstream link remains empty. After next-lane allocation all lanes are occupied by vehicles (*see Figure 13*).

5.1.6. Lane-choices Rule

Signposting and lane-choice are two components of decision point hierarchy in PARAMICS. Signposting makes vehicles aware of hazard ahead and the information on the type of hazard. A hazard is identified by PARAMICS on several types of network features, such as road narrowing, diverges, junctions/intersections, right turns…etc. After assessing the hazard, vehicles will determine if a lane change is required.

Lane-choices can be used to define link specific lane usage rules on a certain approach to a remote node in the network. It allows the user to override the default lane usage rules which are primarily governed by signposting/hazard model in PARAMICS. Lane-choice rule gives more freedom to deal with complex junctions, short links, complex freeway on-ramp/off-ramp combinations and special cases.

One of the important applications of the lane-choice rule is to define the lane usage of vehicles just upstream of an off-ramp. Vehicles which have to exit the roadway using the off-ramp can be told to use only specified lanes in the upstream links. For example, suppose that there is an off-ramp on the left side of the roadway. Vehicles which are destined to exit using the off-ramp will anyway exit, but it may be accompanied with unrealistic maneuvering by vehicles. It may happen that vehicles will keep on traveling on right lanes on upstream links, and then make a sudden lane change to reach the left-most lane just before using the off-ramp. Using the lane-choice feature, such vehicles can be told to stick to one or two left lanes in upstream links so that they exit the roadway smoothly. This rule is not strictly applied, and therefore there might be some vehicles which will use lanes other than the pre-specified lanes. But, it will create a general tendency in the exiting vehicles to move towards left lanes while approaching the off-ramp.

Apart from on-ramps and off-ramps, this feature can also be used when there is addition or drop in number of lanes while going from upstream link to downstream link. Whenever this criterion is met, a set of two (or three) consecutive links can be selected and lane-choice rules can be applied for the selected set of links. These rules are limited to the selected links, and it will be applied to vehicles only when they are traveling on these links. More than one lane-choices rule can be defined and they might overlap each other (i.e., a particular link can be part of more than one lane-choices rule). Lane-choices rule can be applied to vehicles based on vehicle-type and/or origin-destination zones *(this feature was added in V5.1).* Lane-choices rules cannot be applied on a uniform road segment without any on-ramp/off-ramp or intersection, because PARAMICS does not see any hazard in these cases. Since lane-choices rules can be applied in case of narrowing or widening of the roadway, it becomes very relevant for the toll plaza simulation. The ability of the lane-choices rules to control the movement of different vehicle types can be directly useful in simulating the movement of vehicles just upstream of the toll plaza. The only characteristic of vehicles which will be used to identify them and subsequently determine as to which lane-choices rules apply to them, is their vehicle type (i.e., payment type). For the purpose of the toll plaza model, vehicles types have been defined based on their toll payment mode, i.e., manual booth (MB), automatic coin machine (ACM), and electronic toll collection (ETC) payment. This assumption is self-explanatory, because the maneuvering of vehicles just upstream of the toll plaza is solely governed by their toll payment type, and is not a function of vehicles size, origin-destination…etc. The only exception to this assumption might be when there is an off-ramp just downstream of the plaza, and a vehicle wants to exit the roadway using that ramp. In that case, exiting vehicles will try to pay toll using a toll lane which is nearer to the off-ramp and makes it easier for the vehicles to steer themselves out of the traffic stream and reach to the off-ramp smoothly. Since, this is not the case for Holland East Plaza, it can be safely assumed that the vehicle type (which is based on the payment method) is the only criterion which should be used in defining the lane-choices rules. Vehicles can be directed towards lanes which will lead them to the correct toll payment booth. Therefore, lane-choices rules can be customized to serve the purpose of simulating vehicular movement near a toll plaza.

As vehicles approach near the toll plaza they have the choice of selecting from more and more lanes. The most common configuration at a toll plaza is that lanes on the right side lead to manual booth (MB) lanes; center lanes lead to automatic coin machine (ACM) lanes, and left lanes lead to electronic toll collection (ETC) lanes. Lane-choices rules can be used to put intelligence in the vehicles so that they tend to move towards the correct approach lane to plaza depending upon their payment mode.

In PARAMICS, nodes are the primary element required to create a road network. Nodes are created first, and then links are created by joining two nodes. Nodes are added whenever there is a curvature in the roadway (i.e., it is not a straight section), change in number of lanes, joining of on-ramp, diversion of off-ramp, intersection of two roadways…etc. Numbers in Figure 14 represent the nodes, which were created in order to accurately follow the actual geometry of the toll road.

In the present model, the toll plaza is located at Node 11 *(see Figure 14)*, and upstream links 6:7 (i.e., road segment connecting nodes 6 and 7), 7:8, 8:9, 9:17, and 17:10 are approaching the toll plaza. Link 10:11 is marked with solid white lines, which means that vehicles cannot do lane changing maneuvers when they are very near the toll plaza.

Figure 14: Approach lanes to toll plaza

Vehicles traveling in other links can change lanes and move toward the correct lane depending upon their payment types. For vehicles traveling on link 7:8 and moving towards nodes 9 and 17, lane-choices rules can be applied which will tell the vehicles to stick to correct lanes. Link 7:8 has five lanes and links 8:9 and 9:17 have six and nine lanes respectively.

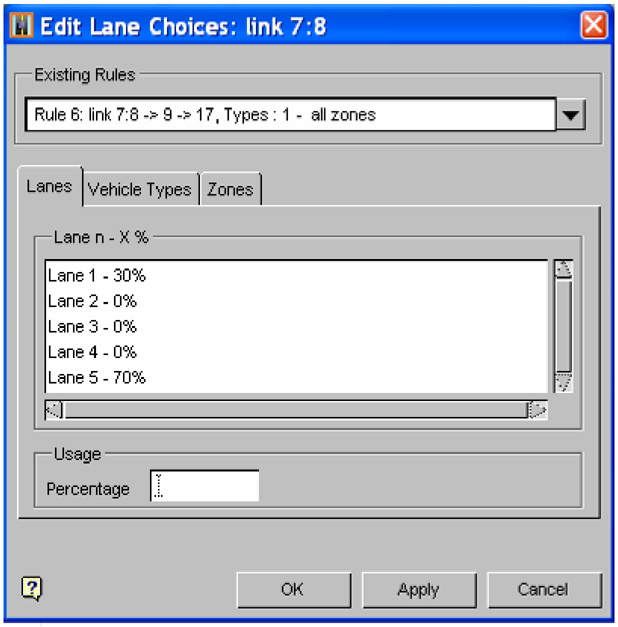
Lane-choices rule is the primary tool used to put intelligence in the vehicles, so that they move towards the correct toll lane(s) while approaching the plaza. Lane-choices rule does not tie a vehicle to a particular toll lane beforehand; it creates a tendency in the vehicle to move towards the defined lane groups and then depending upon the vehicle type (MB, ACM, or E-PASS, *refer to Section 5.1.1*), lane restrictions (Manual, ACM or ETC lane, *refer to Section 5.1.2*), and queue lengths, the vehicle chooses one of the toll lanes based on the logic embedded in the microscopic nature of PARAMICS. Figure 15 illustrates an example of lane-choices rule for MB vehicles (Type: 1) while traveling on link 7:8 and going towards nodes 9 and 17 near the toll plaza.

The toll plaza model shown in Figure 14 represents the configuration of the Holland East Plaza (HEP) in year 1995. This model is created because of the availability of extensive data for year

1995, which helped in calibrating the simulation parameters for the toll plaza model. After this initial experience in the calibration process, later on a network model consisting of HEP and the downstream section of SR 408 has been developed and validated for year 2004. HEP contained nine toll lanes with the following configuration during 1995 (from right to left): M-M-A-A-E-M-M-M-M.

(M – manual booth payment, A- automatic coin machine, E – electronic toll collection)

Link 7:8 has five lanes, and in accordance with the lane-choices rule *(see Figure 15)*, MB vehicles split themselves into these lanes. Since there are two sets of manual payment lanes (2 in the right side and 4 in the left side) at the toll plaza (*see Figure 1*), MB vehicles are split into two groups in roughly 33% (2/6 ratio for right side) and 67% (4/6 ratio for left side) proportions. It was found out after small adjustments, that a split of 30% and 70% produced the maximum throughput for the toll plaza.



Rule 6: link 7:8 -> 9 -> 17, Types : 1 - all zones

Lane 1 - 30%
Lane 2 - 0%
Lane 3 - 0%
Lane 4 - 0%
Lane 5 - 70%

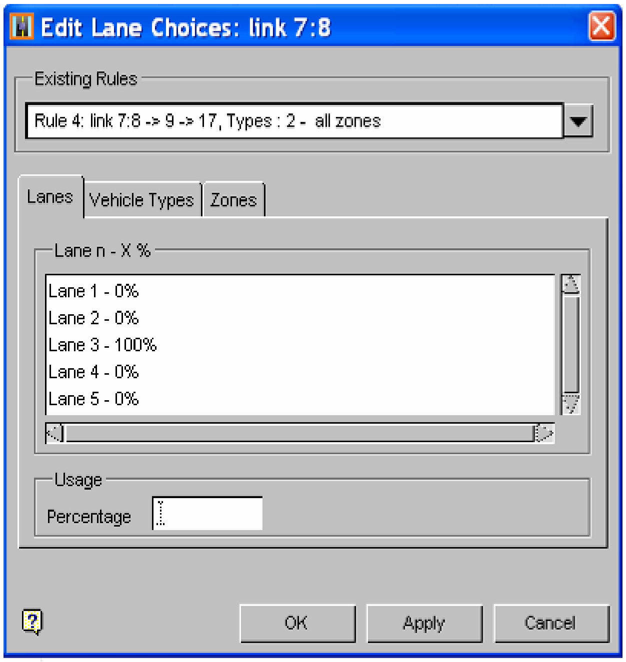
Figure 15: Rule for MB vehicles

It is to be noted that PARAMICS does not enforce this rule strictly; instead it creates a general tendency in manual booth (MB) payment vehicles to occupy rightmost (Lane 1) and leftmost lane (Lane 5) while traveling on an upstream link 7:8. Therefore, some MB vehicles also travel on lanes other than these two lanes, which is a more realistic case.

Rules for ACM and E- PASS vehicles are shown in Figures 16 and 17 respectively. Similarly lane-choices rules have been defined for links 6:7 and 8:9

"Rule 6: link 7:8 -> 9 -> 17, Types: 1" *(see Figure 15)* means that this is rule number 6 and it is applied to vehicles traveling on link 7:8 and moving towards nodes 9 and 17. For a complex network it is possible for vehicles traveling on link 7:8 to have different destination nodes, in which case the last node number (which is '17' in this example) will vary, for the same set of first two nodes. This rule is applied only to vehicle type 1, which is manual booth (MB) payment lane vehicle in the present case. Lanes are numbered from right to left. So lane 1 represents the right most lane which is towards the curb and lane 5 is the left most lane which is towards the median. The present rule tells the MB vehicles to occupy lanes 1 and 5 and their proportion in each of these two lanes.

The next two rules *(see Figure 16)* tell ACM vehicles to occupy the middle lane *(i.e., lane 3, see Figure 14)* and E-PASS vehicles to occupy the lane which is left of center *(i.e., lane 4, see Figure 14)*, while traveling on link 7:8 and going towards node '9'. Keeping the ACM vehicles in lane 3 on link 7:8 will lead them to lane 3 at the toll plaza (which is an ACM payment lane). Between the link 7:8 and the toll plaza, next-lane allocation is used to further split the ACM vehicles into two lanes (lane 3 and the adjacent lane 4) so that lanes 3 and 4 at the plaza are approached by ACM vehicles.



Edit Lane Choices: link 7:8

Existing Rules

Rule 4: link 7:8 -> 9 -> 17, Types : 2 - all zones

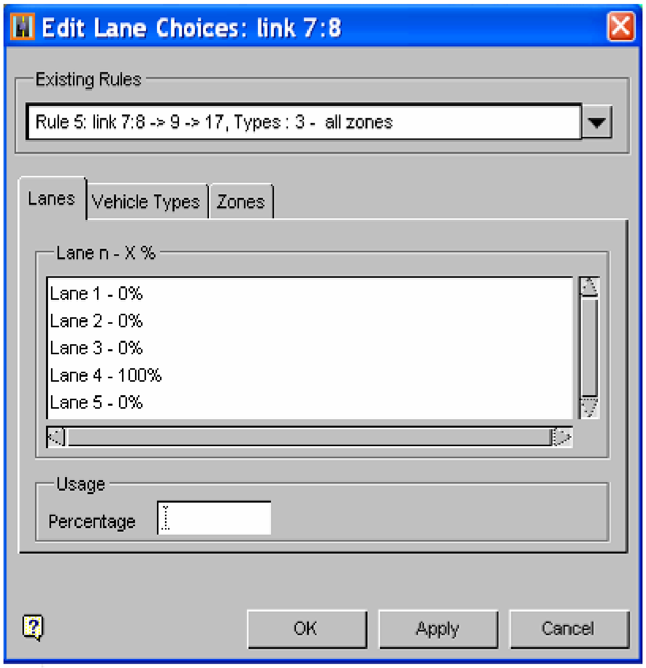
Lane n - X %

Lane 1 - 0%
Lane 2 - 0%
Lane 3 - 100%
Lane 4 - 0%
Lane 5 - 0%

Usage

Percentage

Figure 16: Rule for ACM vehicles



Edit Lane Choices: link 7:8

Existing Rules

Rule 5: link 7:8 -> 9 -> 17, Types : 3 - all zones

Lane n - X %

Lane 1 - 0%
Lane 2 - 0%
Lane 3 - 0%
Lane 4 - 100%
Lane 5 - 0%

Usage

Percentage

Figure 17: Rule for E-PASS vehicles

Since, there is only one ETC lane at the plaza, E-PASS vehicles are assigned to lane 4 on link 7:8, and then with the help of next-lane allocation they are further moved to the left as they approach the toll plaza, so that lane 5 at the plaza is approached by E-PASS vehicles.

Similar rules have been defined for links upstream and downstream of the link 7:8. These rules will produce a tendency in MB vehicles to move towards right and left lanes (because manual payment is available on right and left toll lanes, *see Figure 1*), ACM vehicles to move towards right of center and E-PASS vehicles to move towards center. It will create realistic lane changing maneuvers upstream of the toll plaza and will eventually lead these vehicles to correct payment lanes.

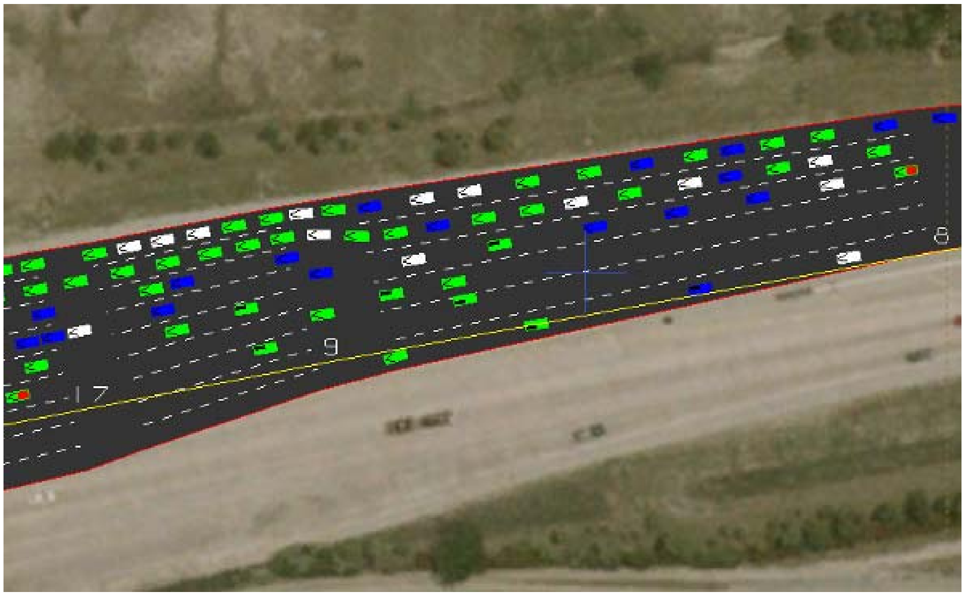


Figure 18: Distribution of Vehicles near Toll Plaza - Before Lane-Choices Rules

(Colors of vehicles: MB vehicles- Green, ACM vehicles- Blue, E-PASS vehicles- White)

Before application of lane-choices rules, some of the ACM and ETC vehicles are traveling in right lanes while some MB vehicles are traveling in center lanes leaving some lanes completely empty of vehicles (*see Figure 18*).

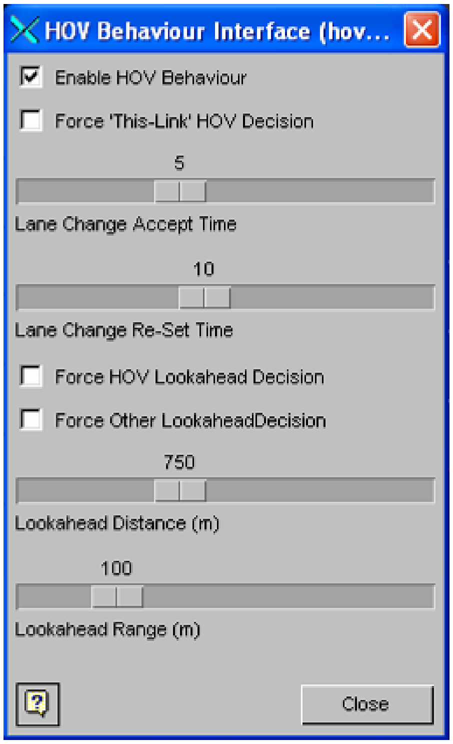
Figure 19: Distribution of Vehicles near Toll Plaza - After Lane-Choices Rules

After the application of lane-choices rules ETC vehicles occupy center lanes, automatic coin machine vehicles occupy lanes right of center, and manual payment vehicles use left and right lanes (*see Figure 19*). This is appropriate lane usage for the given toll lane configuration, i.e., Holland East Plaza for year 1995 (toll lanes from right to left: M-M-A-A-E-M-M-M-M)

5.1.7. High Occupancy Vehicle (HOV) Lanes

In real life, left lanes just upstream of the toll plaza are occupied only by E-PASS vehicles. Some of the E-PASS vehicles may be using center or right lanes if toll booths on those lanes are not queued up. Manual and ACM lane vehicles usually do not drive on left lanes just upstream of the toll plaza, because it is difficult for them to move themselves into respective payment lane in a short span of time.

In PARAMICS, high occupancy vehicle (HOV) lanes are exclusive lanes available only to HOVs. However, HOVs are free to use lanes other than these lanes depending upon network travel cost. For the toll plaza model, E-PASS vehicles can be defined as HOVs and left lanes upstream of the toll plaza can be marked as HOV lanes. HOV behavior can be implemented using application programming interface (API) (*see Figure 20*).



☑ Enable HOV Behaviour
☐ Force 'This-Link' HOV Decision
5
Lane Change Accept Time
10
Lane Change Re-Set Time
☐ Force HOV Lookahead Decision
☐ Force Other LookaheadDecision
750
Lookahead Distance (m)
100
Lookahead Range (m)

Figure 20: HOV Behavior Interface

API provides more flexibility besides basic HOV behavior. HOV vehicles can be forced to use only HOV lanes. Lane changing behavior can be altered by changing lane change acceptance time and look ahead distance.

5.2. Holland East Mainline Toll Plaza

For the purpose of this study, Holland East toll plaza is microscopically modeled. An aerial picture of the plaza is used as overlay *(see Figure 21)*. The overlay is used to ensure that the geometric characteristic of the toll plaza model is same as the real plaza

Figure 21: Holland East Mainline Toll Plaza - Aerial View

(Source: www.terraserver-usa.com)

A model overlaid on actual road section image helps to create more realistic vehicle movements during the simulation. Movement of vehicles are greatly affected by width of road segment, number of toll lanes available and width of road segment at toll plaza, configuration of different types of payment lanes, transition of the toll road from a uniform free-flow segment to the widened toll booth area and the number of lanes available at each point inside the transition area.

Therefore, this model acts like any other microscopically simulation road network area with additional features of toll plaza. This model is fundamentally different from macroscopic models. Macroscopic models do not simulate the transition area just upstream of the toll plaza. These models are only concerned with number of lanes at uniform roadway segment and types of lanes at the toll plaza. Actually, the geometry of the upstream section, the length of the transition area, and the width of the roadway segment along the way do not play a role in such models. Such models only take into account the number of different types of payment lanes and are not affected by their arrangement. Therefore, a toll plaza with three manual lanes near curb side is equivalent to a toll plaza with the first manual lane towards the curb side, the second manual lane in the middle of the plaza, and the third manual lane near the median. For example, Zarrillo (*6*) clearly states that:

> "TPModel does not distinguish between configurations that have the same number of lanes of each lane-type but different arrangements. For instance, both configurations MTE-AE-ME-ME-E and MTE-AE-E-ME-ME will result in the same output value for the estimated-rush-hourly-delay."

However, it has been established that the configuration of different types of lanes has an effect on the operation of toll plaza. Therefore, OOCEA has moved E-PASS lanes towards the left at toll plazas from its old position in the center.

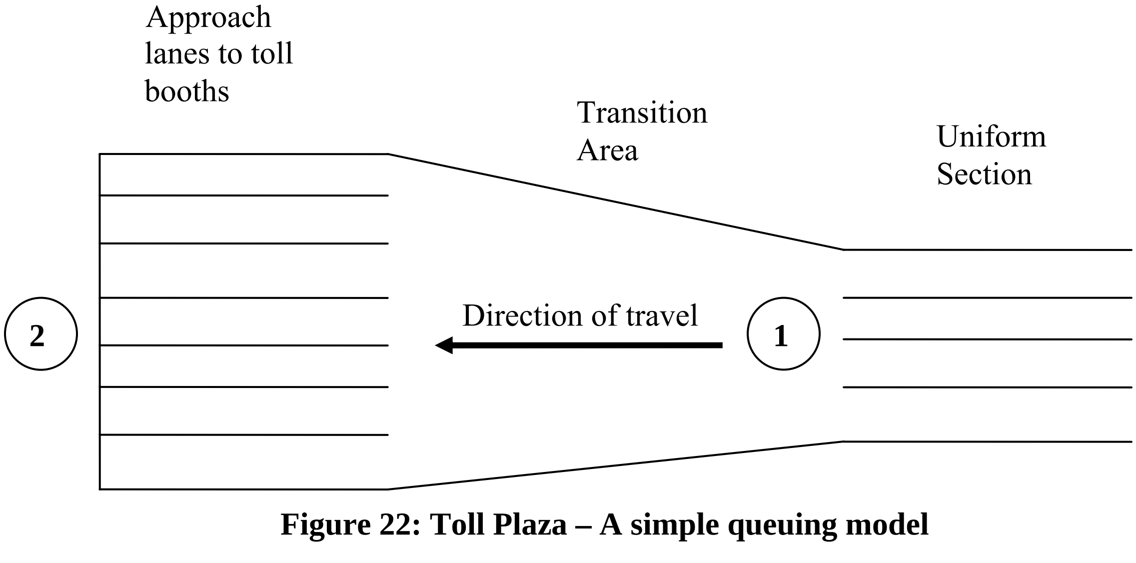


Figure 22: Toll Plaza – A simple queuing model

Many of the indigenously developed toll plaza models are macroscopic and hence contain just the uniform roadway section and approach lanes *(see Figure 22)*.

So, for example when vehicles approach location “1” *(see Figure 22*), they are assigned one of the approach lanes to toll plaza based on queue lengths at location “2” *(see Figure 22*). Vehicles are assigned a particular toll lane even before they approach near the toll plaza. Details of the transition of vehicles from the lanes in uniform free-flow section of the road to the toll lanes at the plaza are not included in the model. The ability of the vehicles to accept gap and steer into correct toll lanes in the transition is not modeled by macroscopic models.

In real life, transition of lanes from uniform roadway section to toll lanes is continuous and number of lanes increase one by one in a specified distance. A microscopic toll plaza model based on a network simulator will treat the whole area as road, and vehicles will follow traffic flow rules also in the transition area. Using the overlay captures the details of the transition area.

Figure 23: Holland East Mainline Toll Plaza - Paramics Model

Curb points of the model are matched with that of the overlay so that the model has same geometry of transition area and widening of roadway as that of the real plaza. Holland East Plaza has been modeled for AM peak direction which is Westbound for morning peak hour 7AM-8AM. Lanes just upstream and downstream of the plaza are separated by solid white lines, so that vehicles do not change lanes in this area. There are eight toll lanes (with one reversible lane) in this direction, and are distributed as follows (*35*):

From right to left: MB, MB, MB, ACM, ACM, ETC and ETC (see *Figure 24*).

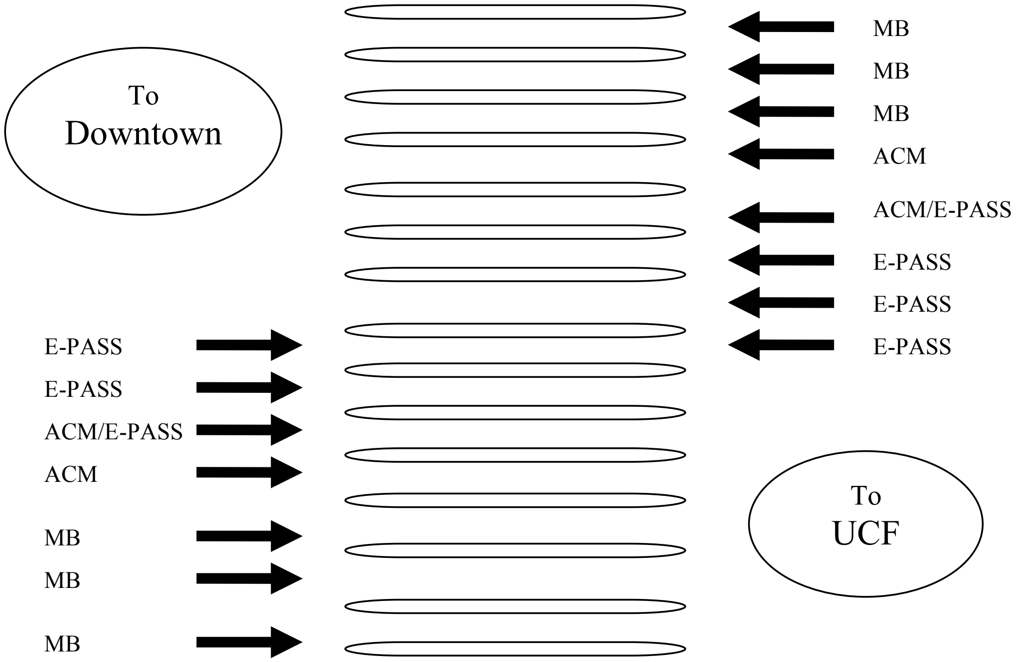
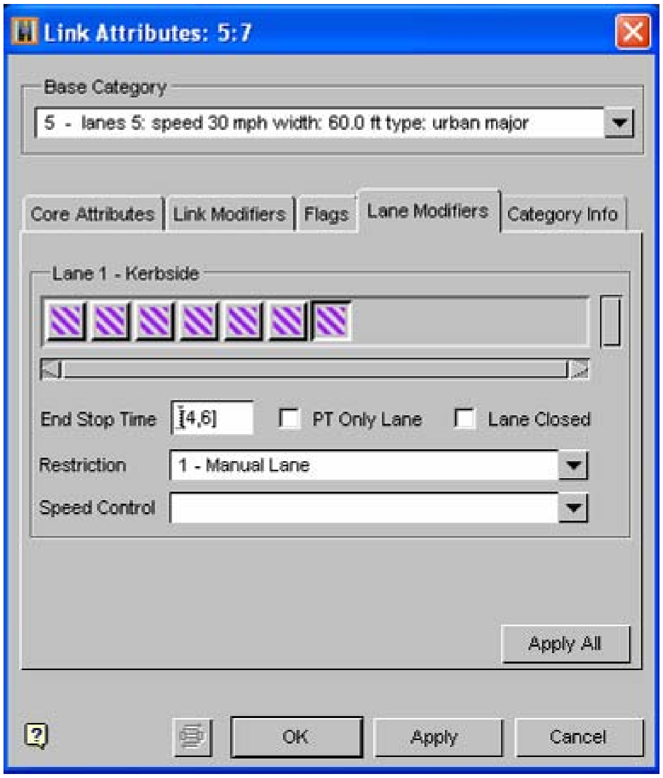


Figure 24: Holland East Mainline Toll Plaza (2004) - Lane Configuration

Once a basic toll plaza model is developed, toll lanes can be assigned relevant attributes using the interface below. The link representing the toll lanes (i.e., link 10:11 in Figure 2) can be selected, and different attributes can be separately assigned for each of the lanes (*see Figure 25*). Each of the square tabs in the figure represents one lane. Once a lane is selected, it can be assigned the following properties:

1. Toll payment method: One of the toll payment methods created in Restrictions Manger (*see section 5.1.2*) can be selected from the drop down list.

2. Speed Control: If specific speed limit is required for a particular lane, which is different from the overall speed limit of the entire link, it can be assigned. This speed control is defined using Speed Control manager (*see section 5.1.4*).



Base Category: 5 - lanes 5: speed 30 mph width: 60.0 ft type: urban major

End Stop Time: [4,6]

☐ PT Only Lane

☐ Lane Closed

Restriction: 1 - Manual Lane

Speed Control:

Figure 25: Applying Lane Restrictions and Stop Time

3. Stop time: Stop time is the duration of time for vehicles stop while using the manual payment or ACM lane. It is either defined as one specific value, or it may be a uniform distribution between given values. In Figure 25, a uniform distribution between 4 sec and 6 sec is specified as an example.
4. Lane Close: A lane can also be closed by checking the correspond box.
5. PT Only Lane: Checking this box will restrict the corresponding lane for use by only public transit.

6. CALIBRATION AND VALIDATION

After developing a working simulation model in PARAMICS which behaves reasonably well at default settings, the next most important step is the calibration of the model. Calibration is the process of adjusting model parameters, so that the model realistically replicates local traffic conditions.

6.1. Objectives of Calibration

Since a single model can not perform with equal accuracy for all traffic conditions and all locations, it is imperative that the model be calibrated for local traffic conditions every time. In real life, traffic conditions are affected by large number of variables and their interactions. Even the most detailed microsimulation model fails to incorporate all of these variables to simulate the vehicular movements. Microsimulation models use a large number of parameters to simulate traffic movements, and their default values are provided by the developers. However, only rarely do the default parameter values produce results which match with observed conditions. Therefore, the objective of the calibration is to find the optimal set of parameter values, for which the model best represents the local traffic conditions. The fundamental assumption of the calibration is that the travel behavior models in the simulation model are essentially sound. This means that there is no need to verify that they produce correct delay, travel time, and density when they are given the correct input parameters for a link. Therefore, the only remaining task for the analyst is to adjust the parameters so that the models correctly predict local traffic conditions (*37*).

The calibration of microsimulation models is a two phase process. The first phase of the model calibration requires checking of input data, i.e., road and network geometry, origin-destination matrices, toll lanes and their modes of payment. Once this part is complete, the second phase involves comparison of model output statistics like, volume and delay, to the observed volume and delay data.

6.2. Parametric Calibration

PARAMICS uses a large number of model parameters to perform simulation runs. The default values of model parameters used by PARAMICS have been calibrated against site specific headway and speed data extracted from loop detectors in the United Kingdom (*33*). It is essential to calibrate the values of such parameters for local conditions, so that the model produces results which are in consonance with real life observations. It is practically impossible to adjust all of the simulation parameters to calibrate the model. Lee et al. (*27*) identified the following key parameters, which were adjusted to calibrate the model for 1.0-mile segment of the I-5 freeway in California.

- Mean target headway
- Mean reaction time
- Aggressiveness of driver
- Awareness of driver

During the course of calibration in this thesis, it was found that this list was far from adequate in simulating vehicular movements near the toll plaza. There are other parameters which directly affect the simulation of the toll plaza and whose numerical values need to be adjusted. These parameters are discussed in detail later. Optimal adjustment of numerical parameters increases the throughput, but it reaches a maximum value which is far below the observed values. After that, the inter-play of qualitative parameters is used to improve the operation at the toll plaza. Therefore, a significant portion of the calibration effort is qualitative in nature. Different types of tools as described in section 5, "Toll Plaza Model", play an important part in the calibration process. Proper configuration of these tools greatly affects the throughput of the toll plaza. In particular, next-lane and lane-choices features play the most important roles. These are used to streamline the movement of different vehicle types and minimize the interference between them while weaving is taking place.

6.3. Models for Holland East Plaza

Holland East Plaza (HEP) is located on the East-West Expressway (SR 408), which meets Interstate-4 in downtown Orlando (*see Figure 26*). Since, HEP is being modeled for morning peak direction, which is Westbound, downstream segments of SR 408 lead to downtown Orlando. SR 408 Westbound is heavily congested during morning peak hours from the Holland East Plaza till I-4 interchange. Therefore, this whole corridor has been modeled to study the traffic conditions. A simulation model has been developed for the present condition of this corridor.

Figure 26: Orlando Metropolitan Area - Road Network
Source: OOCEA *(35)*

6.4. Available Data

Different kinds of data are available for HEP for different years (*see Table 1*). Complete data is not available for any single year, so the toll plaza model has been calibrated by making the best use of all the available data.

1. Holland East Plaza – 1995

- Total plaza volume for morning peak hour 7AM-8AM (*36*).
- Individual toll lane volumes for 4 out of 9 toll lanes (*36*).
- Total vehicle-minutes of delay for entire plaza during morning peak hour (*6*).

2. **Holland East Plaza – 1998**

   - Total plaza volume for morning peak hour 7AM-8AM (*38*).
   - On-ramp/off-ramp volumes for SR 408 Westbound between HEP and I-4 interchange (*38*).

3. **Holland East Plaza – 2004**

   - Total plaza volume for morning peak hour 7AM-8AM (*35*).

For example, detailed lane-wise volume data for the Holland East Plaza, and delay data is available for year 1995. But, volume data for on-ramps and off-ramps on SR 408 which are located between HEP and SR 408 – Interstate 4 interchange is not available for this year. Lane-wise toll plaza volume data is very useful in calibrating the isolated HEP model (without downstream SR 408 section) for year 1995. Since, extensive data in terms of lane-wise volume and delay value is available; it is instrumental in calibrating key simulation parameters, which are identified later, for a toll plaza model.

Moreover, aggregate toll plaza and ramp volume data is available for year 1998. This data is very useful in order to create and simulate the entire SR 408 corridor from HEP to downtown Orlando (i.e. till I-4 interchange). Aggregate toll plaza volume data without ramp data is available for October 2004 (latest data available through OOCEA website) (*35*). After successfully calibrating the above mentioned corridor for year 1998, a model for present configuration (i.e. October 2004) is developed by projecting the ramp volumes from 1998. Different models which have been developed and calibrated are discussed below in detail:

Table 1: Availability of Data

Data	1995	1998	2004
HEP Mainline Volume	X	X	X
Ramp Volumes	NA	X	Projected
Delay	X	NA	NA

NA: Not Available

6.4.1. Holland East Plaza – 1995

Data was collected at the Holland East Plaza using video camera during 1994-96. Data was collected for the morning peak hour (7-8 am) at this plaza in the peak direction, which is Westbound. Video data was used to calculate peak hour volume and delay measurements. This data has been extensively used in previous studies at UCF. For this study, dissertations of Zarrillo (*6*) and Klodzinski (*36*) have been used as the primary sources of video recorded data.

Volume Data

Volume data for the Holland East Plaza has been taken from the dissertation of Kldozinski (*36*). Lane-wise volume for three weekdays in June, 1995 is available for HEP for morning peak hour 7AM-8AM. This plaza operated with nine toll lanes in Westbound direction during morning peak hours. The configuration of the plaza from right to left was as follows: M-M-A-A-E-M-M-M-M*. Total toll plaza volume, and individual lane volumes for four out of nine lanes are available *(see Table 2).*

Table 2: Hourly Volume - HEP 1995

Lane Number*	June 7, 1995	June 8, 1995	June 14, 1995
Lane 2 (M)	318	421	380
Lane 4 (A)	590	609	615
Lane 5 (E)	1218	1290	1320
Lane 6 (M)	485	471	427
Lanes 1-9 (Total)	4972	5234	5018

Source: *Klodzinski (36)*

* M- Manual Lane, A-Automatic Coin Machine Lane, E- ETC Lane. E-PASS vehicles can use any lane.

Delay Data

Actual field delay data for the Holland East Plaza was calculated for morning peak hour by Zarrillo (*6*). It is important to understand how delay was calculated from the field data, so that the same procedure is applied for delay calculation while the model is being calibrated. While calculating delay, length of queue is noted down from the video data for each lane at an interval of one minute. It is assumed that if a vehicle is in queue at the end of the minute, then it is delayed by one minute. $\mathbf{L_{ji}}$ is defined as the queue length in lane **i** at the end of minute **j**. The total number of vehicles stationed at the plaza for each minute **j**, is determined by summing over all **N** lanes at the plaza.

The summation over all lanes at the toll plaza, **N**, is the total vehicle-minutes of delay at the toll plaza for each minute of the rush-hour, as shown below (*6*):

$$L_j = \sum_{i=1}^{N} L_{ji}$$

The summation over all minutes of rush hour, **n**, is the actual rush-hour-delay in units of vehicle-minutes, as shown below (*6*):

$$\text{Rush-hour-delay} = \sum_{j=1}^{n} L_j = \sum_{j=1}^{n} \sum_{i=1}^{N} L_{ji}$$

Actual field delay for June 7, 1995 and June 14, 1995 were recorded as 3334 veh-min and 3654 veh-min respectively during morning peak hour (*6*).

The volume and delay data provided above has been used to calibrate parameters which are important for simulating a toll plaza model. However, the present configuration of the Holland East Plaza during peak hour is different from its current configuration during peak hour in 1995. Therefore, an additional toll plaza model for the configuration of the Holland East Plaza for year 1995 is created. The plaza operated with 9 lanes in AM peak direction in 1995, and the configuration of payment lanes from curb to median side (or, right to left) were as follows: M-M-A-A-E-M-M-M-M.

Important parameters of PARAMICS have been adjusted so that the model produces volume and delay measurements, which are the same ones or similar to those recorded by video camera. The optimal value of the parameters, which are independent of the configuration of the plaza, will be used to study year 2004 model.

GEH statistic is used to compare observed volumes with those obtained from simulation results. The GEH statistic is a modified Chi-squared statistic that incorporates both relative and absolute differences.

$$GEH = \sqrt{\frac{\left(Simulated - Observed\right)^2}{0.5 \times \left(Simulated + Observed\right)}}$$

GEH < 5 - Flows can be considered a ‘good fit’.

5 < GEH < 10 - Flows may require further investigation.

10 < GEH - Flows cannot be considered a ‘good fit’.

The GEH statistic is designed for use in comparing simulated and observed hourly traffic volumes only (*33*).

GEH statistics is used to determine whether a model has been satisfactorily calibrated or not, and thus it helps in determining the optimal values of simulation parameters. The criteria for a calibrated/ validated model have been fixed as:

- 85% of the check points (i.e. mainline plaza, ramp, SR 408 thru) for volumes should have GEH < 5.
- Vehicle-hours of delay should have error < 5%.

HEP model for year 1995 has been developed and then various parameters were changed to see their effect on volume and delay values at the toll plaza. The following five parameters were found to have the most effect on the outputs, and thus they were chosen as key simulation parameters for the toll plaza model. During the course of calibration, values of these parameters have been adjusted to meet the observed volume and delay values according to the above criteria.

These parameters are as follows:

1. Queue Gap Distance - It defines the maximum distance between queuing vehicles. Vehicles further apart are not counted as being in a queue. The default value is 32.81 ft.
2. Queuing Speed – It defines the maximum speed of queuing vehicles. Vehicles moving faster will not be counted as being in a queue. The default value is 4.47 mph.
3. Mean Target Headway – Specifies the global mean target headway, in seconds, between a vehicle and a following vehicle. This will not necessarily be equal to the mean measured headway: the relationship between target and actual depends on traffic flow levels, driver behavior, and several other factors. Each driver-vehicle unit (DVU) in the PARAMICS simulation has a target headway ‘h’. The mean value for target headway is 1 second by default.
4. Mean Reaction Time – The mean reaction time of each driver, in seconds. The value is associated with the lag in time between a change in speed of the preceding vehicle and the following vehicles reaction to the change. The default value is 1.0 second.
5. Minimum Gap – The minimum gap between stationary vehicles in a queue. The default value is 6.56 ft.

Apart from these few important parameters, a lot of qualitative adjustments are required to calibrate the model. A large number of combinations of different available options are tried to reach the optimum point. Although, qualitative adjustments are not directly transferable from one toll plaza model to another, the experience gained in calibrating one model helped a lot in calibrating another.

Calibration for Volume

Average toll lane and plaza volumes (*see Table 3*)have been calculated based on volumes of June 7, 8, and 14 of year 1995 (*see Table 2*).

In the initial phase, calibration effort was primarily focused to reproduce the observed peak-hour volume.

Table 3: Holland East Plaza 1995 – Average Hourly Volume

Lane Number	Average Hourly Volume
Lane 2 (M)	373
Lane 4 (A)	605
Lane 5 (E)	1276
Lane 6 (M)	461
Lanes 1-9	5075

Since the capacity of different types of toll lanes vary significantly, it is important that the traffic stream constitutes correct proportions of manual, ACM, and E-PASS vehicles. Capacity of ETC lanes can be as high as three times the capacity of manual or automatic coin machine lanes. So, if the traffic stream contains a lower percentage of E-PASS vehicles as compared to real life data, it is very difficult to achieve peak-hour volume at the plaza. A higher proportion of Manual and ACM vehicles means that they will be processed slowly at the toll plaza, which will result in a lower throughput. Since Table 1 does not provide volume data for all the lanes, percentage of different types of vehicles cannot be calculated from these tables directly. Zarrillo (*6*) has provided some relevant data for June 14, 1995 for morning peak hour 7AM-8AM which can be used to extract these figures.

Percentage of AVI = 26.56

Percentage of T_M = 0.85

Percentage of NonAVI_A = 33.96

AVI – Percentage of automatic vehicle identification (AVI) is the same as the percentage of E-PASS vehicles.

T_M – It refers to percentage of semi-trucks that require manual service.

NonAVI_A – Percentage of non-AVI users that use automatic coin machines.

From the above values, it can be inferred that the percentage of non-AVI (manual + automatic coin) users is 73.44 (= 100 - 26.56). This value also includes % TM which is part of manual users. Out of these 73.44% non-AVI users, 33.96% users are automatic coin users (i.e. NonAVI_A). Therefore, out of the total volume, 24.94 % (= 73.44 x 33.96 /100) are automatic coin machine (ACM) vehicles and 48.5% are manual lane users.

Once the proportion of different vehicle types is determined, lane restrictions were applied at link 10:11 (*see Figure 27*) just upstream of the toll booths. These lane restrictions will ensure that only the valid vehicle types are processed through each of the toll lanes. Lane configuration used was (from right to left): M-M-A-A-E-M-M-M-M

Figure 27: Holland East Plaza (9 lanes) – M-M-A-A-E-M-M-M-M

Once key simulation parameters have been identified and the criteria for optimal calibration has been set, the Holland East Plaza model for year 1995 has been calibrated in the following five stages, which is explained in details later:

1. Performance of the model was observed at default settings, and at default values of the simulation parameters (i.e., queue gap distance, queue speed, mean target headway, driver reaction time, and minimum gap).
2. Next-lane allocation feature was applied to ensure that all toll lanes are properly utilized by vehicles, which resulted in an increase in the throughput.
3. Lane-choices rules were used in conjunction with Next-lane allocation to streamline the movement of different vehicles types towards valid toll payment lanes, thereby increasing the throughput further.
4. Qualitative adjustment was employed to reduce the weaving phenomenon just upstream of the toll plaza in order to improve the operational efficiency of the toll plaza.

5. Simulation parameters (*as discussed page 59*) were adjusted to further increase the throughput, and to match simulation outputs with real life observed volume and delay values.

These five stages are discussed in detail below.

1. Default Setting and Default Value of Simulation Parameters

At the initial stage, default values of simulation parameters such as queue gap distance, queue speed, mean target headway, driver reaction time, and minimum gap were used. These parameters have been adjusted later on, along with several qualitative adjustments to achieve the target volume and delay data.

Table 4: Simulation Output without using Next-lane and Lane-Choices, at Default Parameter Values

Lane number	Hourly Volume (veh/h)	Percentage of Total Volume	Percentage by Vehicle Type
Lane 1 (M)	473	15.67	M = 64.06
Lane 2 (M)	457	15.14	
Lane 3 (A)	469	15.53	A = 33.26
Lane 4 (A)	535	17.72	
Lane 5 (E)	81	2.68	E = 2.68
Lane 6 (M)	439	14.54	
Lane 7 (M)	272	9.01	
Lane 8 (M)	292	9.67	
Lane 9 (M)	1	0.03	
Total	3019		

A total volume of 3019 vehicles (*see Table 4*) was simulated to pass through the Holland East Plaza during morning peak hour, which is far below the observed value of 5075 vehicles (*see Table 3*). Moreover, the percentage of E-PASS vehicles (2.68%, *see Table 4*) using the plaza is significantly less than its proportion in the observed data (26.56%, *see page 61*).

Careful observation of the simulation over a large number of runs suggests that weaving of vehicles is the primary factor in the reduction in throughput. During most of the simulation period, ETC lane was blocked by manual or ACM vehicles. These vehicles wait till there is a gap in their toll lanes, and then make a sudden 90^0 turn to reach to their payment lanes. During this time, no vehicle uses ETC lanes, and as a result its throughput is much smaller than what it is supposed to be. Almost all of E-PASS vehicles use other lanes to exit the toll plaza.

It can also be observed that the volumes for the three left most lanes (lanes 7, 8, and 9) are less than the volume for the other lanes (except ETC lane). This is due to sudden increase in number of lanes across node 9 (*see Figure 28 , page 72*). Vehicles traveling on six lanes upstream of this node are transferred to only 6 out of 9 lanes downstream of this node (*see section 5.1.5 for this phenomenon*). Only when there is enough queuing in these six toll lanes, some of the vehicles change lanes and pay toll by using one of the three left most lanes.

2. Next-lane Allocation

After this, next-lane allocation was applied to vehicles traveling across node 9. It resulted in proper utilization of the three left most lanes by vehicles along with other lanes. Next lane allocation streamlined the movement of vehicles and it resulted in improved traffic operation upstream of the toll plaza.

Now, the total volume passing the toll plaza during morning peak hour has reached 3386 (*see Table 5*), which is an increase of about 10% from the previous stage. However, it is still far below the observed peak-hour volume of 5075 vehicles.

Table 5: Simulation Output using Next-lane only, at Default Parameter Values

Lane number	Hourly Volume (veh/h)	Percentage of Total Volume	Percentage by Vehicle Type
Lane 1 (M)	500	14.77	M = 65.09
Lane 2 (M)	474	14.00	
Lane 3 (A)	498	14.71	A = 33.14
Lane 4 (A)	624	18.43	
Lane 5 (E)	60	1.77	E = 1.77
Lane 6 (M)	427	12.61	
Lane 7 (M)	222	6.56	
Lane 8 (M)	257	7.59	
Lane 9 (M)	324	9.57	
Total	3386		

After this improvement, the volume for lane 9 has increased significantly, associated with small reduction in volumes for lane 7 and 8. The total volume passing through these three lanes has increased from 19% to 24% approximately.

However, it can be clearly seen that the full potential of ETC lane has not been utilized. As per the observed data, 1276 vehicles (*see Table 3*) passed through the ETC lane during morning peak hour, while only 60 vehicles utilized the ETC lane in the simulation during the same period.

This is again due to the fact that most of the time a manual or automatic coin machine vehicle gets stuck at the beginning of the ETC lane. Since these vehicle types are not allowed to use the ETC lane, they block these lanes until they find a suitable gap in their payment lanes. This results in under-utilization of the ETC lane which also brings down the total throughput of the plaza. In order to increase the throughput further, it is imperative that E-PASS vehicles use dedicated ETC lane. Lane-choices rules have been used to assign different types of vehicles to valid toll lanes, so that a vehicle is not stuck in a wrong lane.

3. Lane-Choices Rules

Ideally, manual vehicles are expected to divide themselves into two groups for two sets of manual lanes (lanes 1, 2, and 6, 7, 8, 9). E-PASS vehicles should stay in the middle of the roadway (lane 5), while ACM vehicles should occupy space just right of the center. Lane-choice (*see Section 5.1.2*) is the primary tool used to distribute vehicles in different lanes. Three links near the toll plaza (links 9:17, 17:10 and 10:11) have each 9 lanes. Other upstream links have 6 or less lanes. Lane-choices rules can only be defined when there is addition or drop in number of lanes. Links 6:7, 7:8, and 8:9 have four, five and six lanes respectively (*see Figure 14*).

Lane-choices rules are applied to vehicles as they travel on upstream links (6:7, 7:8, and 8:9). The following lane-choices rules are found to be the best for the given configuration of the toll plaza model (*defined in Tables 6, 7, and 8*).

Lane-choices rules defined in Table 6 apply to vehicles while they are traveling on link 6:7 and going towards node 8 and 9. It tells the manual vehicles to split themselves into two groups of 30% and 70%, and occupy lanes 1 and 4 respectively. This rule also tells the ACM and E-PASS vehicles to use lane 2 and 3 respectively, while traveling on link 6:7.

Table 6: Lane-choices Rules - Link 6:7 -> 8 -> 9

	Manual	ACM	E-PASS
Lane 1	30 %	0 %	0 %
Lane 2	0 %	100 %	0 %
Lane 3	0 %	0 %	100 %
Lane 4	70 %	0 %	0 %

Similarly, lane-choices rules have been defined for vehicles traveling on links 7:8 and 8:9 (*see Tables 7 and 8*). It was found that the manual vehicles were occupying proper lanes by the time they reach the link 8:9, and therefore there was no need to define rules for them at this point (*see Table 8*).

Table 7: Lane-choices Rules – Link 7:8 -> 9 -> 17

	Manual	ACM	E-PASS
Lane 1	30 %	0 %	0 %
Lane 2	0 %	0 %	0 %
Lane 3	0 %	100 %	0 %
Lane 4	0 %	0 %	100 %
Lane 5	70 %	0 %	0 %

Table 8: Lane-choices Rules – Link 8:9 -> 17 -> 10

	ACM	E-PASS
Lane 1	0 %	0 %
Lane 2	0 %	0 %
Lane 3	100 %	0 %
Lane 4	0 %	100 %
Lane 5	0 %	0 %
Lane 6	0 %	0 %

On links upstream of the toll plaza, manual vehicles were broadly divided into two groups so that each group uses one set of manual lanes (lanes 1, 2, and lanes 6, 7, 8, 9) at the plaza. A split of 30-70 was found to be the most effective for manual vehicles (*see Table 6*). Assigning lane-choices rules for manual vehicles for link 8:9 produced chaotic movement, and it produced unnecessary weaving phenomenon among them. Not defining any rule for this link worked best for manual vehicles. Next-lane allocation was used to assign vehicles to different lanes after this point.

Assignment of zero percent vehicles in lane-choices rules for a particular lane (i.e., lane 2 in Table 7, and lanes 2, 5, and 6 in Table 8) does not mean that these lanes are not occupied by the vehicles. Lane 2 in links 7:8 and 8:9 will be occupied by vehicles coming from lanes 2 and 3 in link 6:7, with the help of next-lane allocation and by the virtue of continuous weaving taking place due to enforcement of the lane-choices rules. For example, if there are ACM vehicles in lane 1 on link 6:7, then they will try to come to lane 3 in links 7:8 and 8:9 (see Tables 7 and 8), and hence lane 2 in these two downstream links will be occupied by the ACM vehicles. Similarly, lanes 5 and 6 in link 8:9 will be occupied by manual vehicles coming from lane 5 in link 7:8 (see Table 7) and lane 4 in link 6:7 (see Table 6). Same is true for each lane, and each vehicle type for every link for which lane-choices rules are defined. Lane-choices rules define the targeted distribution of different vehicle types in lane, which PARAMICS tries to achieve.

Although, there are two ACM lanes at the toll plaza, ACM vehicles are restricted to a single lane in each rule (*see Tables 6, 7, and 8*). Despite this, many ACM vehicles travel on lanes other than the designated lane. It was found that assigning 100% of ACM vehicles to one lane resulted in the least interference, and as a result hourly throughput increased. Near the toll plaza, ACM vehicles were split into two lanes with the help of next-lane feature. Using both lane-choices and next-lane was found to be more effective than using just lane-choices rules to split ACM vehicles in two lanes.

There is only one ETC lane, and therefore E-PASS vehicles are assigned to a single lane from beginning to end (*see Table 6*). Although, other vehicle types are not supposed to use the lane designated for E-PASS vehicles, many manual and ACM vehicles occasionally travel in this lane. As a result, E-PASS vehicles perform lane change, and move onto empty spaces in other lanes. Such E-PASS vehicles usually exit the toll plaza by using either manual or ACM toll lanes. Therefore, the proportion of vehicles using ETC lane (18.78%, *see Table 9*) is significantly less than the proportion of E-PASS vehicles in traffic stream (26.56%, *see page 61*).

Table 9: Simulation Output using Next-lane and Lane-Choices, at Default Parameter Values

Lane number	Hourly Volume (veh/h)	Percentage of Total Volume	Percentage by Vehicle Type
Lane 1 (M)	384	9.91	M = 51.32
Lane 2 (M)	341	8.80	
Lane 3 (A)	551	14.22	A = 29.90
Lane 4 (A)	608	15.69	
Lane 5 (E)	728	18.78	E =18.78
Lane 6 (M)	378	9.75	
Lane 7 (M)	273	7.04	
Lane 8 (M)	279	7.20	
Lane 9 (M)	334	8.62	
Total	3876		

Since a significant proportion of E-PASS vehicles are using lanes other than the dedicated ETC lane, and since other vehicle types (manual and automatic coin machine) are not allowed to use the dedicated ETC lane, this lane remains under-utilized.

As a result throughput of ETC lane (728 veh/hr, *see Table 9*) is only slightly higher than those of ACM lanes (551 veh/hr and 608 veh/hr, *see Table 9*). Moreover, this phenomenon reduces the overall throughput of the plaza. However, application of lane-choices rules and next-lane allocation significantly improved the throughput of ETC lanes, which is up from 1.77 % (*see Table 5*) to 18.78 % (*see Table 9*). Streamlining the movement of vehicles just upstream of the toll plaza brought the throughput value for the toll plaza to 3876 vehicles during morning peak hour, which is about 500 more vehicles compared to the previous stage. However, this figure is still far below the observed value of 5075 vehicles as recorded in the field. Further steps are taken to improve the traffic operation at the toll plaza, and which are discussed in the fourth stage of the calibration.

4. Qualitative Adjustments

After three stages of the calibration, vehicular movements were very smooth due to the absence of excessive weaving upstream of the toll plaza. All the toll lanes were properly utilized (because of the application of Next-lane feature), and most of the vehicles arrived at one of the valid payment lanes (because of the application of Lane-choices rules). However, a small fraction of vehicles still arrived at invalid payment lanes (i.e., manual vehicle at the beginning of ETC lane). These vehicles block the lanes until they find a suitable gap in their payment lanes. When they find a suitable gap in their payment lanes, they perform very unrealistic maneuvering across node 10 (*see Figure 28*) to reach to their lanes. Such vehicles are forced to move to correct payment lane before entering the toll lanes (link 10:11). Once inside the toll lanes (solid white lines), they cannot change their lane. Even if a single vehicle is stuck in wrong lane for some reason, it reduces throughput of that lane very much.

Figure 28: Holland East Plaza -1995 Close View

However, from practical experience it can be observed that lane changing does not take place so near the toll plaza. In real life, almost all of the vehicles reaching node 10 would have already chosen the correct lane. And if for some reason, a vehicle reaches at node 10, and is traveling in a wrong lane, it is not possible for the vehicle to move itself into a correct lane. Such vehicles will drive through the toll plaza using the current lane.

So, lane restrictions have been moved upstream, and are now applied to link 9:17. Most of the vehicles are filtered at this link, but at the same time vehicles are not forced to stay in the lane (mark that link 9:17 has dotted lines unlike solid lines at in toll link 10:11). The majority of the vehicles have already chosen a correct lane at that link. If a vehicle is still in wrong lane, it can easily steer itself into the correct lane because there is enough distance to be traveled before reaching toll booths. Lane blockages just upstream of the toll booth have been alleviated, and this simple improvement results in an upsurge in the throughput of the toll plaza (*see Table 10*).

Table 10: Simulation Output after Weaving Phenomena is Minimized

Lane number	Hourly Volume (veh/h)	Percentage of Total Volume	Percentage by Vehicle Type
Lane 1 (M)	383	7.40	M = 48.70
Lane 2 (M)	403	7.79	
Lane 3 (A)	588	11.37	A = 22.96
Lane 4 (A)	600	11.60	
Lane 5 (E)	1466	28.34	E = 28.34
Lane 6 (M)	442	8.54	
Lane 7 (M)	361	6.98	
Lane 8 (M)	464	8.97	
Lane 9 (M)	466	9.01	
Total	5173		

Now, the total peak-hour volume of 5173 vehicles is very close to the observed value of 5075. Proportions of different types of vehicles are also very close to the real life proportions. Simulation results presented in Table 10 have been compared with the real life observed volume (*see Table 3*) for accuracy. These comparisons are presented in Table 11. GEH statistics is less than 5 for all the lanes, except lane 5, which indicates that the volume has been optimally calibrated for these lanes, and is considered a good fit. GEH value of 5.13 for lane 5 is very close to the target, but it may require further investigation.

In the fifth stage, calibration effort has been further tuned up by adjusting key simulation parameters (queue gap distance, queue speed, mean target headway, driver reaction time and minimum gap). Simulation parameters have been adjusted to bring the results closer to the observed values of volume as well as delay.

Table 11: GEH Statistics for Simulation Results – at Default Parameter Values

Lane number	Hourly Volume (Observed)	Hourly Volume (Simulated)	GEH
Lane 1 (M)	NA	383	NA
Lane 2 (M)	373	403	1.52
Lane 3 (A)	NA	588	NA
Lane 4 (A)	605	600	0.19
Lane 5 (E)	1276	1466	5.13
Lane 6 (M)	461	442	0.89
Lane 7 (M)	NA	361	NA
Lane 8 (M)	NA	464	NA
Lane 9 (M)	NA	466	NA
Total	5075	5173	1.37

NA – Not Available/ Not Applicable

Calibration for Delay

5. Calibration of Key Simulation Parameters

The final stage of calibration is primarily driven by calibration for delay values. Procedure to calculate delay values from the field data is discussed in detail earlier (*see page 56*). To follow the same procedure of delay calculation using the simulation, the number of vehicles queued upstream of the toll plaza is recorded at interval of one minute. Queue lengths calculated over an hour are summed up to calculate total vehicle-minutes of delay.

It has been found that the ‘Queue gap distance’ and ‘Queuing speed’ are the calibration parameters which affect the delay values most. A higher value of ‘Queue gap distance’ results in increased delay values. Similarly, delay values are proportional to the value of ‘Queuing speed’ parameter. ‘Mean target headway’ and ‘Mean reaction time’ primarily affect throughput of the toll plaza. High value of ‘Mean target headway’ results in reduced throughput. When ‘mean reaction time’ is reduced, it also brings down the throughput value. This may be due to the fact that due of smaller reaction time, drivers become very active and aggressive near the toll plaza and add to the already chaotic situation there. This may result in unnecessary lane changing maneuverings, which will lead to lane blockages and ultimately reduction in throughput of the toll plaza. ‘Minimum gap’ parameter also affects the delay value, but is not as sensitive as ‘Queue gap distance’ and ‘Queuing speed’.

Knowing the relation of these parameters with throughput and delay values helped in adjusting them in order to match the outputs with observed data. After optimal adjustment of these parameters, GEH statistics for all the lanes were less than 5 (*see Table 12*). Also, queue lengths calculated over an hour were summed up, which produced delay value 3618 veh-min for the morning peak hour. Zarrillo (*6*) recorded 3494 veh-min of average delay (average of June 7 and June 14, 1995 delay data) from video data for the toll plaza, and therefore delay value from simulation has an error of 3.4 % compared to the observed value. The calibrated values of stop times are as follows: 3 sec for automatic coin machine lanes, and a uniform distribution between 5 sec and 6 sec for manual payment lanes.

Table 12: GEH Statistics for Simulation Results – at Adjusted Parameter Values

Lane number	Hourly Volume (Observed)	Hourly Volume (Simulated)	GEH
Lane 1 (M)	NA	365	NA
Lane 2 (M)	373	401	1.42
Lane 3 (A)	NA	576	NA
Lane 4 (A)	605	609	0.18
Lane 5 (E)	1276	1387	3.04
Lane 6 (M)	461	425	1.71
Lane 7 (M)	NA	362	NA
Lane 8 (M)	NA	449	NA
Lane 9 (M)	NA	437	NA
Total	5075	5011	0.90

NA – Not available/ Not Applicable

After optimal values of all these parameters are obtained (*see Table 13*), the model is satisfactorily calibrated for volume and delay values.

Table 13: Adjusted Values of Parameters

Parameters	Default Value	Adjusted Value
Queue Gap Distance (ft)	32.81	26.00
Queuing Speed (mph)	4.47	15.00
Mean Target Headway (s)	1.0	1.5
Mean Reaction Time (s)	1.0	1.0
Minimum Gap (ft)	6.56	3.00

6.4.1.1 Determining the Number of Simulation Runs (37)

Microsimulation models use random seed numbers to perform simulation runs. The starting points of the simulation runs are different for different seed numbers. This random seed number is used to select a series of random numbers which are used to make certain decisions throughout the simulation run. It can be used to make a decision as to which vehicle type should be loaded next, which lane number the vehicle will start running initially, level of aggressiveness of the driver … etc. Each of these decisions will result in a unique simulation run with a specific sequence of events throughout the simulation runs. Every seed number will result in a different final simulation result. Multiple repetitions of the same model with different seed numbers are required to estimate the mean value with a certain level of confidence that the true mean falls within a target interval.

The following information is required to determine the required number of simulation runs:

- Standard deviation of the sample
- Desired level of confidence
- Desired length of confidence interval

Determining the required number of simulation runs is an iterative process. A preliminary set of simulation runs is usually required to get the first estimate of the standard deviations for the results. This estimate is then used to calculate the number of simulation runs required to make statistical conclusions.

Estimation of Sample Standard Deviation

The initial estimate of the sample standard deviation can be based on the past experience. If it is not known by experience, then a minimum number of simulation runs are executed with different seed numbers to calculate it.

$$s^2 = \frac{\sum (x - \overline{x})^2}{N - 1}$$

Where:

s = standard deviation
x = variable for which sample variance is desired
$\overline{x}$ = average value of the variable
N = number of model runs

Unless the analyst already knows the standard deviation from experience, it is recommended that four repetitions be performed for the initial estimation of the standard deviation. This initial estimate is then revisited and revised later if and when additional repetitions are performed for the purposes of obtaining more precise estimates of mean values or for alternatives analysis.

Selection of Desired Confidence Level

The confidence level is the probability that the true mean lies within the target confidence interval. The analyst must decide as to what degree he or she wishes to know the interval in which the true mean value lies. The usual approach is to pick a 95-percent level of confidence; however, analysts may choose higher or lower levels of confidence. Higher levels of confidence require more repetitions. For the purpose of this study, a confidence level of 95% has been chosen.

Selection of length of Confidence Interval

The confidence interval is the range of values within which the true mean value may lie. The length of the interval is at the discretion of the analyst and may vary according to the purposes for which the results will be used. For example, if the analyst is testing alternatives that are very similar, then a very small confidence interval will be desirable to distinguish between the alternatives. If the analyst is testing alternatives with greater differences, then a larger confidence interval can be tolerated. Smaller confidence intervals require more repetitions to achieve a given level of confidence. Confidence intervals that are less than half the value of the standard deviation will require a large number of repetitions to achieve reasonable confidence levels. For the purpose of this study, 5% of the mean value is chosen as the confidence interval.

Number of Runs Needed

It is impossible to know in advance exactly how many model runs will be needed to determine a mean (or any other statistical value) to the analyst's satisfaction. However, after a few model runs, the analyst can make an estimate of how many more runs may be required to obtain a statistically valid result.

The required minimum number of model repetitions is computed using the following equation:

$$CI_{(1-\alpha)\%} = 2 \times t_{(1-\alpha/2),N-1} \frac{s}{\sqrt{N}}$$

Where:

$CI_{(1-\alpha)\%}$ = (1-α) % confidence interval for the true mean, where α equals the probability of the true mean not lying within the confidence interval.

$t_{(1-\alpha/2),N-1}$ = Student's t-statistic for the probability of a two-sided error summing to α with N-1 degrees of freedom, where N equals the number of repetitions.

s = standard deviation of the model results.

At 95% confidence interval, α = 5, and initial number of runs, N = 4

$$t_{(1-\alpha/2),N-1} = 2.354$$

Initially, simulations were run using ten different seed numbers and total plaza throughputs are recorded in Table 14. These simulation runs are used to determine mean value of the throughput and its initial standard deviation. After that, at 95% confidence level, the required number of simulation runs are determined, which will provide the desired confidence interval. The desired confidence interval is set at 5% of the mean value of the throughput.

Initial number of runs = 10

$$\bar{x} = 5004.7$$
$$s^2 = \frac{\sum (x-\bar{x})^2}{N-1} = 4138$$
$$s = 64.33$$

Level of confidence = 95% (i.e., α = 5)

Since the desired confidence interval is chosen as 5% of the mean value, a confidence interval of 250 veh/hr (5% of 5004.7 veh/hr) is the target.

Table 14: Hourly Volume at Different Seed Numbers

S. No.	Seed Number	Hourly Volume
1	5	5011
2	20	5094
3	50	4988
4	123	4896
5	786	5021
6	1000	5032
7	5432	4916
8	9999	4973
9	12345	5086
10	13579	5030

Solving $CI_{(1-\alpha)\%} = 2 \times t_{(1-\alpha/2),N-1} \frac{s}{\sqrt{N}}$ to determine the required number of simulation runs, N, is an iterative procedure. Initially, it is assumed that N = 2, and then the confidence interval is calculated (*see Table 15*). Since it does not meet the criterion for confidence interval (which is CI = 250 veh/hr), value of N is increased one step at time until the desired confidence interval is achieved.

Table 15: Determining Sufficiency of Simulation Runs

Assumed no. of simulation runs, N	$t_{(1-\alpha/2),N-1}$	CI
2	12.71	1156
3	4.303	319
4	3.181	204

After two steps, it is clear that only four simulation runs were required to achieve the desired confidence interval of 250 veh/hr. Since the actual number of runs (N=10) is more than the required number of simulation runs, statistically valid conclusions can be made using the results of these simulation runs.

6.4.2. Holland East Plaza and Downstream Section of SR 408 – 1998

After successfully calibrating the isolated Holland East Plaza for the year 1995 for volume and delay values, the model has been extended to include the downstream section of SR 408 from the plaza till I-4 interchange in downtown Orlando. The Westbound section of 408 between the Holland East Plaza and I-4 interchange contains 3 on-ramps and 4 off-ramps including the off-ramp to I-4. Satellite pictures of small sections in this corridor have been pasted together to act as the overlay for this Holland East Plaza – SR 408 network model. After that, nodes and links have been created in PARAMICS which follow exact geometry and shape of the roadway in an attempt to create a realistic model.

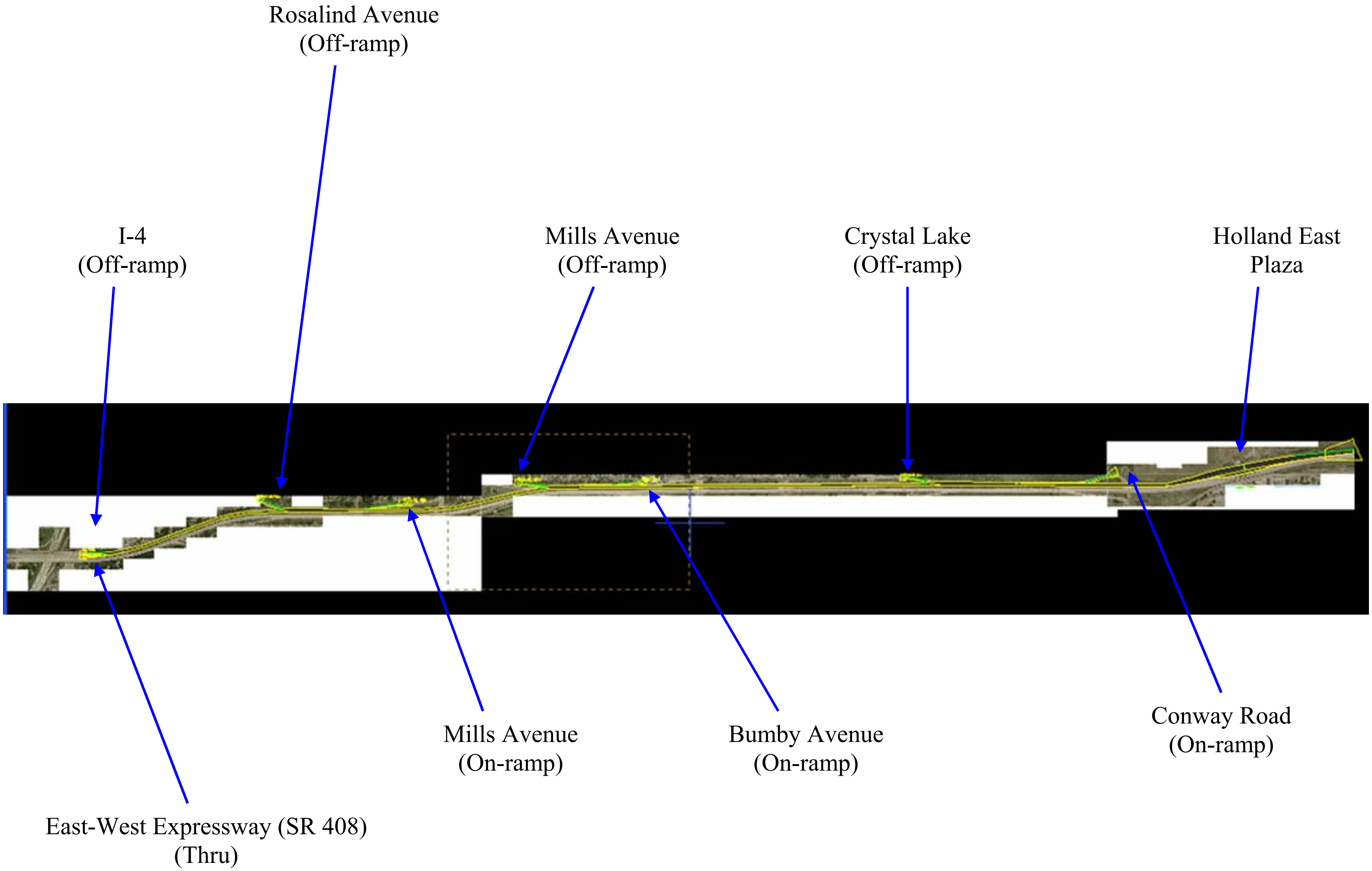


Figure 29: Holland East Plaza – SR408 Corridor

The University of Central Florida (UCF) research team collected the Holland East Plaza mainline volume and individual ramp volumes data in the first week of January, 1998 (*see Table 16*). Data was collected between 6 AM – 9 AM for this corridor.

Table 16: Plaza and Ramp Volumes – January, 1998

	HOLLAND EAST	*CONWAY ON*	*CRYSTAL LK. OFF*	*BUMBY ON*	*MILLS OFF*	*MILLS ON*	*ROSALIND OFF*	*EW (SR 408) THR OFF*	*I-4 RAMP OFF*
TIME SLICE	VOL	VOL	VOL	VOL	VOL	VOL	VOL	VOL	VOL
6:00 AM	119	9	1	6	4	3	21	30	92
6:05 AM	171	26	3	5	4	2	24	44	102
6:10 AM	195	19	3	4	9	3	27	42	140
6:15 AM	239	33	8	5	9	1	41	64	136
6:20 AM	283	31	8	9	7	3	53	83	161
6:25 AM	257	38	12	8	13	2	63	70	174
6:30 AM	337	33	9	7	9	4	78	88	165
6:35 AM	325	47	9	12	22	1	70	106	185
6:40 AM	351	40	10	12	20	1	94	120	154
6:45 AM	376	43	17	10	16	3	93	141	128
6:50 AM	357	43	25	12	19	3	86	144	134
6:55 AM	385	42	21	6	22	3	91	106	170
7:00 AM	389	50	20	11	20	4	83	146	147
7:05 AM	419	45	22	5	26	1	94	140	156
7:10 AM	454	47	34	6	46	6	104	158	158
7:15 AM	503	35	34	14	45	4	125	172	169
7:20 AM	514	58	53	21	62	3	160	161	169
7:25 AM	520	44	37	13	62	5	153	181	149
7:30 AM	584	51	43	13	66	8	132	188	171
7:35 AM	578	64	43	8	59	2	144	199	168
7:40 AM	591	60	53	20	59	2	26	221	152
7:45 AM	589	64	48	18	48	3	62	214	171
7:50 AM	580	62	49	11	74	5	137	239	132
7:55 AM	587	65	45	16	71	1	124	211	179
8:00 AM	587	46	49	10	60	1	135	194	166
8:05 AM	478	37	54	12	63	3	144	187	189
8:10 AM	533	54	40	12	67	5	130	173	162
8:15 AM	500	42	54	15	71	6	139	161	157
8:20 AM	516	48	50	13	66	3	133	165	150
8:25 AM	438	52	50	8	65	2	133	156	157
8:30 AM	419	30	48	16	77	5	127	137	168
8:35 AM	415	45	36	14	64	5	119	131	182
8:40 AM	373	70	37	10	50	3	131	131	168
8:45 AM	419	36	19	21	41	4	111	130	174
8:50 AM	358	41	34	19	49	7	83	109	175
8:55 AM	316	36	21	17	47	2	72	108	175
Date:	1/6/1998	1/6/1998	1/7/1998	1/6/1998	1/7/1998	1/6/1998	1/7/1998	1/6/1998	1/6/1998
Viewer:	Jack	Jack	Ayman	Jack	Marguerite	Jack	Matt	Matt	Matt

These individual ramp volumes and the Holland East Plaza (HEP) volume will be used to calibrated the HEP – SR 408 network model. For the purpose of this study, volume data between 7 AM – 8 AM has been extracted from the above table (*see Table 17*).

Table 17: Plaza and Ramp Volumes, 7 AM - 8 AM

Location	Volume
Holland East Plaza	6308
Conway Rd. (On-ramp)	645
Crystal Lk. (Off-ramp)	481
Bumby Ave. (On-ramp)	156
Mills Ave. (Off-ramp)	638
Mills Ave. (On-ramp)	44
Rosalind Off	1344
SR408 Thru	2230
I-4 Off-ramp	1921

The Holland East Plaza peak-hour volume as recorded in January, 1998 by UCF (6308 vehicles) is very high, and close to the peak-hour volume recorded by the OOCEA in *2004* (6356 vehicles) (*35*). Since Orlando is a major tourist area, and data is collected just after holiday season, mainline toll plaza volume available in Table 16 is not representative of a typical day. Plaza volume was also recorded by UCF research team during March 1998, and this data seems to represent and average day (*See Table 18*). Plaza volume during 7 AM – 8 AM on March 18, 1998 and March 19, 1998 were 5668 and 5474 vehicles respectively. An average volume of 5571 vehicles is used for the calibration purpose. Volumes for SR 408 Thru and I-4 Off-ramp (see *Table 17*) have been proportionally reduced. It is assumed that intermediate ramps between the Holland East Plaza and the I-4 interchange are used by commuter traffic, and therefore the volume data available in Table 16 for such ramps are representative of a typical day.

Table 18: HEP Volume - March 1998

March 18, 1998		March 19, 1998	
Time	15 min Count	Time	15 min Ct
6:00:00	606	6:00:00	535
6:15:00	730	6:15:00	804
6:30:00	1008	6:30:00	999
6:45:00	1035	6:45:00	1021
7:00:00	1213	7:00:00	1162
7:15:00	1425	7:15:00	1388
7:30:00	1651	7:30:00	1543
7:45:00	1379	7:45:00	1381
8:00:00	1323	8:00:00	1310
8:15:00	1241	8:15:00	1222
8:30:00	1149	8:30:00	1120
8:45:00	973	8:45:00	974

After the adjustment of volumes, the following set of volume data has been used in calibrating the HEP – SR 408 network model (*see Table 19*).

Table 19: Plaza and Ramp Volumes (Adjusted), 7 AM - 8 AM

Location	Volume
Holland East Plaza	5571
Conway Rd. (On-ramp)	645
Crystal Lk. (Off-ramp)	481
Bumby Ave. (On-ramp)	156
Mills Ave. (Off-ramp)	638
Mills Ave. (On-ramp)	44
Rosalind Off	1344
I-4 Off-ramp	1697
SR408 Thru	1969

After adjusting the ramp and the plaza volumes, the next step is to set up an origin-destination matrix. Since, on-ramps and the upstream section of the Holland East Plaza are the only sources of vehicles entering this network; they are treated as origins in the O-D matrix. On the other hand, vehicles exit the network using the off-ramps and SR 408 thru link, so these are treated as destinations.

It is to be noted that since the network contains only one direction of the roadway (i.e., SR 408 Westbound), a ramp can only act as either an origin or a destination. In other words, a traffic zone associated with a ramp is either only supplying vehicles to the HEP- SR 408 network, or it is only taking vehicles off the network. This feature greatly simplifies the initial estimation of the O-D matrix, and renders it a linear problem.

In addition, several reasonable assumptions have been made to further simplify the O-D matrix estimation. It is evident from the network diagram (*see Figure 29*) that there are three pairs of "on-ramp – off-ramp" which form weaving zones. These pairs are listed below:

Pair A. Conway Road (on-ramp) followed by Crystal Lake Dr. (off-ramp)

Pair B. Bumby Avenue (on-ramp) followed by Mills Avenue (off-ramp)

Pair C. Mills Avenue (on-ramp) followed by Rosalind Avenue (off-ramp)

Because of the following two factors, it can be safely assumed that no vehicles will enter the roadway using one of the above on-ramps, and exit at the next off-ramp (for example, vehicles will not enter SR 408 using Mills Avenue and exit at Rosalind Avenue):

i. Distance between these pairs of on-ramp and off-ramp is very small, and there is cost associated with using the toll road.

ii. A parallel network of arterials exist (which are direct and free of cost), which will serve as alternative routes to such traffic demands, if any.

However, this condition needs to be relaxed for the first pair, Conway Rd. (on-ramp) – Crystal Lake Dr. (off-ramp). Vehicles coming from Conway Road do not have the option of a direct arterial connection to Crystal Lake Dr. This is not to say that there is no alternative route for vehicles traveling on Conway Road and going to Crystal Lake Dr. Unlike the next two pairs (pairs 'B' and 'C'), the first pair does not have an option of an arterial running parallel to SR 408 which will lead to their destinations directly. Moreover, for pairs 'B' and 'C', on-ramps and off-ramps are on the same side of the roadway, which further makes the option of choosing the arterials more attractive. On the other hand, for pair 'A', vehicles are coming from a road which runs perpendicular to SR 408, and their destination is on the other side of the toll road.

For the initial estimation of the O-D matrix, it can be safely assumed that there will be no traffic from Bumby Avenue (on-ramp) to Mills Avenue (off-ramp), and from Mills Avenue (on-ramp) to Rosalind Avenue (off-ramp). As discussed in the previous paragraph, it has been assumed that there can be small traffic from Conway Road (on-ramp) to Crystal Lake Dr. (off-ramp).

<u>Steps of O-D Matrix Estimation</u>

1. It is clear that none of the off-ramps will act as origins. So, rows in O-D matrix corresponding to the off-ramps will contain zero volume. Similarly, none of the on-ramps will act as destinations. So, columns in O-D matrix corresponding to the on-ramps will contain zero volume (*see Table 20*). It is also known that how much vehicles an origin will release, or a destination will receive (*see Table 19*).

Table 20: O-D Matrix Estimation - Step 1

		Destinations									
		Holland East Plaza	Conway Rd. (On-ramp)	Crystal Lk. Dr. (Off-ramp)	Bumby Ave. (On-ramp)	Mills Ave. (Off-ramp)	Mills Ave. (On-ramp)	Rosalind Ave. (Off-ramp)	I-4 Off-ramp	SR 408 Thru	Total (= 6416)
Origins	Holland East Plaza	0	0		0		0				5571
	Conway Rd. (On-ramp)	0	0		0		0				645
	Crystal Lk. Dr (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	Bumby Ave. (On-ramp)	0	0		0		0				156
	Mills Ave. (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	Mills Ave. (On-ramp)	0	0		0		0				44
	Rosalind Ave. (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	I-4 Off-ramp	0	0	0	0	0	0	0	0	0	0
	SR 408 Thru	0	0	0	0	0	0	0	0	0	0
	Total (= 6129)	0	0	481	0	638	0	1344	1697	1969	

2. Since the initial O-D matrix is constructed using the volumes at entry and exit points in the network, it is not based on an O-D matrix estimation study per se. Therefore, there is a mismatch in the total number of vehicles that origins will release (6416 vehicles) and the total number of vehicles that destinations will receive (6129 vehicles). The numbers of vehicles present inside the network are not taken care of as such. In a perfect O-D

matrix, these two figures should be same. At present, origins are releasing 287 (= 6416 – 6129) more vehicles than what destinations are receiving. These surplus vehicles are distributed to destinations, in proportion of their current volume. For example, Crystal Lk. Dr. (off-ramp) will receive $481+\frac{481}{6129}\times\left(6416-6129\right)=503.52\approx 504$ vehicles.

Table 21: O-D Matrix Estimation - Step 2

		Destinations									
		Holland East Plaza	Conway Rd. (On-ramp)	Crystal Lk. Dr. (Off-ramp)	Bumby Ave. (On-ramp)	Mills Ave. (Off-ramp)	Mills Ave. (On-ramp)	Rosalind Ave. (Off-ramp)	I-4 Off-ramp	SR 408 Thru	Total (= 6416)
Origins	Holland East Plaza	0	0		0		0				5571
	Conway Rd. (On-ramp)	0	0		0		0				645
	Crystal Lk. Dr (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	Bumby Ave. (On-ramp)	0	0		0		0				156
	Mills Ave. (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	Mills Ave. (On-ramp)	0	0		0		0				44
	Rosalind Ave. (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	I-4 Off-ramp	0	0	0	0	0	0	0	0	0	0
	SR 408 Thru	0	0	0	0	0	0	0	0	0	0
	Total (= 6416)	0	0	*504*	0	*668*	0	*1407*	*1776*	*2061*	

(Note: Entries in *Italics* are the ones which are added/updated in the current step)

The adjusted O-D matrix, in which the total number of vehicles released by origins is equal to the total number of vehicles received by destinations, is provided (*see Table 21*).

3. As discussed above, there will be no traffic going from Bumby Ave. (on-ramp) to Mills Ave. (off-ramp), and from Mills Ave. (on-ramp) to Rosalind Ave. (off-ramp) (*see Table 22*).

Table 22: O-D Matrix Estimation - Step 3

		Destinations									
		Holland East Plaza	Conway Rd. (On-ramp)	Crystal Lk. Dr. (Off-ramp)	Bumby Ave. (On-ramp)	Mills Ave. (Off-ramp)	Mills Ave. (On-ramp)	Rosalind Ave. (Off-ramp)	I-4 Off-ramp	SR 408 Thru	Total (= 6416)
Origins	Holland East Plaza	0	0		0		0				5571
	Conway Rd. (On-ramp)	0	0		0		0				645
	Crystal Lk. Dr (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	Bumby Ave. (On-ramp)	0	0		0	*0*	0				156
	Mills Ave. (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	Mills Ave. (On-ramp)	0	0		0		0	*0*			44
	Rosalind Ave. (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	I-4 Off-ramp	0	0	0	0	0	0	0	0	0	0
	SR 408 Thru	0	0	0	0	0	0	0	0	0	0
	Total (= 6416)	0	0	504	0	668	0	1407	1776	2061	

4. An off-ramp which is located earlier (while traveling on SR 408 Westbound) cannot receive a vehicle from an on-ramp which is located later. For example, Crystal Lake Dr. (off-ramp) will not receive any vehicle from Bumby Ave. (on-ramp), because while traveling on SR 408 Westbound, Bumby Ave. comes after Crystal Lake Dr. .

Table 23: O-D Matrix Estimation - Step 4

		Destinations									
		Holland East Plaza	Conway Rd. (On-ramp)	Crystal Lk. Dr. (Off-ramp)	Bumby Ave. (On-ramp)	Mills Ave. (Off-ramp)	Mills Ave. (On-ramp)	Rosalind Ave. (Off-ramp)	I-4 Off-ramp	SR 408 Thru	Total (= 6416)
Origins	Holland East Plaza	0	0		0		0				5571
	Conway Rd. (On-ramp)	*0*	0		0		0				645
	Crystal Lk. Dr (Off-ramp)	*0*	*0*	0	0	0	0	0	0	0	0
	Bumby Ave. (On-ramp)	*0*	*0*	*0*	0	0	0				156
	Mills Ave. (Off-ramp)	*0*	*0*	*0*	*0*	0	0	0	0	0	0
	Mills Ave. (On-ramp)	*0*	*0*	*0*	*0*	*0*	0	0			44
	Rosalind Ave. (Off-ramp)	*0*	*0*	*0*	*0*	*0*	*0*	0	0	0	0
	I-4 Off-ramp	*0*	*0*	*0*	*0*	*0*	*0*	*0*	0	0	0
	SR 408 Thru	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	0	0
	Total (= 6416)	0	0	504	0	668	0	1407	1776	2061	

And, since in the O-D matrix ramps are listed in the order in which they appear on SR 408 Westbound, the lower triangular half of the O-D matrix will have zero volumes (*see Table 23*).

5. Vehicles exiting at Crystal Lake Dr. (off-ramp) can come either from the Holland East Plaza or Conway Rd. (on-ramp).

Table 24: O-D Matrix Estimation - Step 5

		Destinations									
		Holland East Plaza	Conway Rd. (On-ramp)	Crystal Lk. Dr. (Off-ramp)	Bumby Ave. (On-ramp)	Mills Ave. (Off-ramp)	Mills Ave. (On-ramp)	Rosalind Ave. (Off-ramp)	I-4 Off-ramp	SR 408 Thru	Total (= 6416)
Origins	Holland East Plaza	0	0	*452*	0		0				5571
	Conway Rd. (On-ramp)	0	0	*52*	0		0				645
	Crystal Lk. Dr (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	Bumby Ave. (On-ramp)	0	0	0	0	0	0				156
	Mills Ave. (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	Mills Ave. (On-ramp)	0	0	0	0	0	0	0			44
	Rosalind Ave. (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	I-4 Off-ramp	0	0	0	0	0	0	0	0	0	0
	SR 408 Thru	0	0	0	0	0	0	0	0	0	0
	Total (= 6416)	0	0	504	0	668	0	1407	1776	2061	

Total vehicles received by Crystal Lake Dr. (which is 504 vehicles) are divided into the proportions of volume released by above two origins (HEP and Conway Rd.). Therefore, Crystal Lake Dr. receives 452 vehicles from the HEP, and 52 vehicles from Conway Rd. (*see Table 24*).

6. Again, Mills Ave. (off-ramp) will receive vehicles only from the HEP and Conway Rd.

Table 25: O-D Matrix Estimation - Step 6

		Destinations									
		Holland East Plaza	Conway Rd. (On-ramp)	Crystal Lk. Dr. (Off-ramp)	Bumby Ave. (On-ramp)	Mills Ave. (Off-ramp)	Mills Ave. (On-ramp)	Rosalind Ave. (Off-ramp)	I-4 Off-ramp	SR 408 Thru	Total (= 6416)
Origins	Holland East Plaza	0	0	452	0	*599*	0				5571
	Conway Rd. (On-ramp)	0	0	52	0	*69*	0				645
	Crystal Lk. Dr (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	Bumby Ave. (On-ramp)	0	0	0	0	0	0				156
	Mills Ave. (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	Mills Ave. (On-ramp)	0	0	0	0	0	0	0			44
	Rosalind Ave. (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	I-4 Off-ramp	0	0	0	0	0	0	0	0	0	0
	SR 408 Thru	0	0	0	0	0	0	0	0	0	0
	Total (= 6416)	0	0	504	0	668	0	1407	1776	2061	

The method described in Step 5 is applied to calculate volumes. Parts of the volumes originating at these two origins have already been assigned to Crystal Lake Dr. The number of vehicles arriving at Mills Ave., which is 668, is again distributed in proportions of the volumes (remained after assigning traffic to Crystal Lake Dr.) originating at the above two origins (*see Table 25*).

7. Rosalind Ave. (on-ramp) receives volumes from the HEP, Conway Rd., and Bumby Ave.

Table 26: O-D Matrix Estimation - Step 7

		Destinations									
		Holland East Plaza	Conway Rd. (On-ramp)	Crystal Lk. Dr. (Off-ramp)	Bumby Ave. (On-ramp)	Mills Ave. (Off-ramp)	Mills Ave. (On-ramp)	Rosalind Ave. (Off-ramp)	I-4 Off-ramp	SR 408 Thru	Total (= 6416)
Origins	Holland East Plaza	0	0	452	0	599	0	*1223*			5571
	Conway Rd. (On-ramp)	0	0	52	0	69	0	*142*			645
	Crystal Lk. Dr (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	Bumby Ave. (On-ramp)	0	0	0	0	0	0	*42*			156
	Mills Ave. (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	Mills Ave. (On-ramp)	0	0	0	0	0	0	0			44
	Rosalind Ave. (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	I-4 Off-ramp	0	0	0	0	0	0	0	0	0	0
	SR 408 Thru	0	0	0	0	0	0	0	0	0	0
	Total (= 6416)	0	0	504	0	668	0	1407	1776	2061	

Volumes coming to Rosalind Ave. from these three origins are again calculated using the method applied in step 6 (*see Table 26*).

8. Similar method is used to assign traffic coming to I-4 off-ramp (*see Table 27*).

Table 27: O-D Matrix Estimation - Step 8

		Destinations									
		Holland East Plaza	Conway Rd. (On-ramp)	Crystal Lk. Dr. (Off-ramp)	Bumby Ave. (On-ramp)	Mills Ave. (Off-ramp)	Mills Ave. (On-ramp)	Rosalind Ave. (Off-ramp)	I-4 Off-ramp	SR 408 Thru	Total (= 6416)
Origins	Holland East Plaza	0	0	452	0	599	0	1223	*1526*		5571
	Conway Rd. (On-ramp)	0	0	52	0	69	0	142	*177*		645
	Crystal Lk. Dr (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	Bumby Ave. (On-ramp)	0	0	0	0	0	0	42	*53*		156
	Mills Ave. (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	Mills Ave. (On-ramp)	0	0	0	0	0	0	0	*20*		44
	Rosalind Ave. (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	I-4 Off-ramp	0	0	0	0	0	0	0	0	0	0
	SR 408 Thru	0	0	0	0	0	0	0	0	0	0
	Total (= 6416)	0	0	504	0	668	0	1407	1776	2061	

9. All the volumes coming from origins, which have not been assigned till previous step, have been assigned to SR 408 Thru link (*see Table 28*).

Table 28: O-D Matrix Estimation - Step 9

		Destinations									
		Holland East Plaza	Conway Rd. (On-ramp)	Crystal Lk. Dr. (Off-ramp)	Bumby Ave. (On-ramp)	Mills Ave. (Off-ramp)	Mills Ave. (On-ramp)	Rosalind Ave. (Off-ramp)	I-4 Off-ramp	SR 408 Thru	Total (= 6416)
Origins	Holland East Plaza	0	0	452	0	599	0	1223	1526	*1771*	5571
	Conway Rd. (On-ramp)	0	0	52	0	69	0	142	177	*205*	645
	Crystal Lk. Dr (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	Bumby Ave. (On-ramp)	0	0	0	0	0	0	42	53	*61*	156
	Mills Ave. (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	Mills Ave. (On-ramp)	0	0	0	0	0	0	0	20	*24*	44
	Rosalind Ave. (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	I-4 Off-ramp	0	0	0	0	0	0	0	0	0	0
	SR 408 Thru	0	0	0	0	0	0	0	0	0	0
	Total (= 6416)	0	0	504	0	668	0	1407	1776	2061	

After initial O-D matrix is estimated, it is fed into PARAMICS. Simulation parameters obtained after calibrating the isolated Holland East Plaza – 1995 has been used as starting point (*see Table*

13). Since proportion of E-PASS vehicles is more in 1998 compared to 1995, overall mean target headway and mean reaction time is expected to vary slightly for the current model. This is because headway maintained by manual, automatic coin machine, and E-PASS vehicles is different while passing through the toll plaza. Since, now a greater proportion of vehicles (i.e., E-PASS), can maintain a certain speed while passing through the toll plaza and traffic composition is different from that of year 1995, a small change in mean target headway and mean reaction time is expected.

Once the O-D matrix and simulation parameters are fed into PARAMICS, volumes for ramps are obtained as output after the simulation runs. Depending upon the difference between ramp volumes obtained from the simulation and the observed value, the corresponding origin and/or destination volumes are manually adjusted. Mean target headway and mean reaction time are also adjusted to suit the output, and the model is calibrated this way. When GEH statistics for all the ramp volumes is less than 5, the Holland East Plaza model is said to be successfully calibrated. GEH statistics has been calculated after averaging the outputs of ten simulation runs. The final simulation parameters obtained for this model are as follows (*see Table 29*).

Table 29: Adjusted Parameters

Parameters	HEP - 1995	HEP - 1998
Queue Gap Distance (ft)	26.00	*26.00*
Queuing Speed (mph)	15.00	*15.00*
Mean Target Headway (s)	1.5	*1.0*
Mean Reaction Time (s)	1.0	*0.8*
Minimum Gap (ft)	3.00	*3.00*

The final O-D matrix is presented below (*see Table 30*):

Table 30: O-D Matrix

		Destinations									
		Holland East Plaza	Conway Rd. (On-ramp)	Crystal Lk. Dr. (Off-ramp)	Bumby Ave. (On-ramp)	Mills Ave. (Off-ramp)	Mills Ave. (On-ramp)	Rosalind Ave. (Off-ramp)	I-4 Off-ramp	SR 408 Thru	Total (= 7815)
Origins	Holland East Plaza	0	0	501	0	600	0	1400	2000	2200	6701
	Conway Rd. (On-ramp)	0	0	50	0	150	0	170	240	200	810
	Crystal Lk. Dr (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	Bumby Ave. (On-ramp)	0	0	0	0	0	0	48	100	80	228
	Mills Ave. (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	Mills Ave. (On-ramp)	0	0	0	0	0	0	50	0	26	76
	Rosalind Ave. (Off-ramp)	0	0	0	0	0	0	0	0	0	0
	I-4 Off-ramp	0	0	0	0	0	0	0	0	0	0
	SR 408 Thru	0	0	0	0	0	0	0	0	0	0
	Total (= 7815)	0	0	551	0	750	0	1668	2340	2506	

Although, it was earlier anticipated that there will be no traffic going from Mill Ave. (on-ramp) to Rosalind Ave. (off-ramp), the final O-D matrix does contain some vehicles for this O-D pair.

Outputs of ten simulation runs are presented in Table 31.

Table 31: Plaza and Ramp Volumes – Simulation Output (1998)

Location	Volume obtained from Simulation Runs									
	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10
Holland East Plaza	4943	4872	5038	4901	4971	5118	4856	4910	5066	4930
Conway Rd. (On-ramp)	645	645	644	639	684	646	719	694	650	650
Crystal Lk. (Off-ramp)	406	382	425	382	433	437	386	370	394	412
Bumby Ave. (On-ramp)	196	196	189	203	172	208	202	188	180	189
Mills Ave. (Off-ramp)	557	519	556	578	558	560	574	591	548	558
Mills Ave. (On-ramp)	66	53	50	64	63	68	66	63	68	66
Rosalind Ave. (Off-ramp)	1186	1202	1265	1218	1237	1319	1224	1176	1246	1259
I-4 Off-ramp	1756	1692	1753	1672	1664	1754	1683	1735	1760	1708
SR 408 Thru	1910	1838	1829	1884	1850	2009	1764	1821	1831	1790

Average volume obtained from these simulation runs are compared with the observed values (*see Table 32*).

Table 32: GEH Statistics – Simulated and Observed Volumes (1998)

Location	Average Volume (Simulation)	Observed Volume	GEH
Holland East Plaza	4961	5571	8.41
Conway Rd. (On-ramp)	662	645	0.65
Crystal Lk. (Off-ramp)	403	481	3.72
Bumby Ave. (On-ramp)	192	156	2.75
Mills Ave. (Off-ramp)	560	638	3.19
Mills Ave. (On-ramp)	63	44	2.56
Rosalind Off	1233	1344	3.09
I-4 Off-ramp	1853	1697	2.66
SR408 Thru	1718	1969	0.50

GEH statistics is calculated as a measure of error between simulated and observed volume. Eight out of nine checkpoints (89%) have GEH statistics less than 5, which indicates that the criteria for optimal calibration have been met.

6.5. Validation

In section 6.3, calibration of the Holland East Plaza models for years 1995 and 1998 were accomplished. First, an isolated toll plaza model for the HEP for year 1995 was created and calibrated for the observed volume and delay data. Since data in terms of lane-wise volumes for the toll plaza were available for this year, simulation parameters obtained from this extensive calibration are very reliable. Successful calibration of the same model for the delay data instilled further confidence in the calibrated simulation parameters. A lot of qualitative calibrations were also required to streamline the movements of vehicles and to make it more realistic. These qualitative adjustments were primarily accomplished by customized application of various tools available in PARAMICS, which are discussed at length in section 5.

After the calibration of an isolated model for the Holland East Plaza for year 1995, a HEP – SR 408 network model was also developed. This model contained the plaza and Westbound corridor of SR 408 between the plaza and the I-4 interchange. The configuration of the plaza for year 2004 in westbound direction was (from right to left): M–M-M-A-E-E-E-E. This network model was calibrated for the mainline plaza and ramp volumes available for year 1998. A systematic method was applied to estimate the initial origin-destination matrix for this network. Simulation parameters obtained from calibrating the HEP – 1995 model produced reasonably well results for the current HEP – SR 408 network model. However, these parameters were further fine-tuned to account for the fundamental difference between an isolated toll plaza model and a ‘toll plaza- toll road’ network model. In addition, a different composition of traffic streams (in terms of percentages of E-PASS, ACM, and manual vehicles) demanded for small adjustments in simulation parameters. It was found that three out of five simulation parameters behaved well, while the other two were adjusted (*see Table 29*).

After successful calibration of the HEP – SR 408 network model, a similar model for the year 2004 is validated.

6.5.1. Holland East Plaza and Downstream Section of SR 408 – 2004

The mainline toll plaza volume for morning peak hour, 7 AM – 8 AM, for year 2004 is available at OOCEA’s website. Ramp volumes are not available for this year. In an attempt to estimate the volumes for 2004, ramp volumes from year 1998 are projected in proportion of the mainline toll plaza volumes (*see Table 33*). Mainline toll plaza volumes are 6341 and 5571 (*see Table 19*) vehicles for years 2004 and 1998 respectively (*22*).

Table 33: Plaza and Ramp Volumes – 1998, 2004

Location	Volume (1998)	Projected volume (2004)
Holland East Plaza	5571	6341
Conway Rd. (On-ramp)	645	734
Crystal Lk. (Off-ramp)	481	547
Bumby Ave. (On-ramp)	156	178
Mills Ave. (Off-ramp)	638	726
Mills Ave. (On-ramp)	44	50
Rosalind Off	1344	1530
I-4 Off-ramp	1697	1932
SR408 Thru	1969	2241

HEP volume for year 2004 is about 14% more than the volume for year 1998. In order to validate the HEP – SR408 network for year 2004, demand factor for the O-D matrix is set at 114% in the corresponding 1998 model (i.e., each entry in the O-D matrix is increased by 14%). The model is expected to produce toll plaza and ramp volumes which are close to the volumes presented in Table 33. After a small fine-tuning effort, it is found that the demand factor of 116% produced the best result.

In order to estimate the error, an average of five simulation run outputs are compared with the projected volumes (as per section 6.3.1.1, about 4 to 5 runs should be adequate).

Table 34: Plaza and Ramp Volumes – Simulation Output (2004)

Location	Volume obtained from Simulation Runs									
	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10
Holland East Plaza	5814	5882	5874	5781	5795	5761	5725	5711	5698	5761
Conway Rd. (On-ramp)	867	867	870	874	889	861	858	852	872	861
Crystal Lk. (Off-ramp)	508	439	506	465	479	488	513	452	443	488
Bumby Ave. (On-ramp)	235	243	266	235	271	230	255	264	242	230
Mills Ave. (Off-ramp)	624	690	647	635	638	686	625	628	613	686
Mills Ave. (On-ramp)	71	71	84	84	93	82	84	61	76	82
Rosalind Ave. (Off-ramp)	1374	1397	1410	1399	1408	1369	1361	1379	1374	1369
I-4 Off-ramp	1905	1978	1901	1935	1955	1905	1986	1910	1937	1905
SR 408 Thru	2107	2043	2135	2078	2099	2025	1982	2086	2054	2025

Average volume obtained from these simulation runs are compared with the projected volumes (*see Table 35*).

Table 35: GEH Statistics – Simulated and Observed Volumes (2004)

Location	Average Volume (Simulation)	Projected Volume	GEH
Holland East Plaza	5771	6341	7.32
Conway Rd. (On-ramp)	865	734	4.63
Crystal Lk. (Off-ramp)	477	547	3.09
Bumby Ave. (On-ramp)	249	178	4.86
Mills Ave. (Off-ramp)	645	726	3.09
Mills Ave. (On-ramp)	80	50	3.72
Rosalind Off	1386	1530	3.77
I-4 Off-ramp	1931	1932	0.02
SR408 Thru	2065	2241	3.79

Eight out of nine checkpoints (89%) have GEH statistic less than 5, which indicates that the criteria for validation have been met.

After successful calibration of the HEP- SR 408 network model, it will be used to run several hypothetical scenarios.

7. SCENARIOS AND RESULTS

After validation of the HEP- SR 408 network model for the year 2004, this model has been tested for several hypothetical scenarios to assess the performance of the network. The performance of the network is quantified in terms of one or more of the following measures, depending upon the relevancy of these measures to a particular scenario:

1. Holland East Plaza mainline volume
2. Ramp volumes
3. Travel time

Each of these scenarios has been compared with the base model for the year 2004, validated in the previous chapter. Different hypothetical scenarios are listed below, along with their comparison with the base model.

7.1. Base Model

The base model for the network is based on its validation with the observed toll plaza mainline volume, and projected ramp volumes (in absence of observed values). Simulation output in terms of volumes and travel time is presented below (*see Table 36*). In absence of the actual travel time data, the model was not calibrated for travel time. Therefore, travel time comparisons between different scenarios have been discussed only qualitatively, instead of absolute differences in the travel time. Average travel times between O-D pairs have been obtained from simulation results between 7:20 AM – 7:50 AM in an attempt to depict the peak 30-min traffic condition.

Table 36: Base Model – Volume Output

Location	Volume (veh/hr)
Holland East Plaza	5829
Conway Rd. (On-ramp)	873
Crystal Lk. (Off-ramp)	479
Bumby Ave. (On-ramp)	250
Mills Ave. (Off-ramp)	647
Mills Ave. (On-ramp)	81
Rosalind Off	1398
I-4 Off-ramp	1935
SR408 Thru	2092

Table 37: Base Model - Travel Time

Origin	Destination	Average travel time (min:second)
HEP	Crystal Lk. Dr	09:51
HEP	Mills Ave.	10:37
HEP	Rosalind Ave.	11:15
HEP	I-4 off-ramp	11:54
HEP	SR 408 thru	11:50
Conway Rd.	Crystal Lk.Dr	01:19
Conway Rd.	Mills Ave.	02:33
Conway Rd.	Rosalind Ave.	03:20
Conway Rd.	I-4 off-ramp	04:11
Conway Rd.	SR 408 thru	04:06
Bumby Ave.	Rosalind Ave.	01:21
Bumby Ave.	I-4 off-ramp	02:13
Bumby Ave.	SR 408 thru	02:06
Mills Ave.	Rosalind Ave.	00:35
Mills Ave.	SR 408 thru	01:24

7.2. Incident on I-4 Off-ramp – Scenario 1

An incident was simulated on I-4 off-ramp at 7:20 AM, and the incident duration was specified as 10 minutes. Since I-4 off-ramp has only one lane, the ramp was completely blocked. Queues backing up from the exit ramp also blocked the SR 408 thru traffic.

Table 38: Scenario 1 – Volume Output

Location	Scenario 1 (veh/hr)	Base Model (veh/hr)
Holland East Plaza	5793	5829
Conway Rd. (On-ramp)	870	873
Crystal Lk. (Off-ramp)	493	479
Bumby Ave. (On-ramp)	266	250
Mills Ave. (Off-ramp)	583	647
Mills Ave. (On-ramp)	84	81
Rosalind Off	1245	1398
I-4 Off-ramp	*1589*	*1935*
SR408 Thru	*1797*	*2092*

This incident mainly affected the I-4 off-ramp and SR 408 thru volumes (*see Table 38*). Volume on I-4 off ramp decreased by 346 vehicles (18%) and volume on SR 408 thru went down by 295 vehicles (14%).

Travel time has significantly increased for traffic going to I-4 off-ramp and SR 408 thru (*see Table 39*). Shock waves originating from the incident at I-4 exit ramp also affected the traffic going to downtown Orlando, and increased travel time for vehicles exiting at Rosalind Avenue.

Table 39: Scenario 1 - Travel Time

Origin	Destination	Scenario 1 (min:sec)	Base Model (min:sec)
HEP	Crystal Lk. Dr	10:18	09:51
HEP	Mills Ave.	12:30	10:37
HEP	Rosalind Ave.	15:38	11:15
HEP	I-4 off-ramp	*20:30*	*11:54*
HEP	SR 408 thru	*20:17*	*11:50*
Conway Rd.	Crystal Lk.Dr	01:56	01:19
Conway Rd.	Mills Ave.	04:40	02:33
Conway Rd.	Rosalind Ave.	08:22	03:20
Conway Rd.	I-4 off-ramp	*14:02*	*04:11*
Conway Rd.	SR 408 thru	*13:39*	*04:06*
Bumby Ave.	Rosalind Ave.	04:45	01:21
Bumby Ave.	I-4 off-ramp	*10:55*	*02:13*
Bumby Ave.	SR 408 thru	*10:55*	*02:06*
Mills Ave.	Rosalind Ave.	02:47	00:35
Mills Ave.	SR 408 thru	*08:13*	*01:24*

7.3. Incident on SR 408 Thru Lane– Scenario 2

An incident was simulated on the rightmost lane on SR 408 just downstream of the location of I-4 off-ramp. It was simulated at 7:15 AM, the incident duration was specified as 15 minutes.

Table 40: Scenario 2 – Volume Output

Location	Scenario 2 (veh/hr)	Base Model (veh/hr)
Holland East Plaza	*5476*	*5829*
Conway Rd. (On-ramp)	870	873
Crystal Lk. (Off-ramp)	452	479
Bumby Ave. (On-ramp)	266	250
Mills Ave. (Off-ramp)	551	647
Mills Ave. (On-ramp)	84	81
Rosalind Off	1166	1398
I-4 Off-ramp	*1475*	*1935*
SR408 Thru	*1680*	*2092*

SR 408 has two lanes at the location of the incident. Although traffic was not completely blocked, it affected the SR 408 thru and I-4 off-ramp volumes (*see Table 40*). The incident on mainline SR 408 also affected total plaza throughput.

Table 41: Scenario 2 - Travel Time

Origin	Destination	Scenario 2 (min:sec)	Base Model (min:sec)
HEP	Crystal Lk. Dr	11:24	09:51
HEP	Mills Ave.	14:41	10:37
HEP	Rosalind Ave.	*19:47*	*11:15*
HEP	I-4 off-ramp	*23:15*	*11:54*
HEP	SR 408 thru	*23:06*	*11:50*
Conway Rd.	Crystal Lk. Dr	03:04	01:19
Conway Rd.	Mills Ave.	07:34	02:33
Conway Rd.	Rosalind Ave.	*12:18*	*03:20*
Conway Rd.	I-4 off-ramp	*17:42*	*04:11*
Conway Rd.	SR 408 thru	*17:43*	*04:06*
Bumby Ave.	Rosalind Ave.	*06:26*	*01:21*
Bumby Ave.	I-4 off-ramp	*12:50*	*02:13*
Bumby Ave.	SR 408 thru	*13:01*	*02:06*
Mills Ave.	Rosalind Ave.	03:43	00:35
Mills Ave.	SR 408 thru	*10:06*	*01:24*

Travel times increased significantly for traffic heading towards I-4 off-ramp, SR 408 thru and Rosalind Avenue (leading to downtown Orlando) (*see Table 41*).

7.4. Incident on Rosalind Avenue – Scenario 3

This incident was simulated on Rosalind Avenue off-ramp leading to downtown Orlando. The incident took place at 7:15 AM in the right lane, and the incident duration was 15 minutes. None of the ramp volumes are significantly affected by this incident, except I-4 off-ramp volume (*see Table 42*). This is because vehicles trying to exit the toll road using I-4 off-ramp will tend to drive on right lane near Rosalind Avenue, and therefore they are affected most by the queue backed up there.

Table 42: Scenario 3 – Volume Output

Location	Scenario 3 (veh/hr)	Base Model (veh/hr)
Holland East Plaza	5801	5829
Conway Rd. (On-ramp)	870	873
Crystal Lk. (Off-ramp)	498	479
Bumby Ave. (On-ramp)	266	250
Mills Ave. (Off-ramp)	634	647
Mills Ave. (On-ramp)	84	81
Rosalind Off	1357	1398
I-4 Off-ramp	*1752*	*1935*
SR408 Thru	1961	2092

Again, travel time was affected mostly for vehicle using the I-4 off-ramp or going through on SR 408 (*see Table 43*).

Table 43: Scenario 3 - Travel Time

Origin	Destination	Scenario 3 (min:sec)	Base Model (min:sec)
HEP	Crystal Lk. Dr	09:59	09:51
HEP	Mills Ave.	11:55	10:37
HEP	Rosalind Ave.	14:53	11:15
HEP	I-4 off-ramp	*15:54*	*11:54*
HEP	SR 408 thru	*15:44*	*11:50*
Conway Rd.	Crystal Lk.Dr	01:18	01:19
Conway Rd.	Mills Ave.	04:09	02:33
Conway Rd.	Rosalind Ave.	07:41	03:20
Conway Rd.	I-4 off-ramp	*09:19*	*04:11*
Conway Rd.	SR 408 thru	*09:09*	*04:06*
Bumby Ave.	Rosalind Ave.	04:32	01:21
Bumby Ave.	I-4 off-ramp	05:58	02:13
Bumby Ave.	SR 408 thru	05:54	02:06
Mills Ave.	Rosalind Ave.	02:06	00:35
Mills Ave.	SR 408 thru	02:47	01:24

7.5. Elimination of Tolls at HEP– Scenario 4

This scenario was simulated to represent the traffic condition on toll road network during the hurricane evacuation. During the hurricane evacuation, tolls are eliminated in order to facilitate the evacuation, so that vehicles do not have to stop at the toll plazas. Elimination of tolls at the Holland East Plaza is simulated by affecting the following changes in the base model: stop time in the manual payment and automatic coin machine lanes is specified as zero. Secondly, lane restriction for different payment modes is removed. So, any vehicle type (manual, automatic coin machine, or E-PASS) can use any toll lane (manual, ACM, or ETC lane). Since any vehicle can use any toll lane, lane-choices rules have also been removed.

It can be seen that the largest increase in the volume is for the Holland East Plaza (*see Table 44*). Removal of the tolls and lane restrictions at the plaza resulted in improved traffic conditions. There has been a corresponding increase in volume for SR 408 thru and I-4 off-ramp.

Table 44: Scenario 4 – Volume Output

Location	Scenario 4 (veh/hr)	Base Model (veh/hr)
Holland East Plaza	*6871*	*5829*
Conway Rd. (On-ramp)	870	873
Crystal Lk. (Off-ramp)	560	479
Bumby Ave. (On-ramp)	266	250
Mills Ave. (Off-ramp)	718	647
Mills Ave. (On-ramp)	84	81
Rosalind Off	1551	1398
I-4 Off-ramp	*2002*	*1935*
SR408 Thru	*2278*	*2092*

After elimination of the tolls, traffic operation at the Holland East Plaza will resemble free flow traffic condition. Vehicle passing through the plaza do not face delay, and therefore, the travel time for traffic coming through the plaza and going to different destinations has decreased (*see Table 45*). At the same time, the mainline plaza volume has increased significantly (*see Table 43, Holland East Plaza volume)*, which makes it difficult for the vehicles coming from ramps to enter SR 408. Therefore, travel times for vehicles joining SR 408 using the on-ramps (Conway Rd, Bumby Ave., and Mills Ave.) have increased (*see Table 45*).

Table 45: Scenario 4 - Travel Time

Origin	Destination	Scenario 4 (min:sec)	Base Model (min:sec)
HEP	Crystal Lk. Dr	04:56	09:51
HEP	Mills Ave.	05:57	10:37
HEP	Rosalind Ave.	06:53	11:15
HEP	I-4 off-ramp	08:53	11:54
HEP	SR 408 thru	08:48	11:50
Conway Rd.	Crystal Lk.Dr	01:22	01:19
Conway Rd.	Mills Ave.	02:50	02:33
Conway Rd.	Rosalind Ave.	03:40	03:20
Conway Rd.	I-4 off-ramp	06:09	04:11
Conway Rd.	SR 408 thru	06:00	04:06
Bumby Ave.	Rosalind Ave.	01:28	01:21
Bumby Ave.	I-4 off-ramp	03:50	02:13
Bumby Ave.	SR 408 thru	03:50	02:06
Mills Ave.	Rosalind Ave.	00:36	00:35
Mills Ave.	SR 408 thru	03:00	01:24

8. CONCLUSIONS

This research focused on the development of a microscopic network model with enhanced toll plaza simulation capabilities. There are many network simulation models, like PARAMICS, VISSIM, CORSIM … etc, which can model a road network with utmost details and perform very realistic simulations. However, these network simulators do not readily available built-in toll plaza models.

On the other hand, many researchers have developed toll plaza models, like TPASS, TPSIM, SHAKER, TPModel, TOLLSIM, ANATOLL … etc, which can only model an isolated toll plaza, but not the toll road network along with the plaza. They function as queuing models, and work independently of the actual geometry on ground. Vehicular movements around the toll plaza are not simulated microscopically. A vehicle is directly assigned to one of the toll lanes from the uniform toll road segment based upon payment type (manual, automatic coin machine, or electronic toll) and queue lengths at toll booths.

For instance, if a vehicle is traveling in the leftmost lane and the rightmost toll lane has the shortest queue length, then the queuing model will assign this vehicle to the rightmost lane, and the vehicle will do unrealistic maneuvering to reach to the assigned toll lane instantly. In a queuing model, vehicles do not take into account headway, gap acceptance, or inter-vehicle interaction to follow a lead car or to perform lane changing maneuvers. For queuing models, ensuring equal queue lengths at all the toll booths and processing the queued vehicles at a defined rate are the primary mechanisms which account for the toll plaza simulation. They do not simulate vehicular movements just upstream and downstream of the toll plaza microscopically.

However, microscopic network simulation models have lane-changing and car-following modules which take into account headway, gap acceptance … etc while simulating the movements of vehicles in a simple road network. If a network simulation model could be customized to model a toll plaza, not only will it simulate the vehicular movements realistically; it can also model a toll road network along with the toll plaza, unlike the above mentioned models, which can only model isolated plazas.

PARAMICS employs car-following and lane-changing models to simulate the movement of individual driver vehicle units (DVU). A DVU is a combined representation of the behavior of driver and the physical characteristics of a vehicle. Along with lane-changing and car-following rules, there are many simulation tools available in PARAMICS, which made it an ideal candidate to be customized to serve the purpose of microscopic toll plaza simulation.

PARAMICS also provides the flexibility of using an aerial picture of the toll plaza and upstream/downstream sections of the road as overlay, to ensure that the toll plaza model operates under similar geometric conditions as the real plaza. Geometry of a toll plaza can have profound effect on the vehicular movements near the plaza. At a toll plaza with inadequate length of transition area, vehicles may face difficulty in changing lanes to reach the correct toll payment lane. Using an overlay, exact details of the transition area can be fed into the model. In real life, there is a smooth transition (in terms of number of lanes and width of the roadway) from the uniform free-flowing section of the roadway to the toll plaza. In the present case, free-flowing section of the roadway approaching Holland East plaza has four lanes. After going certain distance towards the plaza, width of the roadway increases and it accommodates five lanes of vehicles. As the roadway approaches the plaza, its width increases to accommodate six lanes of vehicles, until it reaches the plaza where it has nine designated lanes. This kind of detail is not available in a queuing model. Behavior of a vehicle in traffic steam is directly affected by the presence of other vehicles in its front and sides. A detailed representation of the geometry and curb of the roadway is vital for a realistic simulation of the traffic.

Next-lane allocation feature in PARAMICS is primarily meant to specify lane behavior at priority and signalized junctions/intersections. However, it has been customized to regulate the behavior of vehicles upstream of the toll plaza. Road segment near toll plaza is wider and has more lanes compared to upstream section of the same road. Lanes are added to the roadway as it approaches the toll plaza. When a new lane is added to a link in the toll plaza simulation model, vehicles have a tendency to occupy old lanes and newly added lane remains empty. For example, if a link in the model has five lanes, then one more lane is added to the downstream link so that it has six lanes. Vehicles occupy only five rightmost lanes in the downstream link while coming from the upstream link, and the sixth lane (which is the leftmost lane) remains empty. This problem further compounds when more and more lanes are added to the road while it reaches near the plaza. Next-lane Allocation feature in PARAMICS can be used to map upstream lanes onto downstream lanes, preventing this unrealistic behavior from occurring in simulation models. It tells the vehicles in a particular upstream lane to choose from one or more of the downstream lanes as per the settings. Next-lane allocation can be used in such a manner that all the downstream lanes are utilized.

While next-lane allocation makes sure that all the lanes upstream of the toll plaza are utilized by vehicles, it does not tell the location of different types of toll payment lanes to the vehicles. So, while all the manual payment lanes at a toll plaza might be towards right side, next-lane allocation can direct a manual payment vehicle to the left side of the plaza. Lane-choices rule in PARAMICS is the primary tool which is used to put intelligence in the vehicles, so that they move towards correct toll payment lane(s) while approaching the plaza. It does not tie a vehicle to a particular toll lane beforehand; it creates a tendency in the vehicle to move towards the defined lane groups and then depending upon the vehicle type (manual, ACM, or E-PASS), lane restrictions (manual, ACM, or ETC lane), and queue lengths, the vehicle chooses one of the toll lanes based on the logic embedded in the microscopic nature of PARAMICS.

For this research, a microscopic model for 'Holland East Plaza – SR 408' network in Orlando, Florida has been developed using PARAMICS. This model constitutes a section of SR 408 Westbound between the Holland East Plaza and the I-4 interchange in downtown Orlando. This model has been successfully calibrated for the mainline toll plaza and ramp volumes for year 2004.

Several hypothetical scenarios were simulated to study the behavior of this corridor. It was found that any incident on the toll road or one of the off-ramps affected the volumes on I-4 off-ramp and SR 408 the most. Volumes for other ramps were not affected in the same proportions. It was also found that while an incident on an off-ramp did not have much effect on the mainline toll plaza volume, an incident on mainline SR 408 decreased the plaza volume significantly. Travel times to I-4 off-ramps and SR 408 thru were the most sensitive in each of the incident scenarios. In case of an incident at an off-ramp, travel times for vehicles using that off-ramp also increased significantly.

Elimination of tolls during hurricane evacuation increased the plaza throughput significantly, along with corresponding increase for I-4 off-ramp and SR 408 thru volumes. Travel times for the vehicles coming through the plaza and going to different destinations decreased as much as 50%. On the other hand, travel time for vehicles trying to enter the toll road using on-ramps increased, because of their inability to merge in the mainline traffic due to the increased toll road volume.

8.1. Future Scopes

The toll plaza model developed for this study can be further improved by using the advanced tools available in PARAMICS. Application Programming Interface (API) further extends more freedom to override the default settings with the help of additional programming.

In the present model, stop times in manual and automatic coin machine lanes are assigned by standard ‘stopper’ feature available in PARAMICS. The stopper stops every vehicle passing through the toll lane for a specified duration of time. This stopper sometimes abruptly pauses during the simulation, and in most cases does not restart again. Therefore, the subject toll lane stops processing the vehicles, and queue backs up. At present, the only way to get around this problem is to try different random seed numbers, and watch the entire simulation run to make sure that it does not happen. Vehicle Actuated (VA) signal feature in PARAMICS can be customized to assign stop times to vehicles (by specifying the length of ‘red’ phase) in toll lanes, and thus it will solve this problem.

When a manual or ACM toll lane is assigned stop time for vehicles, it stops every single vehicle which uses that particular lane for the specified duration of time. So, when occasionally an E-PASS vehicle uses the manual or ACM lane during the simulation, it will stop in that lane for some time. However, in real life E-PASS transponder readers are installed in all the toll lanes, and therefore E-PASS vehicles do not make a stop while using a manual or ACM lane. With the help of programming using the API, it is possible to determine the type of a vehicle (Type 1 - manual booth, Type 2 - ACM, Type 3 - E-PASS) when it enters the toll lane. So, if it is determined that a vehicle of Type 3 (E-PASS) is entering a manual or ACM lane; VA signal can be told not to show any red phase for this particular vehicle. This way, an E-PASS vehicle will use the manual or ACM lane without making a stop.

In PARAMICS, high occupancy vehicle (HOV) lanes can be simulated using the API. HOV lanes are exclusive lanes available only to HOVs. However, HOVs are free to use lanes other than these lanes. High occupancy toll (HOT) lanes can be simulated by defining HOV lanes through the toll plaza. These HOT lanes will be exclusively used by HOVs to pay tolls, and it will reduce their delay at the plaza. API provides more flexibility besides basic HOV behavior. HOV vehicles can be forced to use only HOT lanes. Lane changing behavior can be altered by changing lane change acceptance time and look ahead distance. Open road tolling (ORT) can also be simulated by defining dedicated ETC lanes with free-flow speed of roadway as their posted speed.

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