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D R A F T

**Application of PARAMICS Simulation
At a Diamond Interchange**

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INTRODUCTION

Computer processing advances have led to the increased use of traffic simulation models. Depending on the simulation objectives, models range from macroscopic models that use traffic descriptors such as flow, density and speed to microscopic models, which detail the movement of individual vehicles. (1) Macroscopic models are generally applied over large geographical areas and are more useful for transportation planning and corridor operations analysis rather than detailed traffic engineering in areas with complicated geometry and tight right-of-way restrictions. Because of the level of detail required in a microscopic model, applications tend towards traffic operations over relatively small geographical areas.

The Transportation Research Board's Highway Capacity Manual (HCM) presents methodologies recommended for use in planning and operational analysis of an individual transportation network element such as a signalized intersection or a mainline section of a freeway. (1) The HCM equations and worksheets are based on limited statistical models that can be considered to be macroscopic. In part because the HCM models do not consider the behavior of individual vehicles, and due to the deterministic nature of HCM models, there is a growing recognition that stochastic microscopic simulation models can be very useful in operational analyses on small to mid-sized transportation networks. HCM 2000 includes Chapter 31 titled "Simulation and Other Models," (1) which summarizes a number of strengths and shortcomings of simulation models, as shown in Table 1.

Table 1 Simulation Models

Simulation Modeling Strengths
<ul style="list-style-type: none"> ▪ Can vary demand over time and space ▪ Can model unusual arrival and service patterns that do not follow more traditional mathematical distributions Can experiment off-line without using on-line trial-and-error approach ▪ Other analytical approaches may not be appropriate ▪ Can experiment with new situations that do not exist today ▪ Can provide time and space sequence information as well as means and variances ▪ Can study system in real time, compressed time, or expanded time ▪ Can conduct potentially unsafe experiments without risk to system users ▪ Can replicate base conditions for equitable comparison of improvement alternatives ▪ Can study the effects of changes on the operation of a system ▪ Can handle interacting queuing processes ▪ Can transfer un-served queued traffic from one time period to the next
Simulation Modeling Shortcomings
<ul style="list-style-type: none"> ▪ There may be easier ways to solve the problem ▪ Simulation models may require verification, calibration, and validation, which, if overlooked, make such models useless or not dependable ▪ Development of simulation models requires knowledge in a variety of disciplines, including traffic flow theory, computer programming and operation, probability, decision making, and statistical analysis ▪ The simulation model may be difficult for analysts to use because of lack of documentation or need for unique computer facilities ▪ Some users may apply simulation models and not understand what they represent ▪ Some users may apply simulation models and not know or appreciate model limitations and assumptions ▪ Simulation models require considerable input characteristics and data, which may be difficult or impossible to obtain ▪ Results may vary slightly each time a model is run

One strength of modern simulation models is that they are based on the random movements of each vehicle. This discrete modeling provides the opportunity to view the animated vehicles on a graphical representation of the network. In addition, microscopic traffic simulation models do not need to explicitly model such behavior as queueing, vehicle platoons, or shock waves. These situations occur in the simulation for the same reason they occur on the actual road networks, that is because they are natural consequences of the interaction of drivers, vehicles, road geometry and traffic control mechanisms. (2)

The objective of this paper is to investigate the traffic engineering applications of Quadstone PARAMICS, a popular microscopic traffic simulation model, at a particular site in Oregon. The Oregon Department of Transportation (ODOT) purchased the simulation software in exchange for documentation of research experience gained by Portland State University's Transportation Research Group.

The study site consists of the area surrounding the diamond interchange of Interstate 5 (I-5) and Wilsonville Road, located in the city of Wilsonville, Oregon. Figure 1 shows the location of the study area. This interchange is characterized by high traffic volumes (80,000 average daily traffic—ADT—on I-5) and heavy peak hour traffic to and from the City of Wilsonville. The study described herein details the key features of the PARAMICS software package, reports on actual modeling experience and evaluates its effectiveness in modeling a diamond interchange and several adjacent intersections.

The next section of this report summarizes some of the recent literature related to microscopic simulation of urban and freeway traffic. This is followed by a description of the PARAMICS software package. Descriptions of the network and the data collection phases of the project are then presented. Next, the model implementation stages, from network coding to model calibration and validation are discussed. Finally, the report ends with a review of the major findings and a list of topics requiring future research.

BACKGROUND

There are many microscopic traffic simulation models currently being used for research and practical purposes worldwide. The European Commission's Transport Research and Technological Development program recently completed an assessment of current traffic microscopic simulation tools. As shown in Table 2, the Commission's research revealed the availability of 57 models, and categorized them by the traffic situation they are designed to model, namely urban, freeway, urban and freeway, automated highway systems (AHS) or Other. (3)

Table 2 Traffic Microscopic Simulation Tools

Urban	Freeway	Urban & Freeway	AHS	Other
ARTWORK	AUTOBAHN	AIMSUN2	PHAROS	ANATOLL
CASIM	CARSIM	CORSIM	SHIVA	MIMIC
CASIMIR	FOSIM	FLEXSYT II	SIMDAC	PARKSIM
DRACULA	FREEVU	INTEGRATION	SMART-AHS	TRARR
HUTSIM	FRESIM	MELROSE	SMARTPATH	TRGMSM
MICSTRAN	INTRAS	MICRO	SPEACS	VTI
MISSION	MIXIC	MICROSIM		
MITRAM	PELOPS	MITSIM		
MULTSIM	SIMCO	PARAMICS		
NETSIM	SISTM	PLANSIM-T		
NEMIS	WEAVSIM	TRANSIMS		
PADSIM		VISSIM		
SCATSIM				
SIGSIM				
SIMNET				
SITRA-B ⁺				
SITRAS				
STEER				
STEP				
THOREAU				
Tiss-NET WIN				
TRAFFICQ				

The 12 microscopic traffic simulation models that were deemed capable of modeling both urban and freeway traffic were then evaluated on their ability to model intelligent transportation system (ITS) functions, as shown in Table 3. (3)

Table 3 ITS Modeling Capabilities

	AIMSUN2	CORSIM	FLEXSYT-II	INTEGRATION	MELROSE	MICROSIM	MITSIM	PARAMICS	PLANSIM-T	TRANSIM	VISSIM
ITS Functions modeled											
Coordinated traffic signals	✓	✓	✓	✓	✓		✓	✓	✓		✓
Adaptive traffic signals	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Priority to public transport		✓	✓	✓					✓		✓
Ramp metering	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Freeway flow control		✓	✓	✓	✓		✓	✓			✓
Incident management	✓	✓	✓	✓			✓	✓			
Zone access control	✓		✓		✓			✓	✓		
Variable message signs	✓			✓			✓	✓	✓		
Regional traffic information								✓	✓		
Static route guidance	✓			✓	✓	✓	✓	✓	✓		
Dynamic route guidance	✓			✓	✓	✓	✓	✓	✓		
Parking guidance									✓		
Public transport information				✓							✓
Automatic debiting & toll plazas	✓		✓	✓	✓		✓	✓			
Congestion pricing				✓	✓			✓	✓		
Adaptive cruise control					✓						
Automated highway system					✓			✓	✓		
Autonomous vehicles					✓						
Pedestrians and cyclists			✓								✓
Probe vehicles				✓	✓		✓	✓	✓		✓
Vehicle detectors	✓		✓	✓	✓		✓	✓			✓
Objects & phenomena modeled											
Weather conditions							✓	✓			
Searching for parking space		✓						✓		✓	
Parked vehicles		✓			✓		✓				✓
Elaborate engine model							✓				✓
Commercial vehicles		✓	✓	✓	✓		✓	✓	✓	✓	✓
Bicycles / motor cycles			✓								
Pedestrians		✓	✓		✓						✓
Incidents	✓	✓	✓	✓			✓	✓			✓
Public transport vehicles	✓	✓	✓	✓				✓	✓	✓	✓
Traffic calming measures			✓	✓			✓	✓			✓
Queue spill back	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Weaving	✓	✓	✓	✓	✓		✓	✓	✓		✓
Roundabouts	✓	✓	✓	✓			✓	✓	✓		✓
Other properties											
Runs on a PC	✓	✓	✓	✓			✓				✓
Runs on a UNIX machine	✓			✓	✓	✓	✓	✓	✓	✓	✓
Graphical Network Builder	✓		✓		✓						✓
Graphical Presentation of Results	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Most models are constantly being updated; therefore the data shown in Tables 2 and 3 may not reflect the current state of a model's functionality. As an example, the European Commission report states that PARAMICS runs only on UNIX computers, whereas the PARAMICS release used in this study (Version 3, Build 7) is capable of being run on a PC equipped with emulator software.

What follows are brief summaries of recent literature related to microscopic traffic simulation tools including PARAMICS and other commonly used models.

Gardes, May, Dahlgren, and Skabardonis (4) assessed PARAMICS to serve as a tool for evaluating freeway improvement strategies on Interstate 680 in the San Francisco Bay Area. The study emphasized the importance of calibrating the model and described the process of developing a calibrated model in detail. The authors stated that results from a non-calibrated model should not be used. The authors recommended four key elements when calibrating the model. These include: network characteristics, traffic demand, overall simulation configuration, and driver behavior factors.

Lee, Yang, and Chandrasekar (5) 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. Real-time loop detector data and two field data sets were collected and used in both calibration and validation processes. The authors stated that 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 (6) described a study using PARAMICS to assess ramp meter control for eastbound traffic on Motorway 8 (M8) in Scotland. The author stated that the evaluation was performed with respect to the base model by comparing traffic flows, speeds, travel times, and behavior over strategic sections of the M8. The author found that the traffic simulation software helped confirm that the introduction of ramp metering has improved the flow of traffic on the M8. However, the author cautioned that careful consideration of model boundaries is required since traffic flow on major roadways can be affected by distant flow interruptions.

Moen et al. (7) evaluated three popular simulation packages: CORSIM, and TRANSYT-7F and VISSIM. Although their study did not include a diamond interchange, the modeling of an area of downtown Dallas, Texas described in the paper included closely spaced intersections with queue spillback and heavy traffic volumes. Overall, they found that CORSIM and VISSIM were suitable for predicting measures of effectiveness for various types of intersections, providing input for planning and operational decisions. The authors discussed a salient fact inherent in the attempt to compare simulated traffic delay measures with field data--they explained that the "total delay" computed by the simulation software included all forms of delay, including delay caused by traffic flow factors and geometric delay. This type of "total delay" data is very difficult to collect on actual street networks. The need for adequate model validation and calibration was also stressed.

Lee and Messer (8) assessed three simulation models, two microscopic (CORSIM and SimTraffic) and one macroscopic (Synchro), for diamond interchange analysis. The researchers stated that either of the microscopic models could be used for analysis of actuated diamond interchanges including those with queue spillback. The researchers suggested that a large number of simulation runs be used to produce acceptable estimates of measures of effectiveness.

Bloomberg and Dale (9) compared two microscopic simulation models, CORSIM and VISSIM, for a simple intersection and a congested urban network, both in Seattle, Washington. They concluded that both models are useful for planning and operations level analyses. They made some comparisons of the microscopic simulation results to results of HCM 2000 methodology and concluded that areas with queue spill-back may not be suited for the HCM's macroscopic modeling techniques. The authors stated that many simulation runs are required for the proper use of the model output and they encouraged future research comparing simulated results to field data.

Finally, Wang and Prevedouros (10) compared two microscopic simulation models, CORSIM and WARSim, on three small urban networks, including a diamond interchange in Honolulu, Hawaii. The study networks included video surveillance equipment and freeway loop detectors. The authors found that ability to calibrate such measures as density and speed with "real" traffic data aided in their confidence in the results of the simulation. The authors cautioned that default parameters embedded in simulation software might not always produce reasonable results.

There is a growing body of research related to microscopic traffic simulation as evidenced by the number of research paper presentations on this topic at the most recent Transportation Research Board (TRB) Annual Meeting, in January, 2002. A common theme in much of the research is the need for proper model calibration and validation. The TRB Committee on Highway Capacity and Quality of Service is considering this issue and is planning a microscopic traffic model calibration and validation workshop at their 2002 mid-year meeting.

SOFTWARE DESCRIPTION

PARAMICS is a microscopic urban and freeway traffic simulation software suite used to model the movement and behavior of individual vehicles on road networks.¹ Quadstone along with SIAS Ltd., a private engineering consultancy also based in Edinburgh, developed a Cray supercomputer version of PARAMICS at the University of Edinburgh's Parallel Computing Center in the early 1990's. (11)

The PARAMICS name is an acronym derived from PARAllel computer MICropic Simulation. Since 1998 Quadstone and SIAS have developed and marketed independent versions of PARAMICS. (11) Quadstone distributes PARAMICS outside of the United Kingdom and Ireland, whereas SIAS handles marketing within the United Kingdom and

¹ PARAMICS is marketed in the United States by Quadstone Ltd. of Edinburgh, Scotland, United Kingdom. Website <http://www.paramics-online.com>

Ireland. This paper reports on the Quadstone Ltd. PARAMICS Version 3 Build 7 that is currently being marketed in the United States.

There are five modules within the PARAMICS software package: Modeller, Processor, Analyser, Programmer, and Monitor. A typical transportation engineering package consists of three of these modules – Modeller, Processor, and Analyser. (12) The Modeller module provides the ability to build, simulate, and visualize the road network using a graphical user interface. The Modeller module also allows for the creation of statistical output in the form of raw text files. The Processor module provides the same functionality as Modeller except that simulations occur without visualization, which increases the speed of the simulation. The Analyser module uses output data from each simulation run by Modeller to produce tabular and graphical results for off-line analysis. (12)

With PARAMICS one can model the movements of different types of vehicles. Vehicle type is defined by physical characteristics such as length, height, width, weight, and maximum speed. In addition to cars and trucks, one can model public transportation vehicles such as buses, light rail trains, and heavy rail trains. Pedestrian interaction with the road network can be modeled through the provision of pedestrian phases at signal-controlled intersections. Bicycle traffic can be modeled within in PARAMICS only where the network provides dedicated bicycle lanes. (13)

The PARAMICS Modeller is a stochastic, microscopic, time step, and behavior-based simulation model. Using one set of input data, stochastic models result in unique solutions each time they are run as opposed to deterministic models that produce identical results each time. With stochastic modeling, the idea is that the model can be run many times and mean values of output can be calculated. The delay equations employed in the HCM methodology for analysis of a signalized intersection are an example of a deterministic model. Time step models simulate dynamic traffic conditions by establishing the location and attributes of each vehicle at a given point in time, then “skipping” forward a pre-determined “time step,” and then reestablishing each vehicle’s location and attributes. The motion of vehicles in PARAMICS, like in other microscopic traffic models, is actually composed of a series of discrete steps, which, when strung together, result in the perception of motion. When viewed on a computer screen, the “picture” is refreshed at each time step with the vehicle’s new position on the network. The result is an animation that displays vehicles moving throughout the network. Figure 2 shows simulated vehicles on the study network. Behavior-based traffic models employ factors in order to mimic the behavior of individual drivers. Neither the current literature nor the PARAMICS software documentation contains specific details on the theory behind the driver behavior modeling inherent in PARAMICS. However, reference is made to research conducted at the British Transportation Research Laboratory (TRL) that concludes that driver behavior can be described by two parameters: aggression and awareness. PARAMICS randomly assigns values of aggression and awareness to the driver of each vehicle on a scale of 1-8. These parameters have an effect on such quantities as target headway, top speed, propensity to change lane and gap acceptance of the individuals. One can alter the type of statistical distribution (i.e., Normal, Poisson) of the aggression and awareness parameters to reflect regional variations in driver behavior. With the assigned aggression and awareness parameters, three interacting models then control the movement of

each vehicle: a vehicle following model, a gap acceptance model, and a lane changing model. (12)

The accuracy achieved in a microscopic traffic simulation model depends on the accuracy of the coding of network features. Because vehicles react individually to geometric constraints such as narrow lane widths and small turning radii, it is vital that the modeled network represent actual conditions. Network coding in PARAMICS is based on “nodes” and “links,” where each link is coded as a connector between two nodes. Network creation is accomplished within a graphical user interface that allows the user to build the network with computer drafting commands either in freehand drawing of links or by drawing on top of a template road geometry file such as an aerial photograph or a CAD drawing. Figure 2 shows the PARAMICS network constructed for the I-5 and Wilsonville Road interchange area on a background aerial photograph.

Details associated with each link specify the characteristics of the roadway such as number of lanes, lane width, types of roadway, and design speeds. The PARAMICS driver behavior model interacts with the network geometry, causing changes in vehicle speed and position depending on:

- Position of stop and curb lines
- Intersection signal times
- Intersection coding (fixed time and actuated)
- Location of bus stops
- Location of pedestrian crossings
- Lane control and access restrictions
- Areas where on-street parking affect the performance of vehicles.

An origin-destination matrix defines travel demand in PARAMICS. However, traffic engineers typically collect data in the form of intersection turning movement diagrams. A conversion from turning movements to an origin-destination matrix is required. This step will be explained further in the Model Implementation section of this report.

Traffic assignment in PARAMICS applies to all vehicle types except fixed route vehicles, such as buses and trains. The travel cost for each vehicle to reach its destination is calculated at each time step according to the following generalized cost function.

$$\text{Cost} = a*T + b*D + c*P$$

Where:

- a = Time coefficient in minutes per minute (default 1.0)
- b = Distance coefficient in minutes per kilometer (default 0.0)
- c = Toll coefficient in minutes per monetary cost (default 0.0)
- T = Free-flow travel time in minutes
- D = Length of the link in kilometers
- P = Price of the toll in monetary cost units

Coefficients a , b and c can be changed to reflect conditions on the modeled network.

The following assignment techniques can be implemented in PARAMICS:

- All-or-nothing assignment method – assumes that all drivers are traveling with the same knowledge base for route choice and there is no congestion effect. Link costs do not depend on the flow levels.
- Stochastic assignment method – emphasizes the variability in drivers' perceptions of costs and the composite measure that they try to minimize (distance, travel time, generalized cost).
- Dynamic feedback assignment – assumes that the drivers who are familiar with the road network will reroute if information on current traffic conditions is provided to them.

On-screen observation and evaluation of the animation then allows the user to observe traffic operations and make notes of such things as inefficient signal timings and offsets, queue spillback, insufficient storage and weaving problems. A wide variety of data including route travel time, delay, queue length, and link volumes can be collected during each simulation run and stored in data files for off-line analysis.

The value of the on-screen visualization cannot be overstated; at the model development stage, the animations reveal problems with the network coding immediately. For example, if vehicles are not stopping at a red light or are traveling too quickly around a corner, it is visible and can be easily corrected. Once the model is complete and being used for analysis, the on-screen visualization allows one to see complex traffic interactions such as queue spillbacks and blocked intersections that are extremely difficult to predict with equation-based deterministic models.

Microscopic traffic simulation can also be used to test future geometric layouts and traffic control strategies. Left turn pockets can be lengthened, new lanes can be added to a link and the change in delay and travel time can be estimated. Fixed time signals can be modeled as actuated. Future traffic volumes and traffic compositions can also be modeled.

PROJECT APPLICATION

Project Location

The model network for this project is the area surrounding the intersection of I-5 and Wilsonville Road located in the City of Wilsonville, Oregon as shown in Figures 1 and 2. The network includes the diamond interchange at I-5 and Wilsonville Road as well as the Wilsonville Road intersections with Boones Ferry Road, Parkway Avenue and Town Center Loop West.

Data Collection

Afternoon peak hour intersection turning movement counts for a number of the intersections in the study area intersections were acquired by DKS Associates, an engineering consulting firm, in April 1999. Figure 3 show the DKS turning movement counts. Aerial photographs obtained from GlobeXplorer Inc. and as-built construction CAD drawings provided by the City of Wilsonville were used to establish network geometry. Ground level photographs were taken of the approaches of each intersection to provide network detail that was not apparent from the aerial photographs.

The four signalized intersections in the study area are controlled by fully actuated signals. However, during the congested afternoon peak period, the signals appeared to operate with phase timings that approached fixed-time condition (as is often the case at diamond interchanges). Fixed-timed signal phase lengths for the computer model were based on the average of ten observed p.m. peak period cycles obtained on December 13, 2001.

SOFTWARE INSTALLATION

For PARAMICS operation on a PC, Quadstone recommends a computer with a Pentium 266 or better processor, 64MB Memory, and 100MB hard disk space. A graphics card supporting OpenGL, minimum 1280x1024 resolution, and 32Bit color depth is suggested. The PARAMICS software is designed for UNIX operating systems. In order to execute PARAMICS under a Windows operating system on a PC, a separate piece of emulator software known generically as “X-windows software” is required. PARAMICS recommends the use of Exceed and Exceed 3D X-windows software produced by Hummingbird Ltd. of North York, Ontario, Canada. Exceed software was used in the research detailed in this report. The X-Windows software must be installed on the computer before PARAMICS is installed. (14)

In order to operate PARAMICS with full functionality, a current software license file issued by Quadstone and a hasp key (connected to the computer’s parallel port) are required. PARAMICS Modeller can however, be executed without license or hasp key in a Viewer Mode as described in Figure 4. The Viewer Mode allows models to be viewed but not modified.

MODEL IMPLEMENTATION

The typical implementation steps involved in a microscopic traffic simulation model are as follows:

- Road network coding
- Traffic demand matrix input
- Traffic assignment technique selection
- Simulation run execution (normally with visualization)
- Base model calibration (by comparing model results to observed data)
- Model validation the model against independent data

- Results analysis (in real time by observing visualization and off-line by analyzing model results files)

Road Network

PARAMICS networks are coded using a graphical user interface. PARAMICS uses nodes and links so for this study, a network skeleton was created by placing links directly on a bitmap image of an aerial photograph of the area (Figure 2). Detailed information on each intersection node was then input based on CAD drawings, ground level photographs, and field measurements.

Traffic Demand Matrix

In PARAMICS, an origin-destination matrix defines traffic demand. The network considered for the present study was modeled with nine zones, with a zone located at the end of each link that allows vehicles to either enter or leave the modeled area as shown in Figure 5. It is rare that traffic engineers have a balanced origin-destination matrix available to them for traffic operations analyses. It is more likely, as in the case of this study, that intersection turning movement counts are available, or are easy to collect. For this study, a simple four-step process was employed to create a balanced origin-destination matrix from the available intersection turning movement counts.

First, because the turning movement counts were obtained at different times, there was the potential for unbalanced traffic volumes to exist for each link. For example, referring to Figure 6, the hourly counts at intersection 2 show 1327 vehicles traveling on the eastbound Wilsonville Road link, whereas the counts at intersection 3 show 1323 vehicles for the same link. This link volume was equalized by adding 4 vehicles to the eastbound approach of intersection 3 and allocating these 4 vehicles on a proportional basis to the movements allowed at this approach as shown in Figure 7. This process was repeated for each link in the network to create a set of adjusted turning movement diagrams as shown in Figure 8.

Next, an unbalanced origin-destination matrix was created by distributing each zone trip production total proportionally through each network intersection until an attraction zone was reached. For example, referring to Figure 9, Zone 9 produces 725 vehicles in the design hour; 4.6% or 33 of those 725 vehicles are destined for Zone 6, 4.1% or 30 vehicles are destined for Zone 7, and 12.4% ($91.3\% \times 57.8\% \times 47.5\% \times 91.8\% \times 97\% \times 55.7\%$) or 90 vehicles are destined for Zone 3. This process was repeated for each origin-destination pairing to create the unbalanced origin-destination matrix shown in Table 4.

The next step was an adjustment of each actual zonal attraction total so that the total attractions were equal to the total productions. As summarized in Table 4, the original turning movement counts (TMC) show 10,783 vehicles attracted to the ten network zones. This is 87 more vehicles than the TMC total of 10,696 vehicles produced by these same ten zones. Each zonal attraction total was therefore adjusted by adding a number of vehicles in proportion to that zone's contribution to the total. For example, it can be seen in Figure 3 that Zone 8 attracted 586 ($502+38+46$) vehicles; 586 vehicles represent 5.5% of the total,

therefore 5.5% of the 87-vehicle deficit (5 vehicles) was added to the Zone 8 total making the total 591 vehicles as shown in Table 5. This process was repeated for each zonal attraction total creating a balance among the overall zonal production and attraction totals as shown in Table 5.

Finally, a balanced origin-destination matrix was created by an iterative proportional fitting (IPF) process. The IPF process adjusted the individual origin-destination cell values of the unbalanced matrix (Table 4) through a series of iterations until the overall zonal production and attraction totals matched the adjusted actual turning movement count totals determined in the previous step. For the first IPF iteration, each cell value was multiplied by an attraction-based balance factor that was created by dividing the unbalanced zonal attraction total by the actual zonal attraction total for that zone. For example, Zone 1 attracted 3994 vehicles in the unbalanced matrix, while the actual zonal attraction should be 4095. Therefore a balance factor of $4095/3994$ or 1.025 was established. This process was repeated for each zone and new cell values were computed as the product of the balance factor and the original cell value. The matrix created by this initial iteration has, by design, perfectly matching zonal attraction totals but will leave the zonal production totals out of balance. The next iteration was therefore applied in a similar manner to zonal production totals. The iterative steps that followed alternated balancing between attraction and production totals until a maximum allowable difference was achieved. For this project, the maximum error was set at 2.0 vehicles and thirty iterations were required to meet this goal. The balanced origin-destination matrix for PARAMICS modeling is shown in Table 4.

Traffic Assignment Technique Selection

The study area was a small network with only one route possible between each origin and destination, therefore the all-or-nothing technique was chosen.

Simulation Run Execution

Due to the stochastic nature of simulation models, a relatively large number of runs must be conducted in order to estimate key measures of effectiveness with reasonable accuracy. Each PARAMICS model run with identical operation conditions but with different “random seed” numbers will produce different results.

The “random seed” is required since driver behavior parameters are assigned to each simulated vehicle according to a predefined distribution. For example simulation run 1 with a random seed of 17 might assign to vehicle 1 an aggression parameter of 6, vehicle 2 with an aggression parameter of 4, etc. Each time a model run is initiated with a random seed of 17, each vehicle will be assigned the same behavior parameters as in the previous random seed 17 run and therefore all traffic operations and measures of effectiveness (MOEs) such as delay will be the same. Using the same random seed essentially reduces the model to a deterministic level. For better results, a random number table should be used when assigning random seed numbers.

It is prudent to execute an initial number of simulation runs, and use the statistical estimators from this trial to compute the number of simulation runs required to meet a stated objective

(i.e., 90% or 95% level of confidence), according to commonly accepted statistical principles.

The following equation (15) can be used to compute the required number of simulation runs, where:

$$n_r \geq \frac{s^2 z_{\alpha/2}^2}{\varepsilon^2}$$

- s^2 = variance (based on trial runs)
- $z_{\alpha/2}$ = threshold value for a 100(1- α) percent confidence interval
- n_r = number of runs required
- ε = maximum error of the estimate

The following interchange delay data I-5 Interchange with Wilsonville Road was determined from 15 PARAMICS simulation runs:

- Mean delay = 31.44 s
- s^2 of this data = 3.10 s²
- s = 1.76 s
- α = 0.05 (corresponds with 95% confidence)
- $\alpha/2$ = 0.025 (corresponds with 95% confidence)
- Z = 1.96 from statistical table (15)
- ε = 1.0 s (based on reasonable error of delay estimate)

$$n_r \geq \frac{s^2 z_{\alpha/2}^2}{\varepsilon^2} = \frac{(3.10)1.96^2}{1.0^2} \approx 12 \text{ runs}$$

As shown, for this study it was determined that 12 simulation runs were required in order to establish an estimate for interchange delay with a 1.0 second maximum allowable error and a 95% level of confidence.

Base Model Calibration

Before calibration can be performed, it must be apparent to the modeler that the network is verified so that that all possible movements at the real intersection are being properly modeled. Is easy to verify a PARAMICS network given the visualization that is inherent in the modeling process. This verification step is followed by a more formal base model calibration.

The first step in calibrating a microscopic model is to observe the visualization and determine whether the traffic is moving through the network in a realistic manner. These observations can be compared to on-site observation of the traffic or by viewing traffic camera video

output. During the simulation, statistics such as total travel time, total distance traveled and average vehicle speeds can be written to data files and used to compare differences between each model run and also compared to field data.

In general, the need for further calibration can be identified by comparisons between modeled and observed data that could include the following:

- Traffic flows
- Queue lengths (maximum and average) and stop time
- Delays (network wide and at individual junctions)
- Traffic speeds
- Traffic density
- Travel times

Quadstone suggests that most networks can be sufficiently calibrated by adjusting the physical network to more closely resemble the actual streets and/or by making coding changes to links and nodes to permit vehicle movements like those observed on the actual street. (16) Commonly used calibration parameters include:

- Including actual link gradients (all links are flat by default)
- Inserting link instructions that either force merging or force “stay in lane” behavior that will override the PARAMICS lane changing model

In the case of the Wilsonville Road study, a preliminary calibration was achieved by network alterations suggested by a comparison between modeled and observed travel times.

Model Validation

Validation is the process of determining whether the driver behavior models inherent in the software package are producing results that match with observed driver behavior. In this study, model validation was accomplished with an empirical comparison of the results of several simulation runs with behavior observed during several site visits and also using a comparison with generally expected driver behavior. Again, the on-line viewing of the simulation runs greatly enhanced the modeler’s ability to identify unexpected driver behavior.

The overall behavior of the PARAMICS model can be changed considerably by modifying the “mean target headway” and “mean reaction time” or by altering the driver behavior “aggression” and “awareness” distributions. (4, 16) Alteration of these values based on model run comparisons to data sets collected on the actual network constitute a more rigorous model validation procedure.

Quadstone has set the PARAMICS mean headway and reaction times to default values of 1.0 seconds based on speed and headway data extracted from loop detectors on freeways in the United Kingdom (16). For a small, suburban network like the Wilsonville road study area, these default values should suffice, since, with the exception of the ramp entrances to I-5,

there is little high-speed, high-volume traffic. Current research (4) suggests that for freeway analysis, there is a real need to validate the model by calibrating the headway and reaction times to match local conditions.

Analysis of Results

Travel Time

Travel time data were collected during ten PARAMICS simulation runs on three routes as shown in Figure 10. A small data set comprised of five actual timed trips for each route was acquired at the site on December 13, 2001. PARAMICS simulation results appear to be reasonable predictors of travel time for Routes 1 and 3. The discrepancy in the simulated versus actual travel times on Route 2 may have resulted from simulating the intersections with fixed time coordinated signals while the actuated signals at times did not appear to be coordinated to provide progressive flow. The nature of the actuation logic may lead to a lack of coordination among the series of signals traversed in Route 2.

Average Vehicle Delay

Average vehicle delay data were collected during ten PARAMICS simulation runs for selected approaches of the two I-5 ramp intersections with Wilsonville Road. For each simulated intersection movement, delay was computed using procedures outlined in the HCM. Chapter 26 (Interchange Ramp Terminals) of the HCM 2000 recommends the evaluation of delays at diamond interchanges using procedures from Chapter 16 (Signalized Intersections). (1) These procedures form the basis for the "Signals" module of the Highway Capacity Software (HCS) 2000. Examples of lane group delays predicted by HCS and PARAMICS are shown in Figure 11.

The HCM lane group incremental delay computation includes an Upstream Filtering or Metering Adjustment Factor (I) to account for the effect of metered arrivals from an upstream intersection. The HCM methodology recommends that a factor of $I = 1.0$ be used for isolated intersections where the arrival pattern would follow a random distribution. For the closely spaced intersections such as those in the study network, the HCM methodology suggests that the I factor be computed using the following equation:

$$I = 1.0 - 0.91X_u^{2.68}$$

X_u is approximately the volume to capacity (V/C) ratio of the upstream through movement. While it appears logical that the delay of a lane group will be lower when the arrival rates are non-uniform and the signals are coordinated to take advantage of this type of arrival pattern, the HCM delay calculation method contains empirical factors which makes the comparison of a single factor such as the Upstream Filtering or Metering Adjustment Factor to a fundamental principle of traffic flow very difficult.

Incremental delay is defined in the HCM 2000 as "delay due to non-uniform arrivals and temporary cycle failures ... as well as delay caused by sustained periods of over saturation." After viewing ten hours of PARAMICS simulations, there were virtually no instances of oversaturation or cycle failures observed using existing volumes.

Comparisons of HCS and PARAMICS average vehicle delay for all eight movements reveal relatively small differences. While this is an interesting observation, it does not necessarily prove the usefulness of either method. The HCS methodology for delay calculation is simply a “model” of traffic flow that can be described as deterministic and macroscopic.

Traffic Demand Variations

The hourly traffic volumes used in this study were based on p.m. peak hour vehicle volume data acquired by DKS Associates in May 1999 as shown in Figure 3. These data came in the form of intersection turning movement counts for the six intersections in the network. To explore how the network would respond to changes in traffic demand, the network was loaded with several hypothetical levels of traffic volumes (referred to here as Low, Medium, High, and Very High). These traffic levels corresponded to 0.5, 0.75, 1.0 and 1.25 times the May, 1999 p.m. peak hour volumes respectively.

Figure 12 shows the simulated interchange delay at these four traffic levels. Interchange delay was again computed by weighting the delay of each of the ramp intersection movements by that movement’s average proportion of total vehicles served. Average delays increased with increasing traffic, which is consistent with expectations. Of particular interest was the observation of the animation during the Very High traffic load. The animation showed that there were several instances when the queues of both eastbound and westbound Wilsonville Road traffic spilled back, limiting movement at the adjacent ramp intersection. Any methodology that aims to accurately predict interchange delays at times heavy traffic flow must recognize the impact of queue spill-back.

Modeling Geometric Changes

One of the strengths of simulation models is the ability to experiment with new situations that do not exist today. The traffic demand variation analysis discussed in the previous section is one example of such future situations. Another example is modeling hypothetical changes in network geometry such as the addition of a new lane, turn bay, or other physical change to the network.

In the traffic demand variation, it was observed that at Very High traffic levels (1.25 times the 1999 levels) there was a substantial delay for the I-5 Northbound ramp left turning movement to westbound Wilsonville Road. With a single left turn lane, the average vehicle delay was 74.9 seconds. When a second left turn lane was added, the delay of this same movement was reduced to 34.4 seconds. While it is clear in this case that a lane addition would decrease delay, the simulation model allows for detailed analyses of such situations with a minimum of effort. With PARAMICS, once the initial network is coded and validated, it is a simple process to make changes and to study the impact of the changes, both visually on-line and by an off-line analysis of the collected data.

CONCLUSIONS

This report has documented experience with the use of a computerized microscopic stochastic traffic simulation tool (Quadstone PARAMICS) as means of evaluating a small

urban traffic network including a diamond interchange on an interstate highway. From the analysis of results, the following conclusions were drawn.

Simulated interchange delay results from the PARAMICS model appear to be consistent with delays predicted by HCM 2000 methodologies. Model to model comparisons in themselves are not entirely meaningful. However, it appears that the microscopic simulation and the animation that is inherent in the simulation provide a good tool for evaluating the movement of traffic at diamond interchanges.

The importance of modeling nearby intersections that influence the diamond interchange intersections was clearly observed. The PARAMICS model generates traffic according to a random distribution, therefore it is vital that the metering effects of nearby intersections be included in the analysis of an interchange. The ramp terminals studied had non-random arrival patterns and only by modeling adjacent intersections were these non-random arrivals properly simulated.

The stochastic nature of the PARAMICS simulation models will result in unique results each time the model is executed with new random seed numbers. It is vital, therefore, that a statistically sound method be followed in determining the required number of model runs. Due to the stochastic nature of actual traffic, all studies of real traffic for validation and calibration must also include a large number of observations.

Future Research

The following areas appear to be starting points for future research on traffic flow at diamond interchange and other closely spaced intersections.

- A more statistically rigorous comparison of modeled results to field data resulting in improved validation and calibration
- A detailed analysis of the internal logic (car-following, gap acceptance, mean headway, mean reaction time etc.) Of the PARAMICS models and comparison to field data related to this logic.
- Analyses incorporating actuation logic at signalized intersections.
- Extension of the analysis to include ramp metering
- Extension of the analysis to include freeway weaving sections near the study interchange
- Evaluation of freeway traffic near closely spaced interchanges.

Also, it would be helpful to continue to explore ways that microsimulation tools such as PARAMICS can be used to simulate larger multimodal freeway/arterial corridors.

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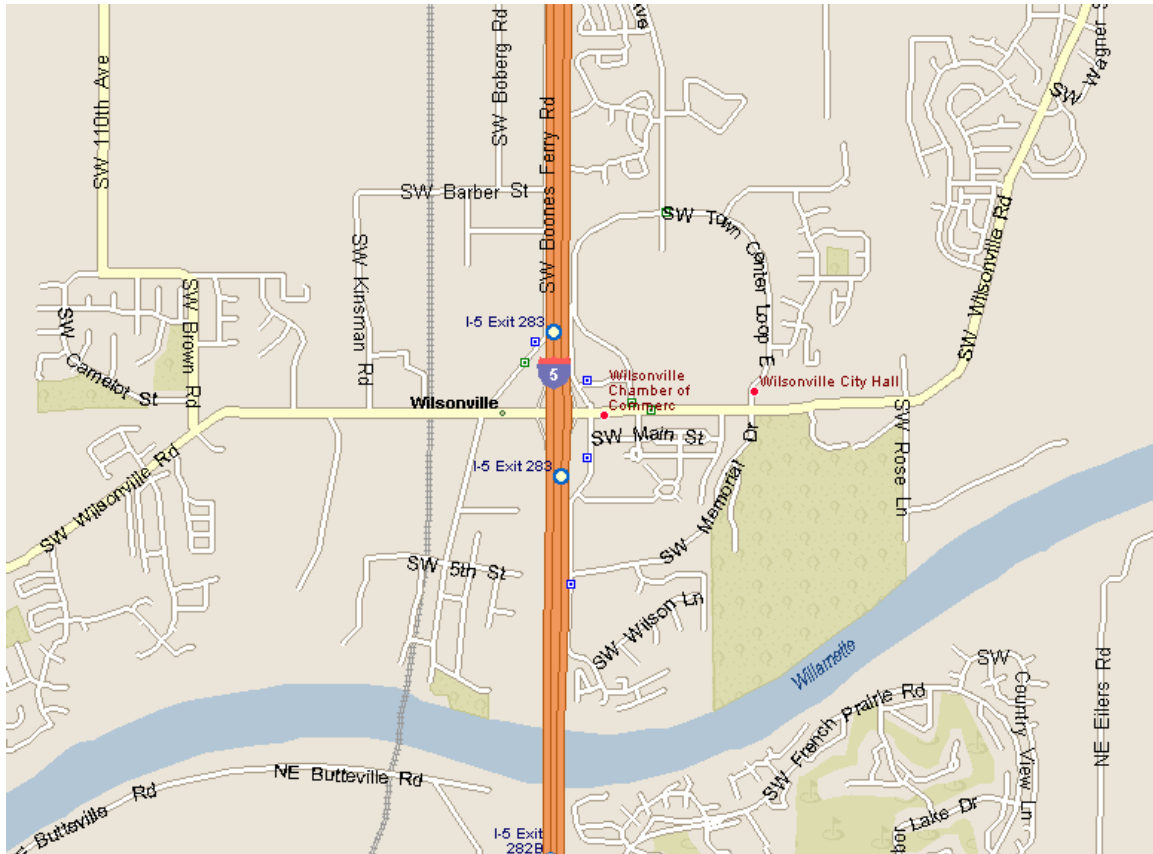


Figure 1 Study Location Map

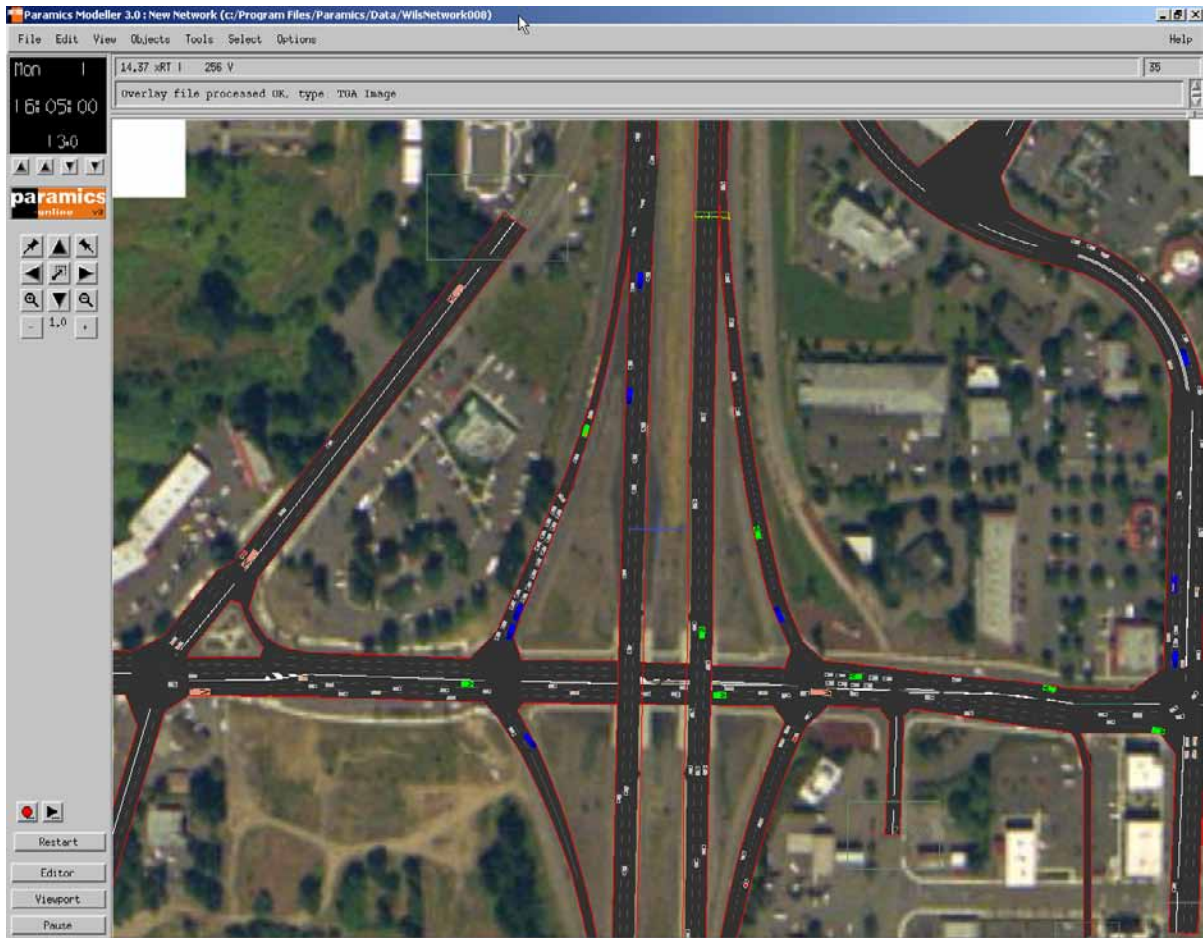


Figure 2 PARAMICS Screen Showing Network on Aerial Photo.

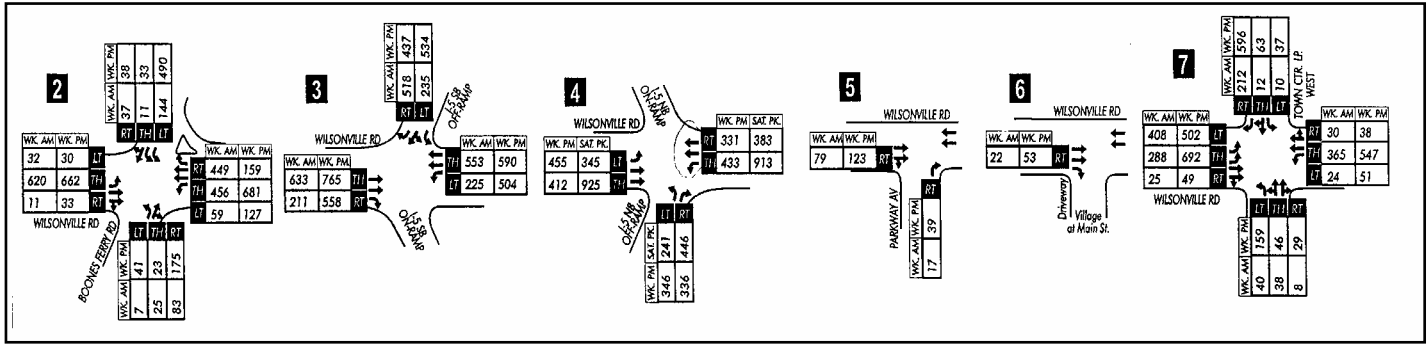


Figure 3 Turning Movement Counts at Study Location

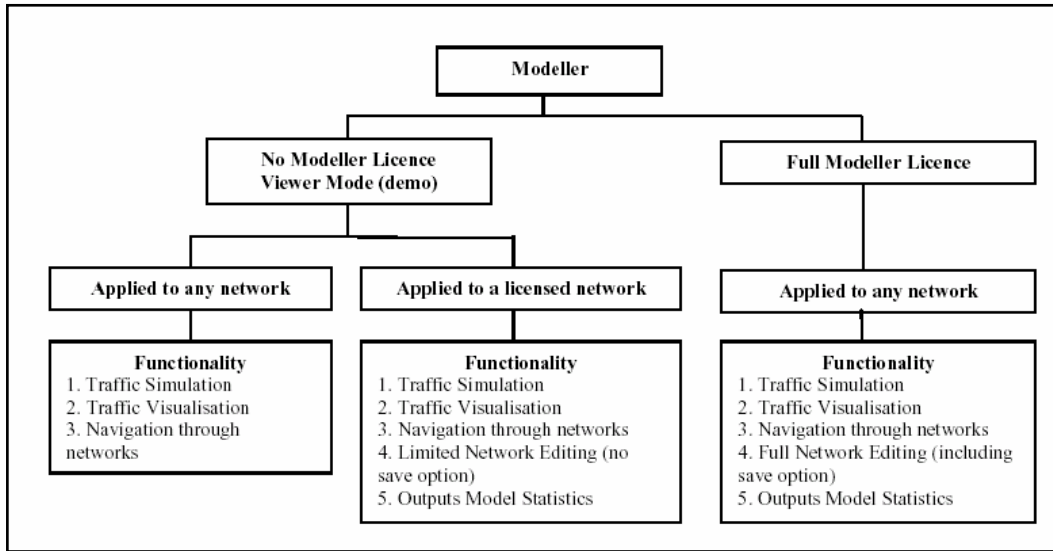


Figure 4 PARAMICS Modeller Software Functionality

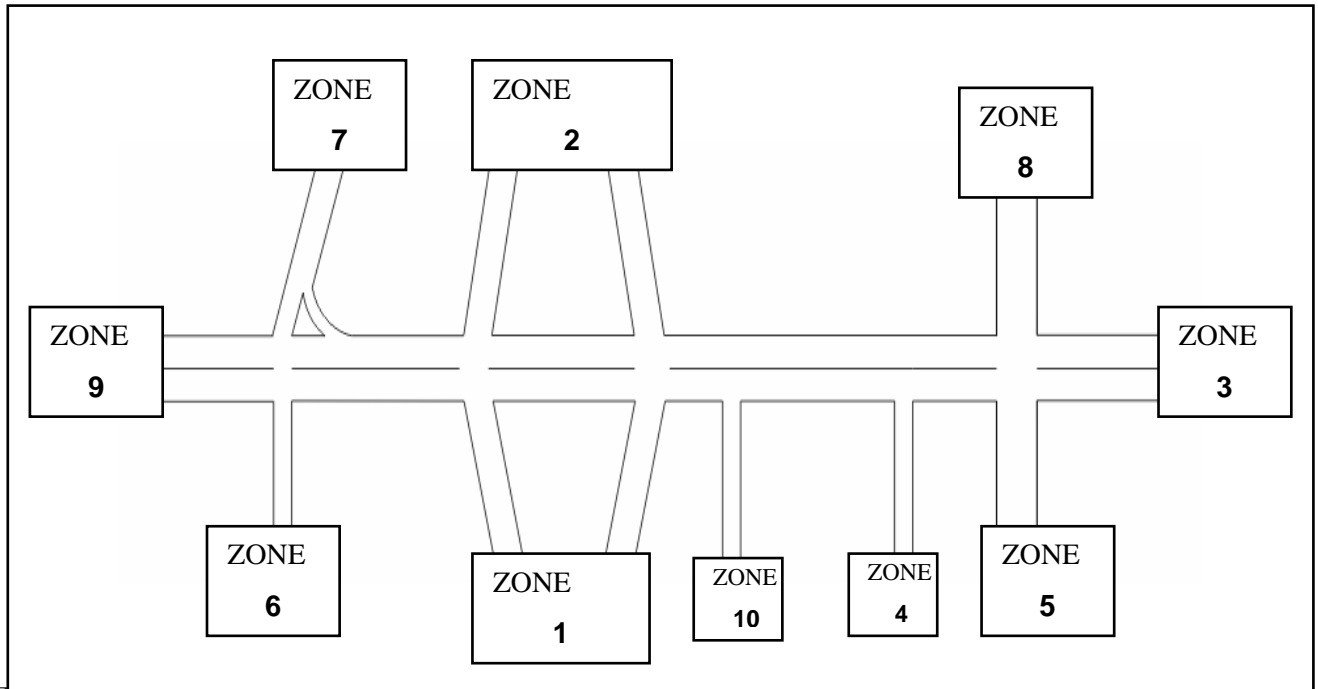


Figure 5 Origin-Destination Zones

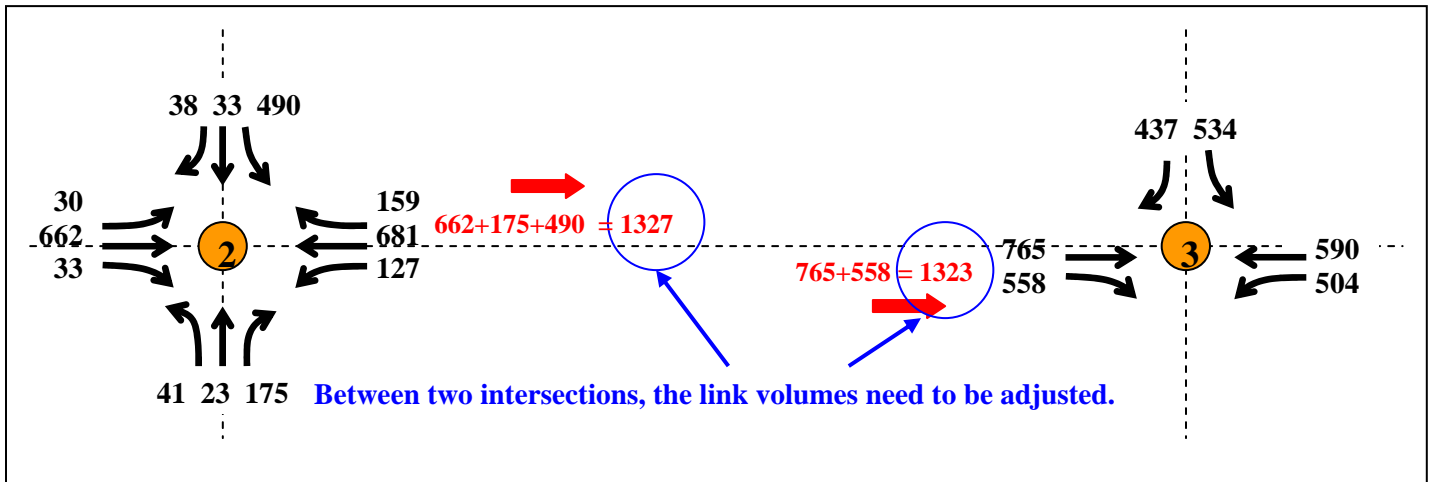


Figure 6 Unadjusted Link Volumes

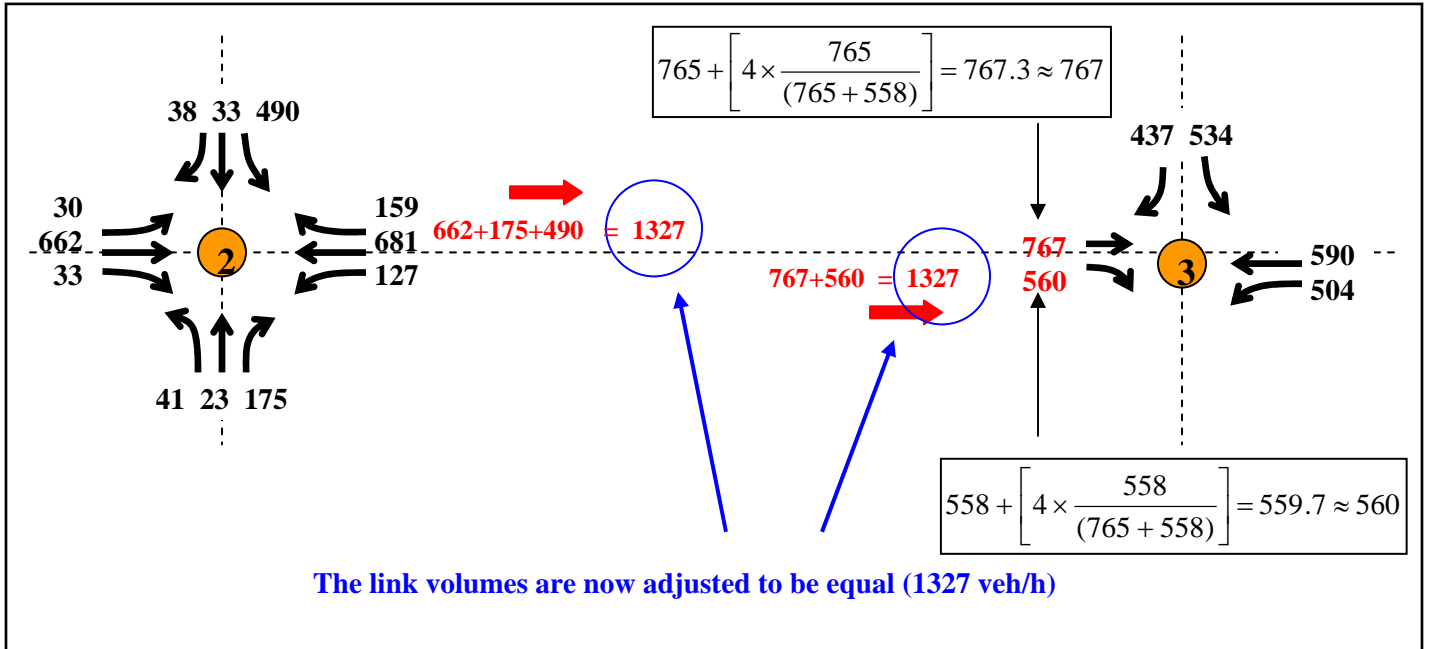


Figure 7 Adjustment of Link Volumes

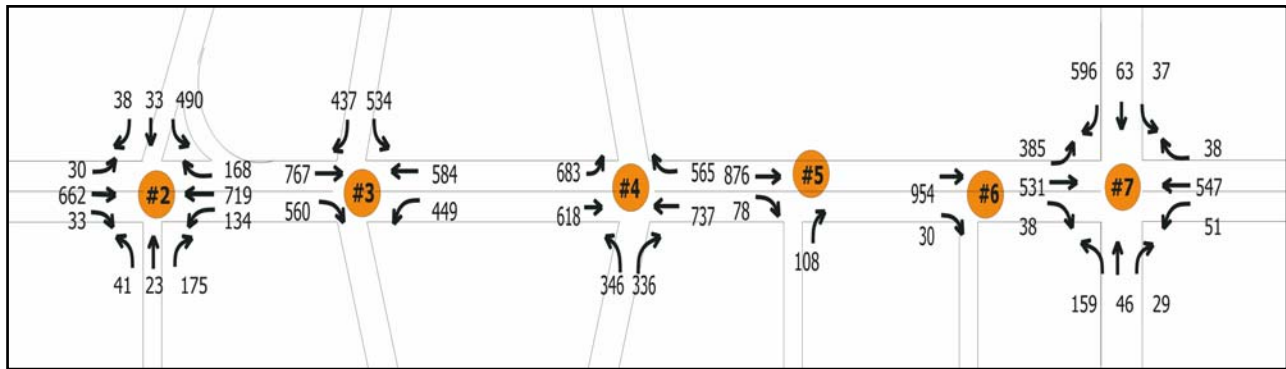


Figure 8 Adjusted Turning Movement Counts

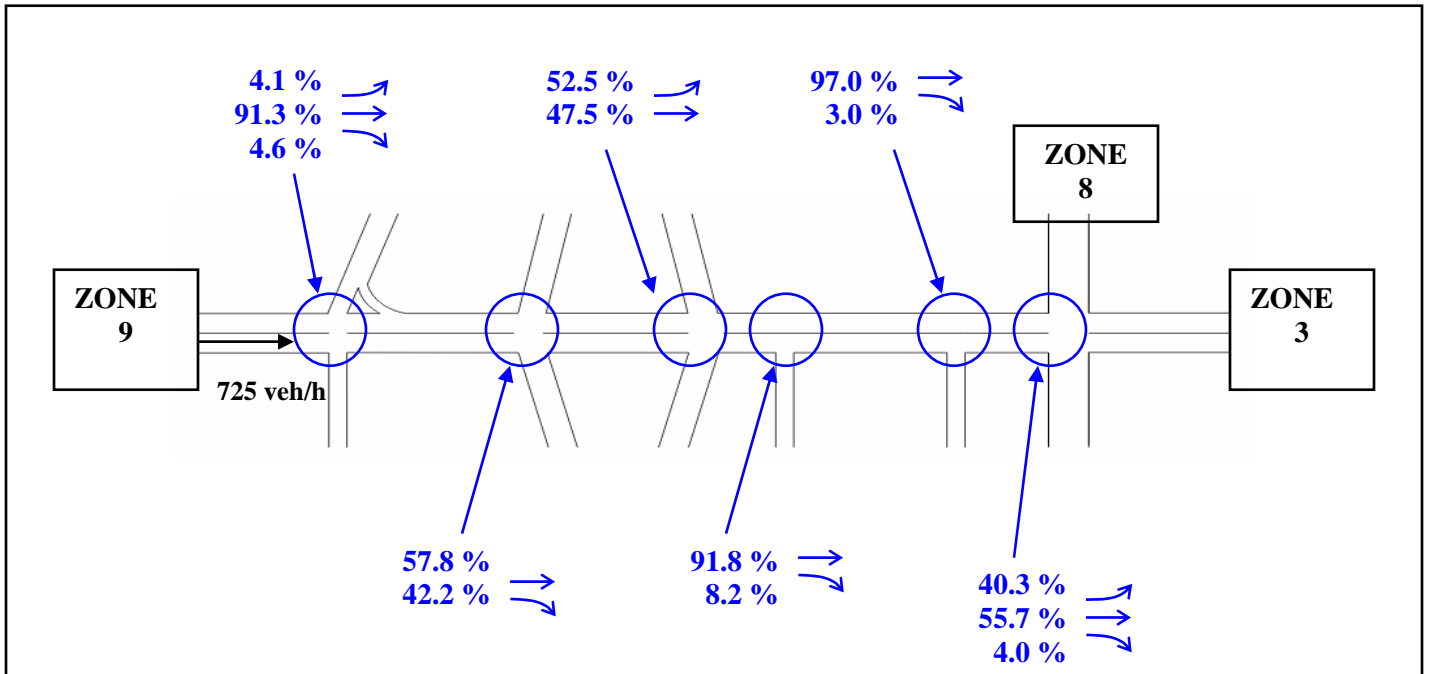


Figure 9 Trip Distribution

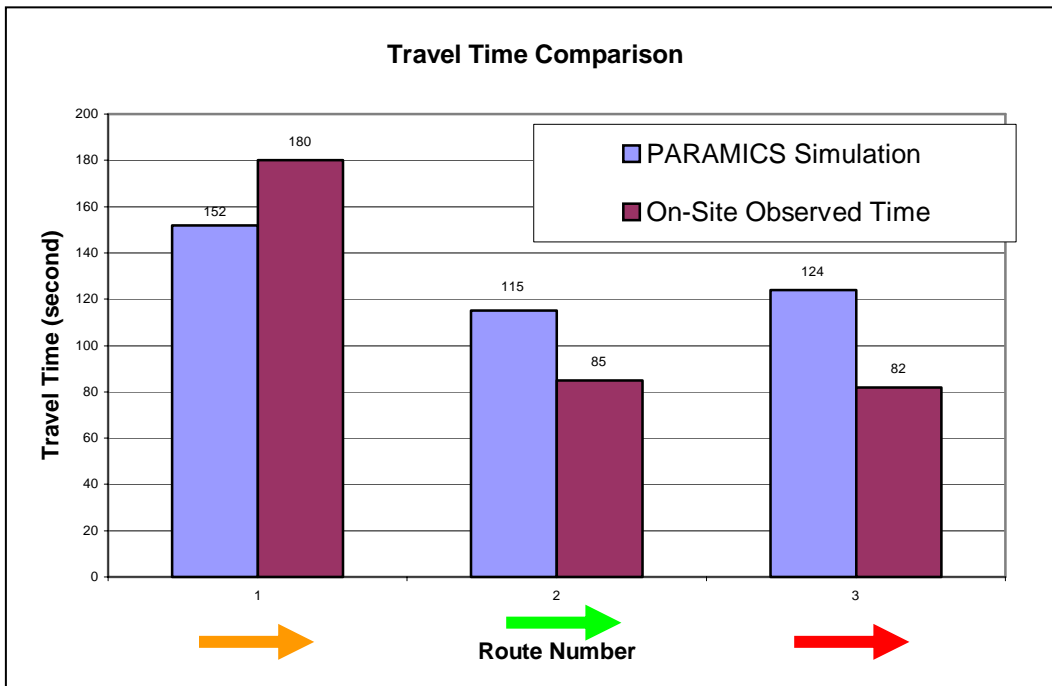
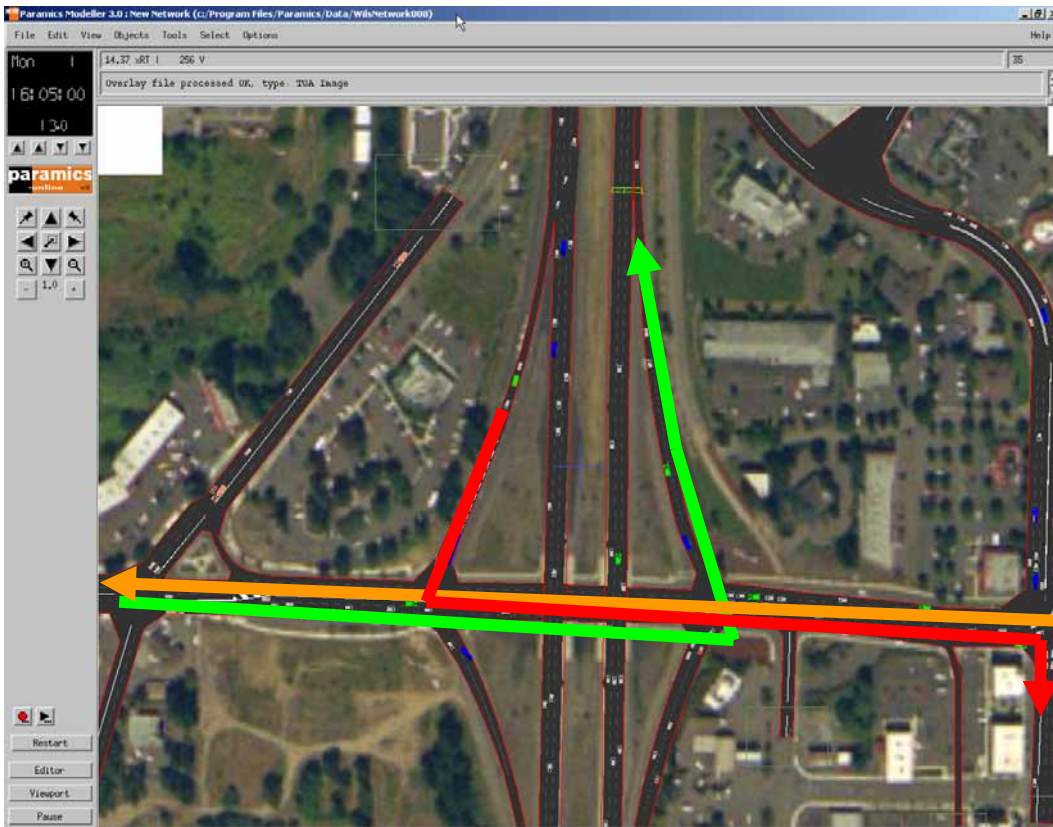


Figure 10 Travel Time Comparison

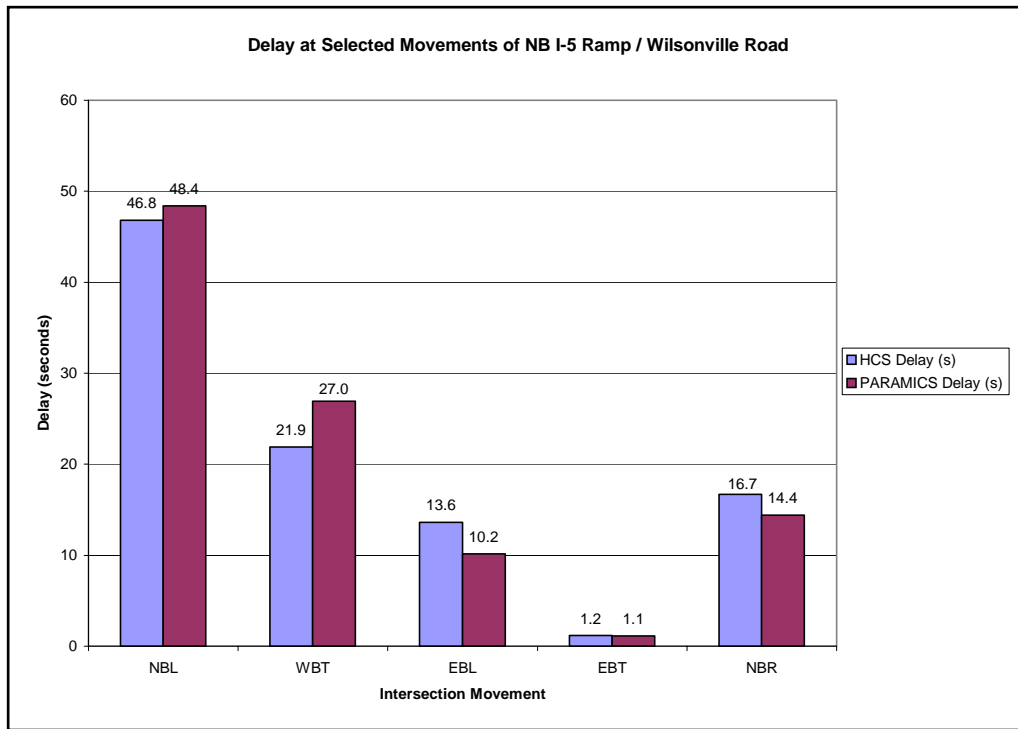


Figure 11 Intersection Movement Delay

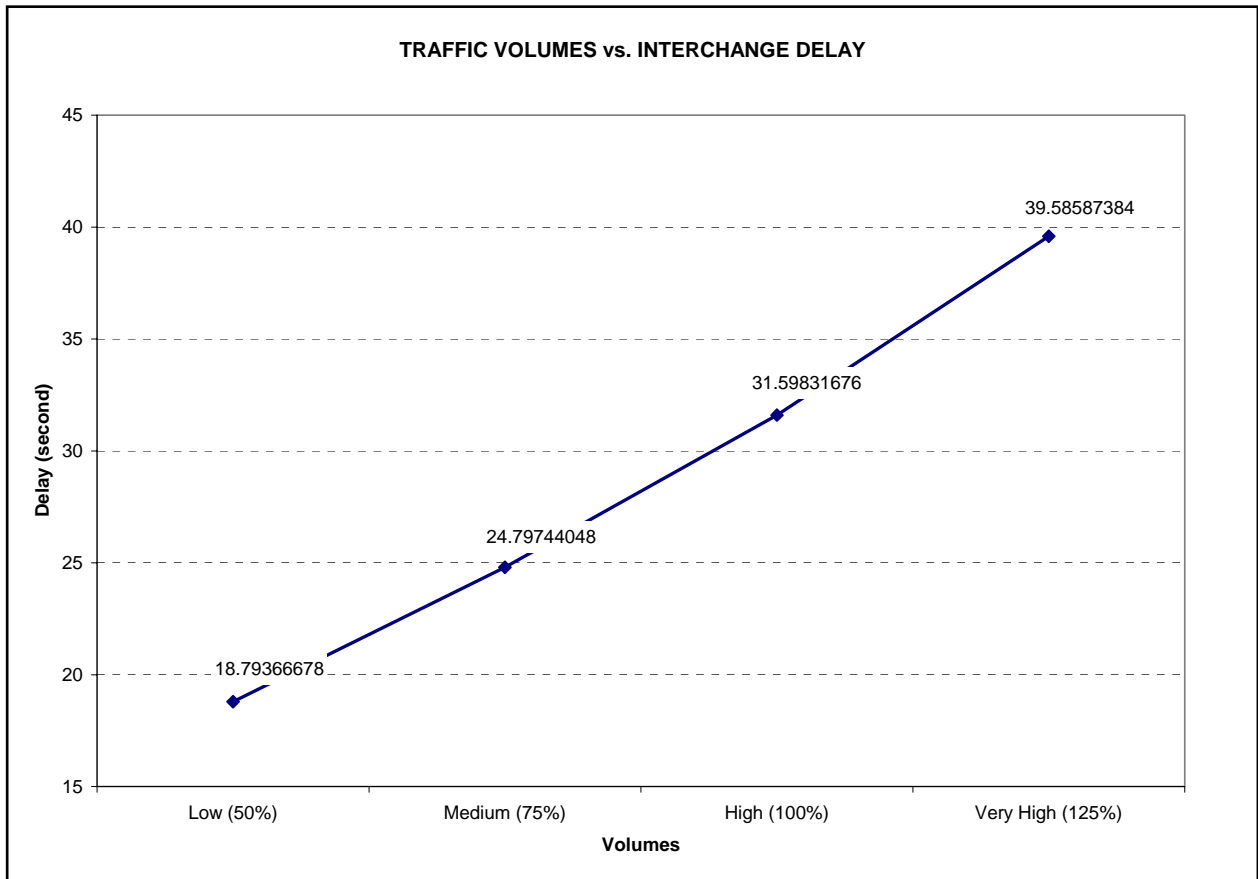


Figure 12 Traffic Volume vs. Interchange Delay

Unbalanced Origin-Destination Matrix

FROM	TO										Total	Final Target	Delta	From TMC
	1	2	3	4	5	6	7	8	9	10				
1	0	3000	166	9	12	24	31	121	131	27	3523	3682	159	3682
2	3000	0	126	7	9	57	72	91	308	21	3691	3971	280	3971
3	237	143	0	0	51	22	27	38	118	0	636	636	0	636
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	41	69	29	0	0	6	8	46	34	0	234	234	0	234
6	74	53	24	1	2	0	23	17	41	4	239	239	0	239
7	207	149	67	4	5	33	0	48	38	11	561	561	0	561
8	155	259	37	0	63	24	30	0	128	0	696	696	0	696
9	279	201	90	5	6	33	30	65	0	15	725	725	0	725
10	0	0	58	3	4	0	0	42	0	0	108	39	-69	39
Total	3994	3873	597	30	152	200	221	469	798	78	10412			
Final Target	4095	3817	764	53	164	195	214	591	766	124	10783			
Delta	101	-56	167	23	12	-5	-7	122	-32	46	371			
From TMC	4062	3786	758	53	163	193	212	586	760	123	10696			

Balanced zonal attractions

Total zonal attractions (from TMC) need to be balanced with total productions

Table 4 Unbalanced Origin-Destination Matrix

Balanced Origin-Destination Matrix													
FROM	TO										Total	Final	
	1	2	3	4	5	6	7	8	9	10		Target	Delta
1	0	3010	239	19	14	25	31	171	129	45	3683	3682	1
2	3155	0	184	15	11	60	73	131	308	35	3972	3971	1
3	234	137	0	0	56	21	26	51	110	0	635	636	-1
4	0	0	0	0	0	0	0	0	0	0	0	0	0
5	38	61	37	0	0	6	7	57	29	0	235	234	1
6	69	49	31	2	2	0	21	22	37	6	239	239	0
7	190	133	85	7	5	30	0	61	33	17	561	561	0
8	154	249	51	0	70	23	29	0	120	0	696	696	0
9	256	179	115	9	7	30	27	82	0	22	727	725	2
10	0	0	21	2	1	0	0	15	0	0	39	39	0
Total	4096	3818	763	54	166	195	214	590	766	125	10787	10783	4
Final Target	4095	3817	764	53	164	195	214	591	766	124	10783		
Delta	1	1	-1	1	2	0	0	-1	0	1	4		

Table 5 Balanced Origin-Destination Matrix