



Development of Next Generation Simulation Models for the Twin Cities Freeway Metro-Wide Simulation Model – Phase 1

Final Report

Prepared by:

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Executive Summary

The objective of the “Development of Next Generation Simulation Models for the Twin Cities” program is to strengthen the ability of local stakeholders, to respond to emergencies and to develop transportation plans that have wide-area impacts by developing the next generation of simulation models for the Twin Cities metro area. The only currently available model of this size is the regional travel demand model maintained by the Metropolitan Council. Considering the current state-of-the-art in simulation models and the results of a feasibility study project concluded in 2008 (Hourdos and Michalopoulos, 2008) it became clear that higher resolution and ability models of large areas are feasible under certain conditions. The recommendation of the aforementioned study was that the best solution in terms of accuracy and capabilities is a Hybrid Mesoscopic + Microscopic simulation model. Regardless, until now simulation models of this size were strictly mesoscopic while microscopic attempts, when computationally feasible, encountered difficulties in securing all the necessary calibration data. Another advantage of a hybrid approach is that the two model levels do not have to be developed sequentially; therefore the development effort can be broken down and distributed among several analysts. This is the manner in which the present program was formed by dividing the effort between teams in terms of modeling resolution and in phases in terms of calibration and validation. The team lead by Dr. Henry Liu took the task of developing the mesoscopic model of all major arterials in the metro area. The results of this effort are described in a separate project report. This report describes the first phase of the development of a microscopic model of all freeway and major highway segments in the Twin Cities metro area based on the AIMSUN NG simulation application.

Phase 1 of the development of the Twin Cities metro-wide freeway microscopic model covered the importation of the roadway geometry into a microscopic simulator, generation of demand information for the entire model as well as for the calibration of as many as possible individual segments, and the integration of the Twin Cities ramp control strategy in the simulation. Due to effort requirements as well as project priorities the latter was not concluded during this phase but combined with other ongoing efforts that have similar objective. The processes of accomplishing the objectives of this phase are presented along with the first steps of a methodology for the utilization of the freeway model and the integration with the mesoscopic in the next phase. In total, 1,199 directional kilometers of freeway mainline were included in the model. Including ramps and major highways, the number rises to 2,492 directional kilometers. The demand in the model is generated from 859 zones and included in three O/D matrix sets of 24 matrixes each corresponding to the three vehicle classes defined in the regional travel demand model; single occupancy vehicles (SOV), high occupancy vehicles (HOV), and trucks. For the calibration of the individual freeway segments 24-hour flow and turning % demands updated every 15 minutes were generated after three “normal” days were identified for each segment. The calibration of the individual segments followed the methodology described in Hourdos, et. al 2003. Preliminary experiments with the calibration of the route choice model parameters were conducted in a subarea of the whole model in which all roadways freeways and arterials were included. This last experiment was in preparation of the later integration of the freeway model with the arterial mesoscopic one. It is important to note that this phase of the project included large amounts of data entry, and for this reason, in this report no significant insight on the bigger modeling issues is offered.

Chapter 1: Introduction

1.1 Background

This report describes work done for the project Development of Next Generation Simulation Models for the Twin Cities: Freeway Metro-wide Simulation Model, Phase 1. The main objectives of this project were to (1) enter the geometry of all Twin Cities metro freeway and major highway segments in a microscopic simulation application, (2) identify and develop demand information suitable for the operation and calibration of the model as a whole as well as of individual freeway segments, (3) calibrate as many freeway segments as time and funding would allow, (4) identify the needs and proper methodology for the calibration of the whole model route choice parameters, and (5) integrate if possible the stratified ramp metering strategy with the simulation model.

The recent collapse of the Interstate 35W Highway Bridge over the Mississippi River in Minneapolis resulted in unexpected loss of life and had serious consequences on mobility and accessibility in the Twin Cities metropolitan area. In response to the network disruption caused by the bridge collapse, a number of traffic restoration projects were proposed and implemented by MnDOT in a very short order. Selection and prioritization of these projects, however, was mainly based on engineering judgment and experience. The only decision-support tool available to traffic engineers was the regional transportation planning model, which is static in nature and decennial. Although such a model is suitable for the evaluation of long-term (in the order of 5 years or longer) transportation investments, it is not appropriate or adequate for short-term (within days or weeks) operational planning in response to a disaster or other emergencies. This is in part because the macro model does not take into account temporal and spatial changes in the O/D information nor captures the effect of traffic control. It thus became apparent that there is a very strong need for a region-wide simulation tool that can be used to evaluate the effectiveness of temporary traffic restoration projects as well as of other emergencies and rapid response to on-demand planning needs, some of which are dictated by political or budget requirements. Due to the significant impact of emergencies of this kind a dynamic traffic assignment simulation tool is needed to handle traffic pattern changes at the regional level. In addition, because such a tool will be used for the purpose of operational planning, realistic representation of traffic flow dynamics is required so that the temporal and spatial extent of traffic congestion can be realistically quantified.

1.2 Traffic Simulation Models

The increasing complexity of transportation systems highlights the demand for a variety of modeling capabilities for the distinct purposes of (1) long-term transportation planning, (2) short-term operational planning, and (3) traffic operations analysis. Depending on the level of detail of their traffic flow representation, transportation models can be categorized into three types, namely macroscopic, mesoscopic, and microscopic. Each of these complementary approaches plays a well-defined role in transportation analysis, as each one has unique characteristics to answer certain questions that the others cannot answer as effectively. The following table summarizes the pros and cons of each approach.

Table 1.1 Levels and Characteristics of Transportation Simulation Models

	Macroscopic Travel Demand Models	Mesoscopic Traffic Simulation Models	Microscopic Traffic Simulation Models
Geographic Coverage	Regional Network / Metropolitan Area	Regional Network / Metropolitan Area	Small to medium size subarea networks
Demand	Static O-Ds	Dynamic O-Ds	Dynamic O-Ds
Traffic Control	No signal/ramp setting	Coarse signal/ramp settings	Detailed signal/ramp settings
Analysis	Static user equilibrium assignment	Dynamic user equilibrium assignment	Behavioral modeling based on car-following, lane-changing, etc. No equilibrium is considered.
Advantages	Available from local MPO, can analyze mode shift, low calibration effort	Able to analyze regional traffic diversion, bring the time dimension into planning analysis. Moderate calibration effort.	Suitable for detailed dynamic analysis of traffic control, such as ramp metering, traffic signal re-timing, etc.
Limitations	Not sensitive to operational strategies; not capable of analyzing regional dynamic diversion	Not able to evaluate detailed traffic control strategies (i.e. fully actuated or transit signal priority)	Data availability for proper calibration

The most widely used models are the Macroscopic Travel Demand Models partly because they are the oldest most mature technology and because they require the least amount of information for their development and operation. The focus of these models is to utilize 10-year census socio-economic data with estimated roadway capacities to produce rough estimates of the distribution of traffic over a very large metropolitan network. These models produce static O/Ds for either an average day (24-hour matrix) or at best peak period ones. Considering the aforementioned limitations, such models can totally miss out the effects of ordinary traffic fluctuations, special events, traffic control, or traveler information strategies. Regardless, these models are the most logical first step for any traffic analysis. Programs like AIMSUN Planner, CUBE Voyager, VISUM, TransCAD, and others belong to this category.

Mesoscopic models are a recent addition in the traffic analysis tool box. These models supports transportation network planning and traffic operations decisions, including evaluation of ITS deployment options, through the use of simulation-based dynamic traffic assignment. Mesoscopic models provide the capability to model the evolution of traffic flows in a traffic network, which result from the decisions of individual travelers seeking for the best paths en-

route over a given planning horizon. It overcomes many of the known limitations of static tools used in current planning practice. These limitations pertain to the types of alternative measures that may be represented and evaluated, and the policy questions that planning agencies are increasingly asked to address. Meso models define a new generation of transportation planning methodologies, which can interface readily with existing four step procedures, yet provides a meaningful jump in the range and type of measures that can be evaluated. Because it considers the time-varying nature of traffic flows, it is expected to produce more useful estimates of state variables such as speeds, queue lengths, delays, and congestion effects to better assess the functional and environmental impacts of a variety of traditional and emerging transportation planning measures, including the deployment of ITS and non-ITS technologies. Naturally, mesoscopic models require more information for their development than the macroscopic ones but one can still get by with an average picture of the system. For example, use a default traffic plan for non-critical intersections rather than the real one. Mesoscopic models generally recognize two types of traffic, moving and queued. This is adequate for arterial streets where traffic is governed by intersection control and traffic fluctuations are small. Freeways, where road geometry and factors like traffic composition and driver behavior generate large and wide spread traffic fluctuations, are not captured well by the currently available mesoscopic models. Programs like AIMSUN Meso, Dynasmart-P, DynaMIT, Dynameq, and CUBE Avenue Extension belong to this category and focus mainly on the implementation of dynamic traffic assignment.

Microscopic traffic models have reached the market earlier than the mesoscopic ones, initially oriented towards specific, limited size projects of new construction or traffic control. These models emulate traffic down to the individual vehicle based on models of driving behavior. Due to their detail in representing the system, these models require the largest amount of information for their development. Accurate traffic control plans, link costs, roadway geometric features, traffic composition, and driving behaviors are essential information. Assuming one could collect all this information and calibrate them; microscopic models would produce the most accurate result as well as provide the most robust platform for evaluating any traffic management strategy. With the progress made in more sophisticated computing systems as well as larger and more organized GIS systems, metro-wide implementations of microscopic models have emerged. Notable are the models of Singapore, Madrid, Sydney and others (Hourdos et al, 2008). One common factor in all of these projects is that all required well behaved macroscopic travel demand models to produce the starter set of O/D information for time division and adjustment based on accurate closely spaced detector infrastructures. The Macroscopic model prerequisite has prompted an all out integration of macroscopic travel demand applications with microscopic simulation ones, and the offer of these now as a single application. The availability of detector measurements still renders large scale model development a very costly proposition or in many cases an impossible one. The programs with the largest market share in microscopic simulation are AIMSUN NG, PARAMICS, and PTV Vision. During the most recent large scale implementations of these models, it was observed that in the larger areas of the network (most arterial streets) where traffic has few fluctuations, microscopic models produced similar results with the mesoscopic therefore not justifying the very large cost of their development. This realization, as we explain in the following section, has sparked the yet embryonic development of mesoscopic-microscopic integrated models.

Examples of large transportation simulation models as well as a comprehensive feature outline of most of the aforementioned simulation applications can be found in the final report of the “Access to Destinations: Twin Cities Metro-wide Traffic Micro-simulation Feasibility Investigation” project by Hourdos and Michalopoulos, 2008. The aforementioned project among other things developed the methodological roadmap for the research described in this report.

1.3 Integrated Multi-Resolution Simulation Model

Following the aforementioned categorization of the currently available models, our discussion will not seek to define whether one approach is better than the other, or if there is a unique approach that can adequately replace all the others. Our focus is on how we can integrate these approaches to work together to answer the questions at hand. For the purpose of this research program, which is to develop decision support simulation tools for operational planning and traffic operations in the event of severe network disruption, a multi-resolution approach that combines both mesoscopic and microscopic simulation models is the most appropriate (see Figure 1.1). The mesoscopic model will predict and evaluate regional traffic diversion, and the resulting traffic flow from this model can serve as input to the microscopic simulation model, where detailed traffic control strategies can be evaluated. It is essential to model the freeway network at the microscopic level because geometric features, control strategies, and even traffic composition play the most significant role in traffic state evolution. Unlike for the arterial system, the limited access nature of freeways makes path selection a lesser issue. Naturally the two systems need to be appropriately modeled in order to capture regional traffic patterns.

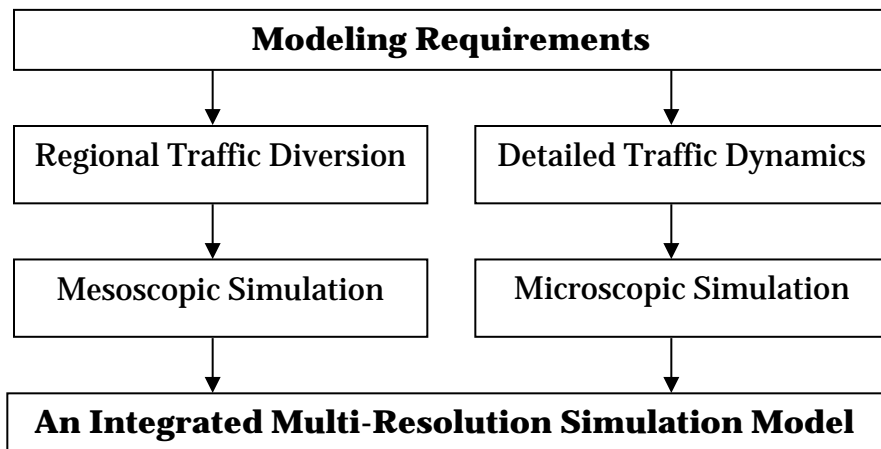


Figure 1.1 Multi-Resolution Simulation Model Development

Current research and practice make extensive use of both mesoscopic and microscopic traffic simulation models, but they rarely integrate the two. However, there is a growing awareness that single resolution simulation models may not be sufficient to handle large-scale complex transportation network problems, and that integration of simulation tools at different resolutions is required. As a signal of this trend, several commercial traffic simulation developers, for example, TSS and Caliper, have started to offer simulation models at all three levels.

1.4 Brief Description of Phase I Effort

Capitalizing on the fact that in a hybrid approach the two model levels do not have to be developed sequentially, the development effort was broken down and undertaken by two different teams. The team lead by Dr. Henry Liu took the task of developing the mesoscopic model of all major arterials in the metro area with the results of this effort described in a separate project report. The Minnesota Traffic Observatory team undertook the development of a microscopic model of all freeway and major highway segments in the Twin Cities metro area. The results of the first phase of this effort are described in this report.

The effort in this phase focused mainly on the first stages of development which are mostly mundane data entry. Regardless, the size of the area covered by this modeling effort prohibits following the traditional, mostly manual, methods of entering the geometry and demand of the network in the simulation application. Before proceeding with the description of the project effort a short description of the AIMSUN NG simulation environment is include in chapter 2. Chapter 3 describes the method followed and final results of the network geometry development. Chapter 4 describes the steps followed in the definition of the most suitable demand configuration and development both for the operation of the model as a whole as well as for the calibration of individual freeway segments. Chapter 5 describes the results from the calibration of approximately 60% of all freeway segments. Finally, chapter 6 focuses on the remaining work for phase 2.

Chapter 2: AIMSUN NG Transport Simulation Environment

From experience and as a result of the earlier feasibility study we know that there are very few commercially available simulators that are capable of handling the network size developed in this project, AIMSUN NG is one of them. A more practical reason why we selected this package is the familiarity and accumulated experience we have with it. Specifically, several prior projects involving the microscopic simulation of freeways have completed successfully offering not only familiarity with the model parameters but a very good start for calibrating them. Additionally, the Twin Cities past and present ramp metering strategies have been integrated with this simulator offering a considerable head start on the work of this project.

AIMSUN NG is a modular environment that incorporates different functionalities for planning, simulation, logistics and other. For the purposes of this report we will summarize the characteristics of two modules, the AIMSUN PLANNER and the AIMSUN simulator. At the time this report was originally written AIMSUN simulator encompassed two separate models meso and micro. Presently a third choice has been added that combines the two into a hybrid model that uses a different models for different parts of the network.

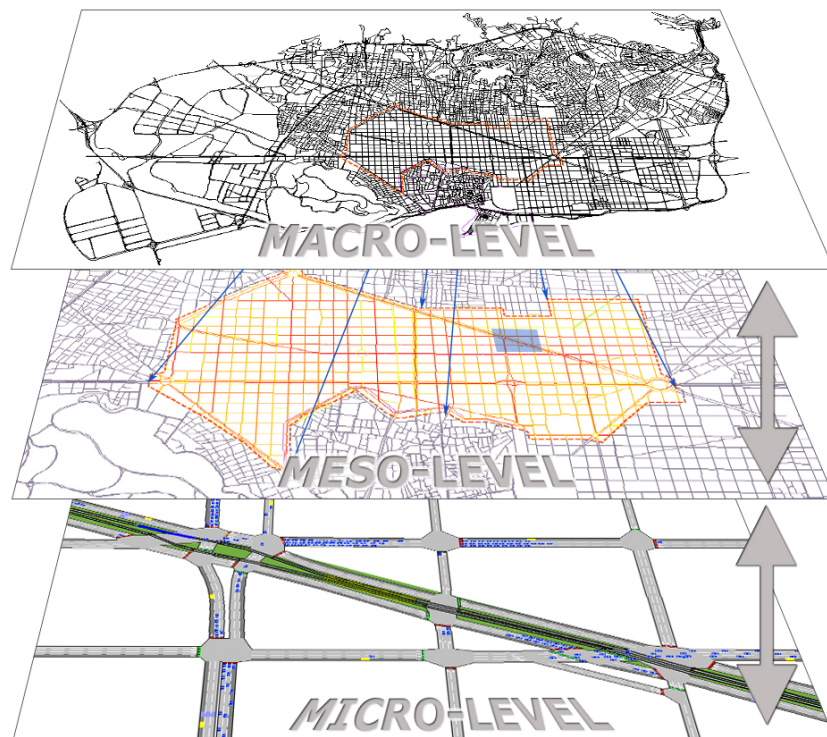


Figure 2.1 Macroscopic and Microscopic Simulation Levels

2.1 AIMSUN Planner

The AIMSUN Planner has been designed and implemented to support the analyst in the manipulation of O/D information, calibration of model traffic assignment parameters, and generation of a subarea traversal matrix.

- Traffic Assignment

The Equilibrium Traffic Assignment is based on Wardrop's user optimal principle: No user can improve his travel time by changing routes. Every section in the network must have an associated volume delay function (VDF). A default template offers a set of VDFs associated with every Road Type in it. VDFs can be set by Road Type or defined on a per section basis. VDFs are defined by the user as equations using parameters provided from the model. The VDF units are in seconds of delay but they can as well represent link travel time. An example VDF corresponding to the know Spiess Delay function is expressed as the following:

$$\text{DELAY} = (\text{LinkLength}(S)/\text{LinkSpeed}(S)) * (2 + \text{SQRT}(16 * (1 - ((\text{LinkVolume}(S) + \text{LinkAddVolume}(S))/\text{LinkCapacity}(S))^2 + 1.361) - 4 * (1 - ((\text{LinkVolume}(S) + \text{LinkAddVolume}(S))/\text{LinkCapacity}(S)) - 1.167)))$$

Following the assignment procedure, results may be presented in a graphical or non-graphical format. Output that may be reviewed includes:

- Flows and Travel Times
- Turnings – the percentages of the volume on a section that take each of the possible turnings when arriving at a node, the volume of vehicles taking each turning, and the turning time.
- Shortest Path – for each O/D pair the list of shortest paths, together with their path proportion and travel time obtained in the assignment is displayed.
- Validation – the ability to compare results obtained during assignment with detection data.
- Refinement – with this information, the user can decide whether to continue the assignment with more iterations or forcing the gap to be smaller.
- Demand Analysis (including matrix import and export, matrix manipulation, matrix balancing and matrix adjustment). The most important tool in this category is the Matrix Adjustment one which uses real data from detectors to modify O/D matrixes generated by other travel demand models. As we will discuss later this is a very important step in the transition from a macroscopic model to a meso and/or micro.
- Traversal Generation

The objective is to extract an origin-destination matrix for a subarea. Its traversal matrix will contain the gate-to-gate traversal trips calculated from the Assignment of the trips of a global matrix in the global network. The problem area may be selected using a polygon defined by the user. When the traversal matrix is calculated, a new centroids configuration in accordance to the problem area is automatically calculated.

Given a generic network with a defined centroids configuration and a subarea of the network, a new centroids configuration for the subarea is created adding a centroid at every in and out gate and for the centroids connected with sections inside the subarea, a new centroid will be created for each of its connections.

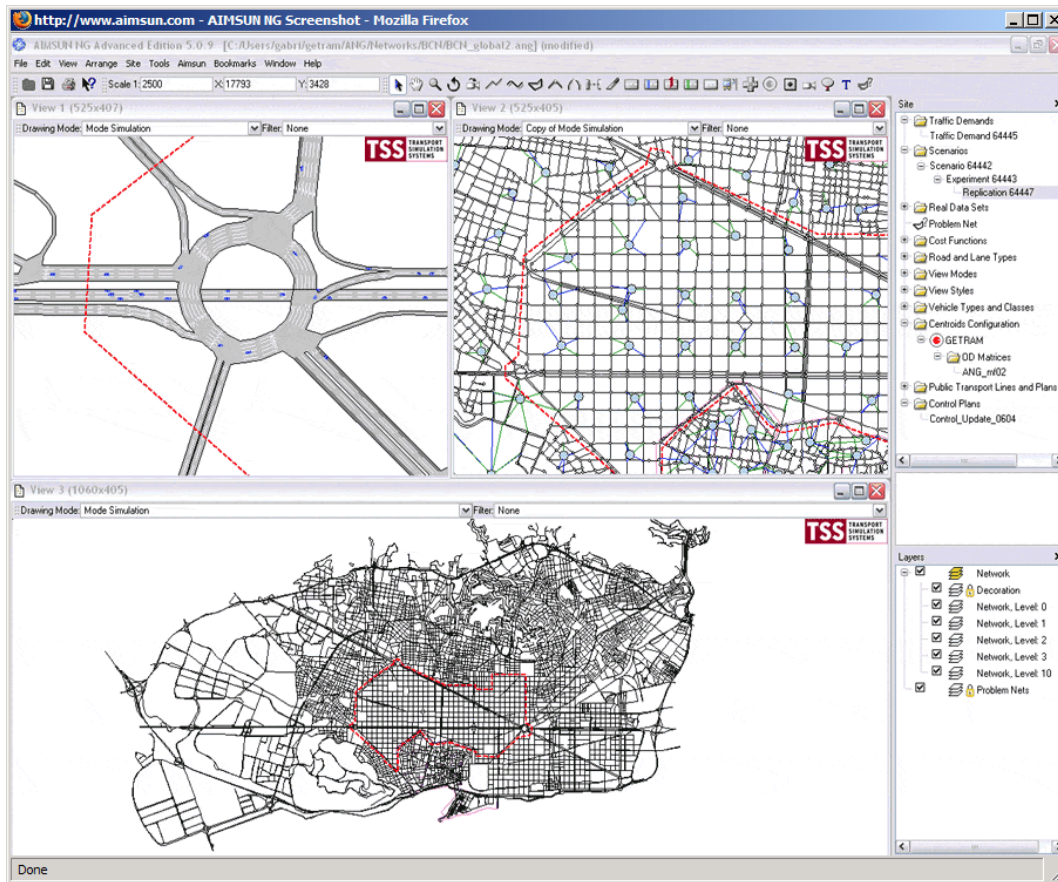


Figure 2.2 AIMSUN NG

2.2 AIMSUN SIMULATOR

AIMSUN (Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks), is a mesoscopic and microscopic traffic simulator that can deal with different traffic networks: urban networks, freeways, highways, ring roads, arterials and any combination thereof. It has been designed and implemented as a tool for traffic analysis to help traffic engineers in the design and assessment of traffic systems. It has proven to be very useful for testing new traffic control systems and management policies, either based on traditional technologies or as implementation of Intelligent Transport Systems.

AIMSUN can simulate adaptive traffic control systems such as SCATS, VSPLUS and C-Regelaar; vehicle actuated, control systems that give priority to public transport, Advanced Traffic Management Systems (using VMS, traffic calming strategies, ramp metering policies, etc), Vehicle Guidance Systems, Public Transport Vehicle Scheduling and Control Systems or applications aimed at estimating the environmental impact of pollutant emissions, and energy consumption.

AIMSUN currently follows two independent simulation approaches a mesoscopic and a microscopic. A beta version of an upcoming hybrid meso-micro simulator has been released. The reported functionality is similar to the one found on TransModeler simulation application. For the purposes of this report we will only elaborate on the microscopic simulation part. In

AIMSUN the behavior of each vehicle in the network is continuously modeled throughout the simulation time period while it travels through the traffic network, according to several vehicle behavior models (e.g., car following, lane changing). AIMSUN is a combined discrete/continuous simulator. This means that there are some elements of the system (vehicles, detectors) whose states change continuously over simulated time, which is split into short fixed time intervals called simulation cycles. There are other elements (traffic signals, entrance points) whose states change discretely at specific points in simulation time. The system provides highly detailed modeling of the traffic network, it distinguishes between different types of vehicles and drivers, it enables a wide range of network geometries to be dealt with, and it can also model incidents, conflicting maneuvers, etc. Most traffic equipment present in a real traffic network is also modeled in AIMSUN: traffic lights, traffic detectors, Variable Message Signs, ramp metering devices, etc.

The input data required by AIMSUN is a simulation scenario, and a set of simulation parameters that define the experiment. The scenario is composed of four types of data: network description (geometry), traffic control plans, traffic demand data and public transport plans. The simulation parameters are fixed values that describe the experiment (simulation time, warm-up period, statistics intervals, etc) and some variable parameters used to calibrate the models (reaction times, lane changing zones, etc). The outputs provided by AIMSUN are a continuous animated graphical representation of the traffic network performance, both in 2D and 3D, statistical output data (flow, speed, journey times, delays, stops), and data gathered by the simulated detectors (counts, occupancy, speed).

2.2.1 Simulation Process

The logic of the simulation process in AIMSUN is illustrated in Figure 2.3. It can be considered as a hybrid simulation process, combining an event scheduling approach with activity scanning. At each time interval (simulation step), the simulation cycle updates the unconditional events scheduling list (i.e. events such as traffic light changes which do not depend on the termination of other activities). The “Update Control” box in the flow chart represents this step. After this updating process, a set of nested loops starts to update the states of the entities (road sections and junctions) and vehicles in the model. Once the last entity has been updated, the simulator performs the remaining operations such as inputting new vehicles, collecting new data, etc.

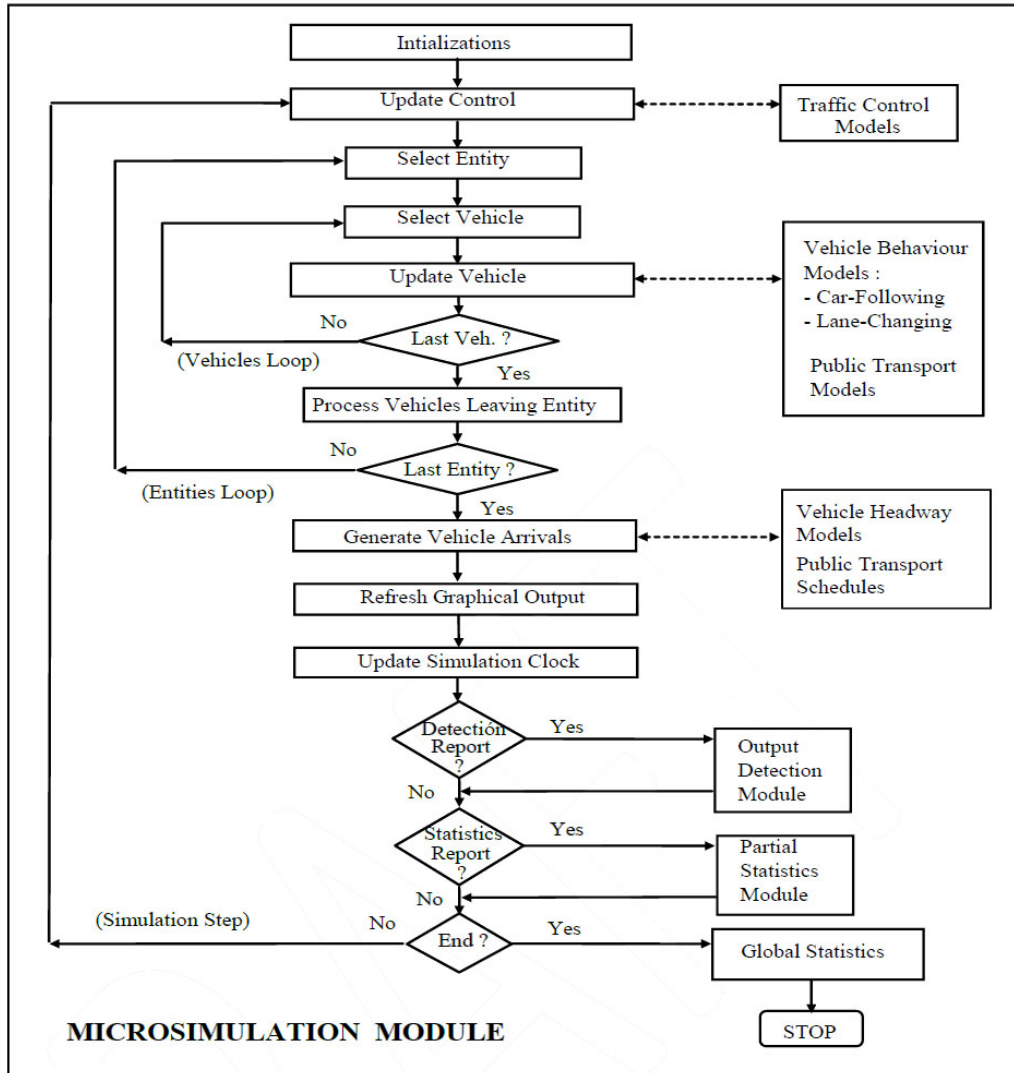


Figure 2.3 AIMSUN Simulation Process – Volume Based

Depending on the type of simulation, new vehicles are input into the network according to flow generation procedures (headway distributions for example) at input sections, or using time sliced O/D matrixes and explicit route selection. It is rare the use of flows and turning percentages in the case of a network that has parallel routes. In the case of the network in this study where the balance of traffic over different freeways is of interest, flow/turning percentages was not an option. In the case of a single freeway corridor it is preferable to use such a demand description since detector information can be used directly. When the demand is described in terms of O/D matrixes, the simulation process includes an initial computation of routes going from every section to every destination according to link cost criteria specified by the user. Figure 2.4 shows the simulation process for the Route Based model. In this case, a shortest route component periodically calculates the new shortest routes according to the new travel times provided by the simulator, and a route selection model assigns the vehicles to these routes during the current time interval. Vehicles keep their assigned route from origin to destination unless they have been identified as “guided” at generation time. They can then dynamically change their trajectory en-route as required for simulating vehicle guidance and vehicle information systems.

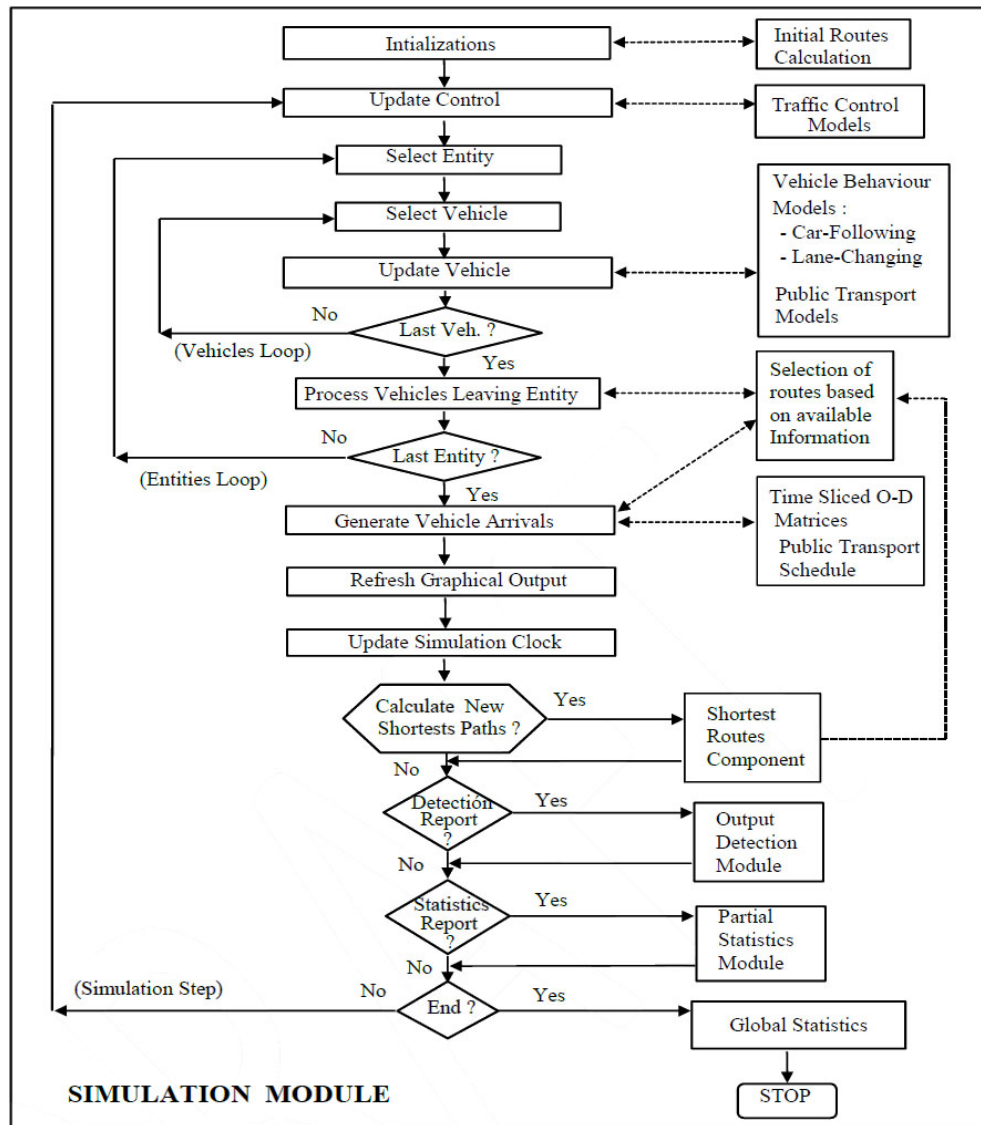


Figure 2.4 AIMSUN Simulation Process – Route Based

For the purposes of this project we are using both of the aforementioned simulation processes. Specifically, the route based is the intended final product of this project although not completed in phase 1, while the volume based simulation is used during the calibration of individual freeway segments.

2.2.2 Network Layout

An AIMSUN traffic network model is composed of a set of sections (one-way links) connected to each other through nodes (intersections), which may contain different traffic features. To build the network model, the following input data is required:

- Map of the area, preferably a digitized map in .DXF format.
 - GIS data from sources like ArcGIS, Mapinfo and NAVTEQ can be used to build a sub-area/corridor, or a metropolitan region.

- Details of the number of lanes for every section, reserved lanes and side lanes (on and off ramps).
- Possible turning movements for every junction, including details about the lanes from which each turning is allowed and solid lines marked on the road surface.
- Speed limits for every section and turning speed for allowed turns at every intersection.
- Detectors: position and measuring capabilities.
- Variable Message Signs: position and (optionally) the possible messages

2.2.3 Traffic Demand Data

Traffic demand data can be defined in two different ways:

1. By the traffic flows at the sections; or
2. By an O/D matrix

Depending on the type of model selected, the following input data must be provided:

1. Traffic Flows
 - Vehicle types and their attributes
 - Vehicle classes (for reserved lanes)
 - Flows at the input sections (entrances to the network) for each vehicle type
 - Turning proportions at all sections for each vehicle type
2. O/D Matrix
 - Centroid definitions: traffic sources and sinks
 - Vehicle Types and attributes
 - Vehicle Classes (for reserved lanes)
 - Number of trips going from every origin centroid to any destination one

2.2.4 Traffic Control

AIMSUN takes into account different types of traffic control: traffic signals, give-way signs and ramp metering. The first and second types are used for junction nodes, while the third type is for sections that end at join nodes. The input data required to define the traffic control is as follows:

- Signalized junctions: location of signals, the signal groups into which turning movements are grouped, the sequence of phases and, for each one the signal groups that have right of way, the offset for the junction and duration of each phase.
- Un-signalized junctions: definition of priority rules and location of Yield and/or Stop Signs.
- Ramp metering: location, type of metering, control parameters (green time, flow or delay time).

For the purposed of this project the signalized intersection control is used to facilitate realistic movements on intersections adjacent to freeway entrance and exit ramps. For the purposes of ramp metering we have overridden the native control with an external system that emulates the Twin Cities logic.

2.2.5 Public Transport

The user may opt to have AIMSUN take Public Transport into account. The input data required to define Public Transport is as follows:

- Public Transport Lines: a set of consecutive sections composing the route of a particular bus.
- Reserved lanes.
- Bus Stops: location, length and type of bus stops in the network.
- Allocation of Bus Stops to Public Transport Lines.
- Timetable: departures schedule (fixed times or frequency), type of vehicle, and stop times (specifying mean and deviation) for each bus stop.

For the purposes of this project we haven't utilized the transit features of the application but it is anticipated that this is something we will use once the complete hybrid model is assembled. In fact evaluating transit operations and optimization can be one of the main functions of the final model.

Chapter 3: Geometry Representation

As eluded in several points earlier in this report one of the necessary steps in building a traffic simulation model is the network description or in different words, to build the geometry of the actual roadways in the particular simulation application. All commercially available simulation packages have some form of graphical user interface that allows the user to manually build the network geometry. This is the most common method of entering the geometry since each simulation application, and AIMSUN is no exception, has its own particular way of representing roadways and roadway elements. The size and complexity of the network in this project demanded the development of a method for automating the above process if not entirely at least in parts. This chapter describes the steps followed for the importation of the Twin Cities freeway and major highway roadway geometry into the AIMSUN simulation environment.

3.1 Importation of the Geometry of the Twin Cities Regional Planning Model

One good source of digitized roadway information for the Twin Cities is the existing Regional Planning Model (RPM) developed and maintained by the Metropolitan Council. In fact, even if there was another source for geometry information our model still had to conform to the RPM because this is the source used later for demand information. Fortuitously, in the summer of 2008 a new version of the RPM became available. The major feature of the new version is that is geometrically correct, meaning that the lines representing the network links follow the actual roadway centerline. Until that point the RPM was based on straight lines for the links since the geometry has no bearing on the operation of the travel demand model. Other types of information were also available through the RPM like roadway segment free flow speeds, capacities, road types, and other.

Like most of the available simulators, AIMSUN allows for the importation of GIS shapefiles and their translation, to the extent possible, into its own representation of roadway geometry. Unfortunately, the GIS translation of the RPM does not allow for the complete geometry description required for microscopic simulation therefore as described later, substantial effort remained in manually fine-tuning the network geometry. It is interesting to note that the other piece of this program, the development of the mesoscopic model, utilized the same GIS version of the RPM but in that case very little additional editing was necessary since mesoscopic simulation does not require the geometric detail necessary for the microscopic model.

From the RPM representation in CUBE Voyager a GIS version was exported and imported into AIMSUN. This was assisted by the provided GIS importer tool. The imported geometry had several problems of which their correction consumed the bulk of the effort in this phase. The following sections outline these problems and how they were corrected.

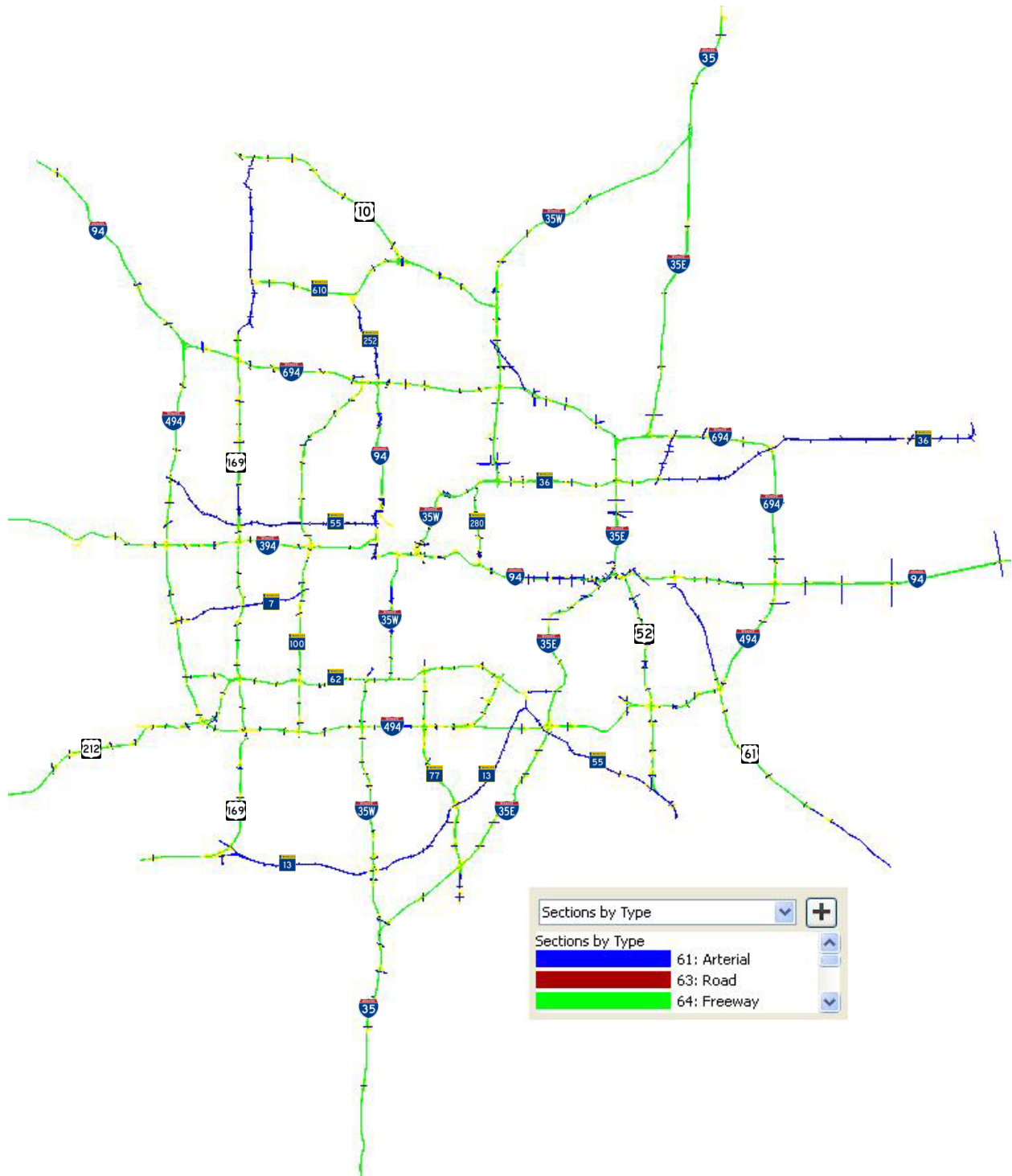


Figure 3.1 Twin Cities Freeway-wide Simulation Model Geometry

3.1.1 Unnecessary Roadway Sections

The RPM contains approximately 25,000 links representing all important roadways in the Twin Cities 7 county metro area. These include freeways, ramps, highways, arterials, and collector links. For the purposes of this project only the freeway and ramp links are necessary as well as some of the major highway sections. The latter segments were selected based on their known utility as alternative routes to freeway trips. This inclusion or exclusion of highway links will be further fine-tuned when the route choice parameters are calibrated in the next phase. Figure 3.2 shows on the left the network geometry as imported from the GIS and on the right the remaining roadway segments after the elimination of unnecessary links.

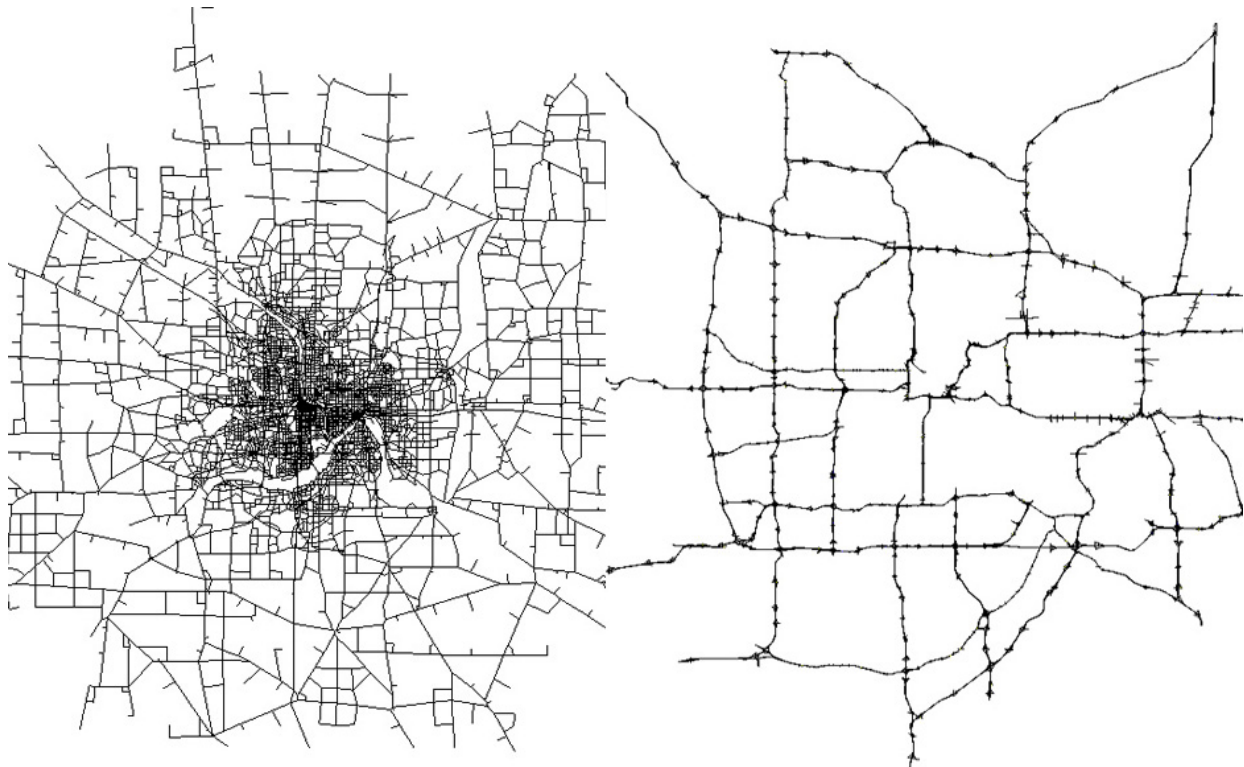


Figure 3.2 Trimming of Roadway Network Geometry

3.1.2 Incomplete Section Geometry Representation

Another problem of the geometry as imported from the GIS is the incomplete representation of freeway segments specifically in the locations of entrance and exit ramps. In the RPM all nodes are the same regardless if they represent a node connecting freeway and ramp links or the links of an arterial intersection. Naturally these two geometries are fundamentally different and these differences are important for microscopic simulation. The AIMSUN GIS importer has no way of distinguishing between arterial and freeway nodes and it applies a basic representation fitted more for arterials. Substantial effort was spent in the manual correction of this problem. Specifically, as seen in figure 3.3 the imported geometry is missing all acceleration and deceleration lanes and it simply assigns vehicle movements from all upstream lanes to all downstream freeway and ramp ones.

These details are essential in capturing the correct vehicle weaving movements as they enter or exit the freeway mainline and in extend help define those locations operational capacity. In result, all network nodes had to be deleted and manually recreated based on the real geometry.

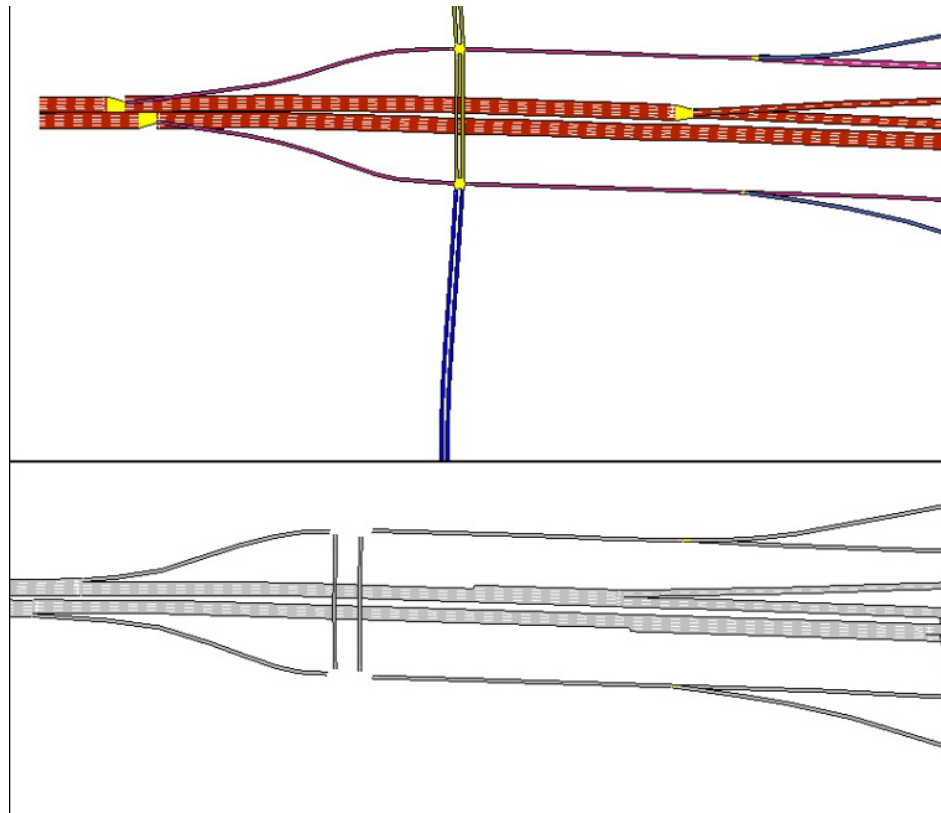


Figure 3.3 As Imported (top) and With Nodes Removed (bottom).

The accurate description of freeway weaving areas was based in the majority of cases on ortho-rectified aerial imagery imported as background in the simulator. We utilized the available 2006 USGS ortho-rectified 1-meter imagery in the majority of locations and 2008 Twin Cities CBD 0.5-meters imagery (higher resolution) where available. The goal was to enter the geometry as it existed in the end of the 2009 construction season. This goal required in certain cases the extrapolation of future geometry for 2008 and 2009 active freeway reconstruction project locations. For each section of freeway it was necessary to consider a number of things when adjusting the geometry. As mentioned before, the need for accurate and up to date aerial photographs was paramount to the effort. Most of the time the USGS imagery represented the only resource that was needed as they accurately portrayed both the state and position of the sections in question. However, in a significant number of cases there were issues that necessitated the use of some additional information sources. In most of these cases it was possible to resolve issues with maps and images from other sources such as Google and Google StreetView or equivalents depending on which set of images was the most up-to-date. In more extreme cases it was necessary to use the MTO feeds of MnDOT freeway cameras (figure 3.4), and in rare locations site visits and drive-by videotaping.

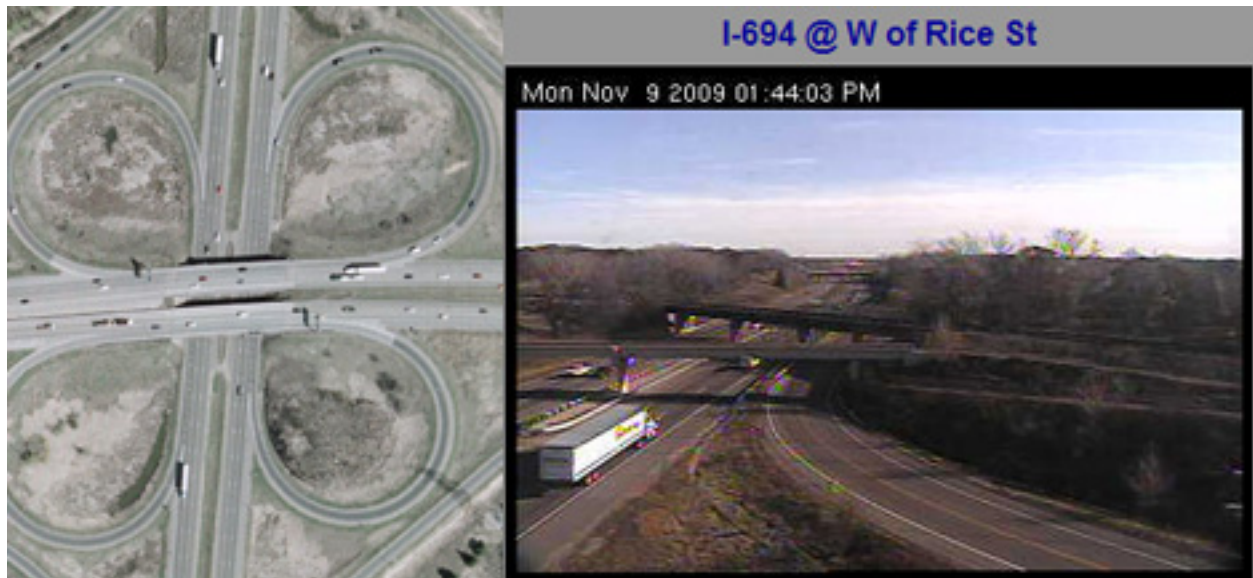


Figure 3.4 MTO Feed of MnDOT Freeway Cameras

Figure 3.5 shows part of a freeway interchange. The top image is the 2006 ortho imagery and the bottom shows the same with the overlaid simulation geometry. Figure 3.5 also shows the location of an additional correction at the exit ramp. In many instances the traffic light at the ramp intersection with the arterial street generates backup queues on the freeway during peak periods. Such an event is important to be replicated in the simulation therefore, as we will describe later the correct intersection geometry was entered and that includes the ramp geometry, pockets and auxiliary lines. The RPM describes all ramps as single lane roadways for their full length. Additionally, in the RPM the exact location of the node between the freeway mainline and the ramp is not important. In a microscopic simulator every feature counts and specifically the length of the taper line defines the available space drivers have to perform lane changes entering and exiting the freeway mainline. It is interesting to note that in many occasions drivers have made their own path by consistently driving over the taper line. Based on the available imagery we used the color difference between pavement frequently driven over and pavement that is not. It is more desirable to replicate the way people drive rather than following the indented road design.

All microscopic simulators are very particular in their description of weaving areas. Such idiosyncratic issues require a specific way the freeway and ramp sections are laid and especially their sequence. For example, in AIMSUN one such “feature” affects/controls the distance simulated drivers start to perform lane changes in order to exit the freeway on a downstream location. Unfortunately, in many cases it was more efficient to delete large chunks of the imported geometry and redefine it based on the imagery and understanding of the simulator modeling features. Although the GUI of the program is very easy to learn and operate the aforementioned issues required the intervention of an experienced modeler and eventually the training of the students hired to perform the bulk of the work.



Figure 3.5 USGS Ortho-rectified Aerial Imagery and Simulator Geometry Overlay

3.2 Freeway Interchange Design

Although the goal of this project is to develop a microscopic simulation model of the freeway mainline for several reasons the particular design of interchanges including the pieces of the surface streets and intersections play a major role. In the previous section it was pointed out that the actual surface street intersection geometry and control is necessary to capture the effect of queue backup on the freeway mainline. An additional reason for the detailed description of such intersections is to correctly merge with the surface street system where demand originates or is destined to. As will be explained in more detail in the next chapter the choice of the way the interchanges between freeway and surface streets are modeled affects the methodology demand information is produced/extracted from the RPM. From the several possible geometries we elected to include the actual geometry of all approaches of the first intersection connecting surface street with entrance and exit ramps. This geometric representation includes the surface street segment of the overpass/underpass connecting intersections on each side of the freeway mainline.

Figure 3.6 shows an example of a diamond interchange on I-94, specifically the one on Snelling Avenue. The left part of the figure shows the whole interchange while the right part shows the detail of the modeling of the intersection movements and control.



Figure 3.6 Modeling of Freeway-Arterial Interchange

The Origin/Destination centroids where demand is described are connected to sections leading away of the interchange. Modeling the interchange in such detail, in addition to allowing for accurate representation of traffic flow conditions, it allows for vehicles to select routes to/from their destination/origin that can utilize either direction of the freeway. Additionally, in the rare but known cases of vehicles missing their exits due to heavy traffic conditions, downstream interchanges can be used as U-turns allowing them to reach their destination through the opposite direction of the freeway. More discussion on freeway/arterial interchanges follows in the next chapter of demand information.

3.3 Modeling HOV/HOT and Other Special Lanes

The actual operations of the I-394 and I-35W HOV/HOT lanes are a complex modeling challenge that in addition to geometric design decisions require detailed calibration. This task was not possible given the available resources in the first phase of this project and therefore is scheduled to be attacked in phase 2. Specifically, not only the pricing algorithm of the HOT lane needs to be implemented and integrated into the path assignment process we fear that a better lane selection model needs to be developed and implemented. Such models have been developed during the NGSIM project but have not yet become part of the commercial versions of micro simulators. Regardless, even if the details are not finalized/calibrated in order for the present model to be complete, a decision on the general design was necessary. During past projects some of the different ways the I-394 freeway can be modeled were explored. From that experience we know that, although the simulator is capable of emulating HOV/HOT lanes, the way it is accomplished does not have the desirable result. Specifically, it is possible to define specific lanes on a section as restricted with their use as mandatory or optional for a particular vehicle type. Additionally, it is possible to model section segments where lane changing is prohibited

(double white lines). Unfortunately, this straight forward way of modeling does not produce the correct utilization of the HOV/HOT lane since the simulator cannot differentiate between paths that utilize the HOV/HOT and paths that utilize the general purpose lanes. Although in reality these lanes have different costs both in a monetary as well as travel time sense, in the single section with restricted lane representation, they share the same cost. This is a deficiency shared with the RPM. Similarly to the RPM, the HOV/HOT lanes are modeled as separate single lane sections connected with the general purpose lanes at the gate locations where the double line is interrupted. Figure 3.8 shows the detail of the model at one of the I-394 HOT gates. Although with this modeling strategy the correct routing is possible, correct utilization of the special lanes requires calibration of the link costs. Modeling the I-35W Dynamic Priced Shoulder Lane is for the moment easier since there is only one entry point.

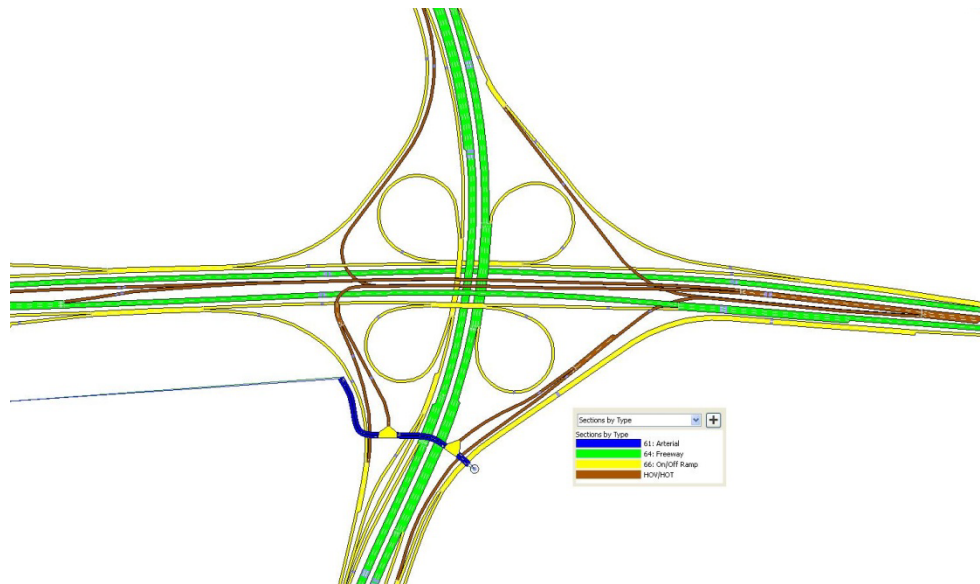


Figure 3.7 HOV/HOT Model Detail

Another issue is the modeling of the I-394 HOV/HOT reversible lanes. These lanes have different directions in the AM and PM periods controlling this flow scheduled redirection with special ramps and gates at the downtown and TH-100 boundaries. The way this operation is modeled in the simulator is by defining these lanes as two separate roadways one on top of the other and with different directions. AIMSUN allows for the opening and closure of selected sections based on a schedule. In the rare case where an entire day will be simulated this feature will allow for the correct redirection of flow. Manually connecting or disconnecting sections is another way of accomplishing the same effect if only one peak period is simulated. Integration of the MnPASS system into the simulator is a task left for a later phase. Until then the effect can be partially emulated by defining a scheduled change in link user costs.

Modeling the current I-35W and future I-94 managed lane systems is a task for the distant future since at the moment we have no knowledge or observations to guide us. It will require sufficient long term data collection and analysis to understand driver behavior under these systems before attempting modeling. In difference, entrance ramp HOV bypass lanes are modeled in a straightforward way as long as the appropriate demand information describing the population of HOV eligible vehicles is available.

3.4 Minor Model Geometry Features

A complete microscopic model geometry includes other elements some of straightforward nature, some that require modeling decisions, and some that their final values will be defined after the simulation is operational. Freeway loop detectors are a rather straight forward geometry feature. They are necessary since these are the data collection points directing calibration and validation as well as necessary elements for the implementation of ramp metering. The simulator allows for the placement of emulated detectors on section lanes and also allows for defining the actual length of these detectors. Although simulated detectors are capable of "measuring" everything (flow, density, speed, occupancy, headways) the real ones can only do counts and occupancy and the very important measurement of speed is actually an estimation based on counts, occupancy, and the assumption of an average vehicle length. The correct operation of the ramp metering logic requires the calibration of the simulated detectors to match the operational length of the real ones and therefore produce the same occupancy. Naturally, this is also a direct effect of the modeled vehicle size distribution. In the present network all 5,298 detectors and 1200 detector stations have been entered but their calibration will be accomplished over time since it involves a very large effort. Specifically, since detector station is more of an operational feature rather than an actual device the simulator cannot tell the difference. The way we selected to model stations is with the placement of simulator detectors that span all lanes in the section. They are differentiated in the output by their name which starts with an "S" while regular lane detectors only have a numeric ID.

Ramp meters are another feature of the geometry. Although the ramp metering logic is the subject of another part of this project, their location is part of the geometry information while the actual entrance ramp implementation is a modeling issue. Fortunately, the project team has long experience both in modeling ramp metering as well as modeling it with this particular simulator. Leaving the detailed explanation of the entrance ramp operation for later, for the sake of completeness, figure 3.8 presents the design that operates best based on the particular simulators capabilities.

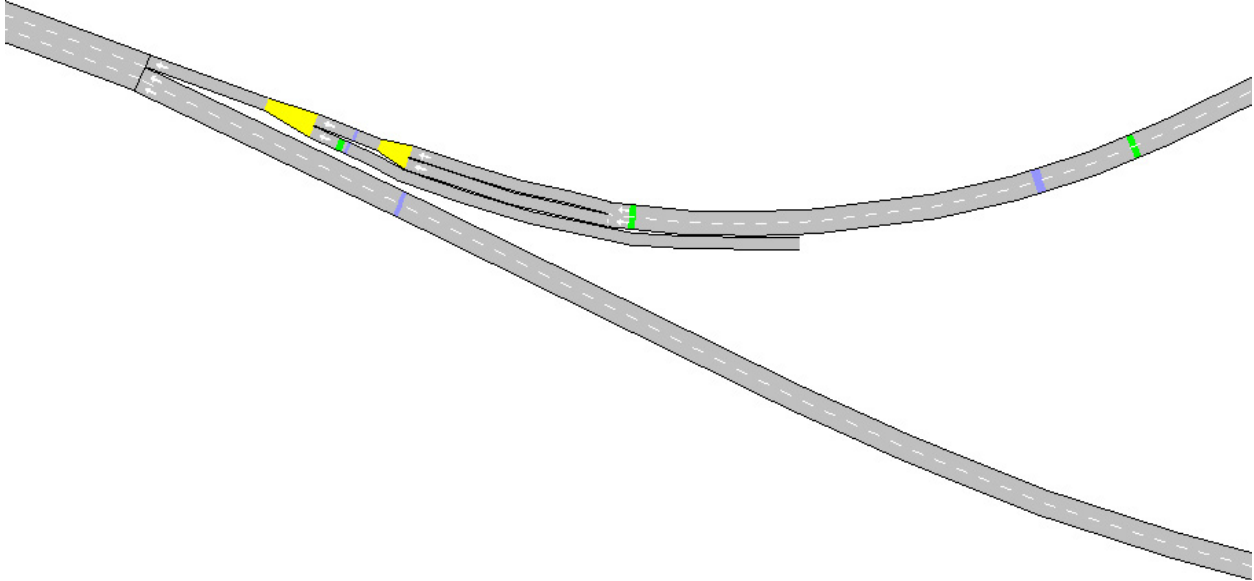


Figure 3.8 Entrance Ramp Geometry for Accurate Ramp Metering

Chapter 4: Demand

The second step in developing the simulation of a roadway network is the definition of demand. By demand we mean the model's boundary conditions or in simpler terms how many vehicles will be loaded in the network, where are they coming from, and where they are going. There are several different sets of demand information needed during the process of a simulation project and these demand sets may have different forms for describing the load of the network. The following are the major sets and forms demand was created and utilized in this project.

1. Demand information for the entire freeway network
 - Calibration sets (traffic assignment model)
 - Past and future projection sets
2. Demand information for individual network segment calibration

4.1 Whole Network Demand Information – Origin/Destination Matrixes

As was briefly described in chapter two, there are two different ways demand can be described in a microscopic simulation model; Origin/Destination matrixes or entrance section volumes and junction turning percentages. The main difference between these two demand forms is that the first allows for route selection while the second blindly assigns the correct number of vehicles in each link. For describing the demand on a network where alternative routes between two or more points exist, demand should be described through O/D matrixes allowing the simulator to assign vehicles in the proper routes depending on the prevailing traffic conditions.

The selection of the final network geometry and the method demand is described in a complex network are closely interlinked. It is essential that the geometry includes all the necessary links vehicles can be assigned under various scenarios. Demand is an input to the simulator that must be valid under any scenario the analyst would like to emulate. To illustrate this issue, consider the simple network of figure 4.1. If the only geometry included is the inner piece (red) then demand will be described based on the inner nodes and be locked to enter the network at these point regardless the conditions in it. If in the case of congestion in the real network users select the alternative path, the demand description in the simulation will be wrong. The correct way will be to include all the geometry between origin i and destination j and describe demand at those two points. Another example related to the Twin Cities network is the decision to include or not the part of the network outside the I-494/I-694 ring road. If we do not include the geometry and in extend the demand outside the ring road the route choices between 35W and 35E, 394 and 55 or 7 would not be possible although it is well understood that these roadways are regularly operating in unison allowing users to select the most desirable route. Although practical limitations often constrain the extent of the network geometry/demand it is important to minimize the locking down of route selection.

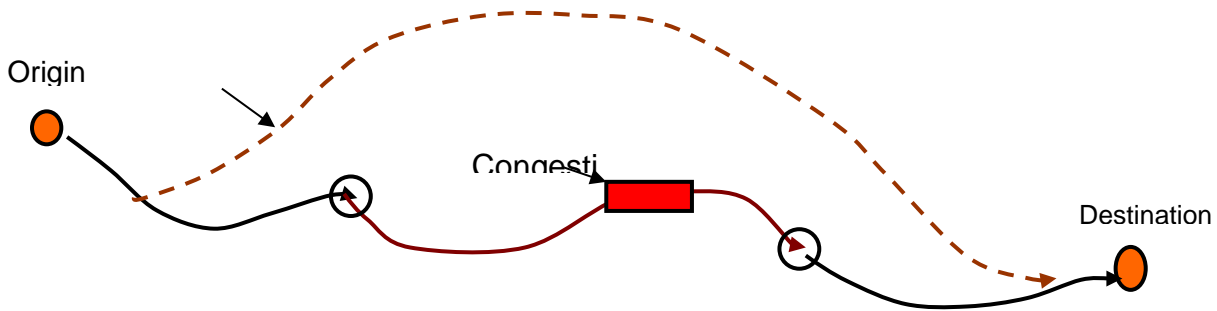


Figure 4.1 Geometry and Demand Interrelationships

Origin/Destination demand information in the majority of cases will be provided by a regional travel demand model. Another way of collecting this information is from a cordon study but that only works for very small networks. Research in the last ten years (Casceña et al, 2001, Muthuswamy et al, 2003) has produced methodologies of artificially generating O/D information from detector measurements. The Paramics Estimator is a commercial implementation of such methodologies but it has still not proven adequately accurate for large or complicated network geometries. For the purposes of this project O/D demand was generated from the RPM in close cooperation with Metro Council travel demand modeling experts.

4.1.1 Trimming the Regional Planning Network

The goal of this project is to create a microscopic simulation model of the Twin Cities freeway network; therefore we are interested only on trips that use the freeways. The selection of modeling only a part of the roadway network introduces certain limitations that are important in the subsequent use of the model. In the real world drivers have many choices on how to complete a trip. These choices include all combinations of freeway and arterial links that represent a valid path for the trip. In the case of a freeway only model one basic assumption is that drivers have no choice on the point they enter or exit the freeway network. Once in the freeway network they can seek and follow the most efficient path between their origin and destination. This assumption introduces a serious constraint in the use of the model for hypothetical scenarios that include severe congestion points or incidents. In the real world, road users have the option of exiting the freeway on ramps near their destination and complete the trip through the adjacent arterials. This behavior will not be able to be simulated with the freeway only network. One way other modelers have chosen to circumvent this problem is by combining several exits/entrances of the freeway with one origin/destination centroid. This is a very dangerous modeling decision because the division of the freeway in such segments becomes very important while it does not guarantee accurate utilization of the freeway network. Considering that the ultimate goal of this project is to be combined with a mesoscopic simulation model of the arterial streets it is more preferable to create a freeway model that can be accurately calibrated under normal conditions and allow the final hybrid model be the tool for evaluating scenarios where the users flip between freeway and arterial links. So, with this modeling decision made we require O/D demand information for each freeway interchange. This demand is estimated by trimming the RPM to produce O/D only for the freeway network. As mentioned already the RPM is maintained by the Twin Cities Metropolitan Council. Although the Minnesota Traffic Observatory maintains a full license of CUBE Voyager and has a duplicate of the RPM in house,

correct operation of such a complicated model is best left with people with the right expertise and experience. The assistance provided by the Metro Council chief modeler Mark Filipi was instrumental in completing the task of estimating the model's O/D information.

A usual procedure performed by travel demand models is the extraction of O/D information for a subarea of the network. This operation is so common that all programs offer tools assisting the user in graphically selecting a subarea and extract demand information. Unfortunately, in this project we didn't need to extract a specific area in the region but to trim the model by removing all arterial links and assign the right amount of trips to each freeway interchange. Some experimentation has shown us that the methodology for accomplishing this, can utilize the same core assumptions used when extracting a subarea. Basically, the methodology involved a detailed analysis of the final user equilibrium paths produced by the travel demand model, selecting all trips with paths utilizing a freeway link, and translating their origin/destination to the first/last link included in the microscopic model. Although the steps for accomplishing this are relatively simple, implementation required a lot of iterations and point by point analysis to correctly assign trips to the new boundary zones. The basic iterative steps are summarized as follows:

1. A network of highways, ramps and major expressways was identified and the nodes of those facilities coded with an identifying attribute (subarea=1). This then allowed the extraction of the sub-network using CUBE's functionality in the GIS window.
2. Once the trimmed network was created, TP+ was used to load each of the 24 daily time periods in the model, creating for each time period an O/D matrix containing three trip tables: SOV, Truck, and HOV. These were then converted to ASCII text format for importing into the micro simulator.

The step that is omitted above is the point-by-point inspection of the paths in each freeway interchange. This inspection generated an iterative process during which the university team suggested a trimmed network, send this information to the MetCouncil modeler who followed the aforementioned steps. The resulting paths were analyzed and a new trimming alternative was produced repeating the cycle again. To assist the reader in comprehending this process we include examples of a couple of particularly troublesome locations.

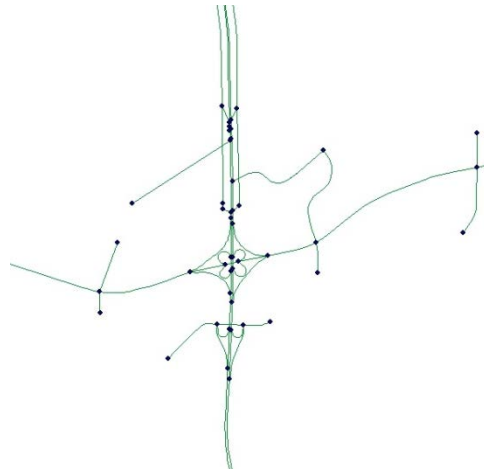


Figure 4.2 Interchange of I-35W with TH-13.

Figure 4.2 shows the trimmed RPM in the area of the interchange of I-35W with TH-13 in Shakopee, MN. As can be seen from the figure there are two entrance/exit ramps to/from I-35W and three for TH-13. TH-13 is actually a signalized expressway included in the model due to its important as an alternative route. The two centroids in the northwest part of the interchange, although geographically belonging to a relatively small area, have no surface streets included in the RPM that can easily direct demand from one to the other therefore were included separately. The same applies to the ones in the southwest and southeast corners. The area on the northeast of the interchange though has sufficient surface streets providing more than one alternative routes from/to I-35W. For this reason they all combined into one O/D zone.

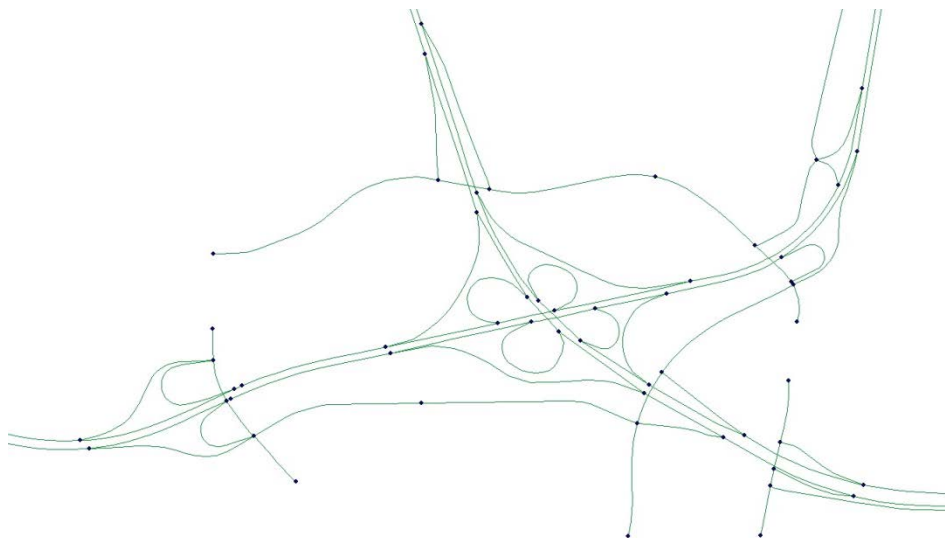


Figure 4.3 Junction of I-494 and TH-212

Figure 4.3 displays the junctions of I-494 and TH-212 in the southwest corner of the Twin Cities area. In this area the new interchange between TH-212 and I-494 is the main connection but a number of established urban streets operate as detours to trips traversing this location. In the south Technology Dr. connects the two freeways and provide a double access from/to the

industrial/retail zone in this location. Similarly in the northeast, Valley View Rd. functions in a similar way. The detail of the included and excluded links in these locations greatly affect the generated O/D information therefore a close inspection of the equilibrium paths was necessary.

In the process of trimming the network we also encountered a few cases where the RPM contained the wrong links or had connections that are not feasible in reality. All such cases were identified and both models were improved to better reflect reality. For example figure 4.4 shows the geometry in the RPM for the junction between TH-13 and TH-77. Notice in the middle the extra link connecting 77southbound with 13 westbound. This link actually was a remnant from the old non-conflated RPM network.



Figure 4.4 Error in the Junction of TH-13 and TH-77

4.1.2 Origin/Destination Demand Estimation Results

As described already, the final product of the collaboration between the U of M research team and Metro Council is a set of O/D matrixes. The set is comprised of three matrix groups belonging to single occupancy vehicles (SOV), high occupancy vehicles (HOV), and trucks. For each of the three groups 24 matrixes covering 24 hours were generated. These are not all one hour long matrixes but concentrate around the peak periods (45 min matrix) while are larger during the low demand times (2 hour matrix). In total, 859 zones were identified as entry/exit points of the network. Figure 4.5 shows a representation of the network with the red dots representing the zone centroids.



Figure 4.5 Metro-wide Freeway Network with Centroids

It is important to note that this demand set is the seed for generating a bigger set of O/D matrixes for the same vehicle types, a set that better represents traffic conditions actually measured by the freeway loop detectors. This process is called *Matrix Adjustment* and is only briefly described in this report since it is both complicated beyond the scope of this project and in many ways still not mature enough. Matrix adjustment of large urban networks is one of the research subjects we will explore in the future with the help of the Twin Cities freeway-wide simulation model. In this project phase we utilize the matrix adjustment process included with the AIMSUN software and described in (Cascetta et al., 1993). In summary, the matrix adjustment is accomplished at the macroscopic level of the given model and it is basically an optimization procedure where the

results of traffic assignment are compared to actual volume counts from detectors in the field. Each cell in the O/D matrix is adjusted so the final traffic assignment result produces link volumes as close as possible to the measured ones. One sensitive point involving matrix adjustment is that it should be included in an iterative process that includes all three levels of the model. The traffic assignment at the macroscopic level depends on the user specified relationship between the volume and delay or travel time for each link and any other parameters that affect route selection, in general terms, the cost of each link. In the mesoscopic and microscopic levels this relationship changes since travel time does not have to be estimated through volume but it is a direct output of the model allowing for better calibration of route selection parameters. This calibration though is contingent to the quality of the demand information and so the circle goes. In the following chapter of Calibration we propose an iterative procedure that includes matrix adjustment. A preliminary matrix adjustment was performed in this phase but not tested in the entire network at the microscopic level.

4.2 Individual Freeway Segment Demand Information

A microscopic simulation model, being the level of highest resolution, is very sensitive to model parameters, geometry and demand. When a system operates close to capacity, a 2% change in freeway demand may be the deciding factor between uncongested conditions or hours of congestion delay. Therefore, it is counterproductive to try to calibrate the microscopic model parameters, global and local, for a freeway network. Instead it is better to calibrate these parameters for individual freeway segments modeled independently and then use them in the full network. Specifically, global parameters are a single set and if all goes well the same values will be reached for all the individual parts of the network. The goal is to reach a common set of global parameters and fine tune each sub-network based on local parameters. The segments of the full network are finally edited to match the local parameter settings of each individual sub-network. Since calibration is the continuous process of parameter adjustment and comparison of the model output with actual field measurements, the demand used in this process must be as close as possible to the actual observed during the data collection days. Although, the aforementioned process of generating O/D matrixes can also be applied to this case, it is simpler to develop demand information based directly on the actual detector counts. This simplification of course can only work for pure freeway roadway segments that have no alternative routes between entrances and exits. An additional benefit from piecewise calibration is that demand information from a normal day can be selected for each freeway segment. By normal we describe a day that has a typical demand level, no capacity reducing incidents, or workzones. When the entire network is considered it is very difficult to find a normal day; some people say that there is never a normal day since something out of the ordinary happens all the time in one of the freeway segments. So, the process involved in generating demand states for each freeway segment involves the following steps:

1. From the loop detector database extract counts of mid-week days (Tuesday, Wednesday, and Thursday).
2. Use sufficient number of days in order to determine what is the average level of demand on each of the freeway detector locations. Specifically, the typical days were selected by using GEH statistics (Chu et. al, 2003). If the GEH results of data from 80% of the detectors were less than five, the day can be defined as typical day.

$$GEH = \sqrt{\frac{(V - V_a)^2}{(V + V_a)/2}}$$

3. Inspect each of the average days for incident patterns with the help of occupancy or speed measurements if available.
4. Select 2 to 3 days that have the fewest malfunctioning detectors.

Having selected 2 to 3 days for each freeway segment we utilized tools developed at the MTO to produce demand states that describe the entrance volumes and exit turning %s every 15 minute for 24 hours. These are the demand states used in model calibration.

4.3 Conclusions

This chapter described the steps and procedures utilized in generating demand scenarios for the freeway-wide network. As eluded in section 4.1.2 the task of generating the final demand information for the entire network has not been concluded because it is closely linked with the calibration of the route selection model parameters. Such calibration was not part of the effort in this stage of model development. Regardless, the major step of extracting the seed O/D demand information from the RPM has been accomplished and with it the description of the network geometry is also complete. Naturally, even that is temporary since the freeway network is always evolving through new construction projects but at least now the effort will be incremental.

Chapter 5: Model Calibration/Validation

Simulation models are reliable when the simulated results are close to reality. The most important step in developing a microscopic simulation model is calibration, which is an iterative trial-and-error process during which model parameters change and simulated measurements are compared to actual measurements from the field. The real-life traffic data could be traffic volumes, speeds, occupancies, travel times, queue lengths, etc. Depending on the scope of the calibration (segment or full network) these measurements can be synchronized or collected over a period in time. Definitions of reliable measures of goodness-of-fit are important, since they are used to evaluate the difference between real and simulated measurements. Again the types of these GOF measures depend on the scope of the calibration. For example, during freeway segment calibration, often used GOF measures are the correlation coefficient, the root mean square percent error (RMSP), and Theil's inequality coefficient (Hourdos et al., 2003).

Usually, if the network is large or contains freeways and arterials, the calibration can be complicated due to the limited availability of real data. This is not the case of the Twin Cities freeway-wide model since almost all modeled segments¹ have detectors but still volume/occupancy measurements are not very helpful during route choice parameter calibration. This study summarizes the procedure for the calibration of a large freeway network but it also represents the base for calibrating a smaller freeway/arterial network as well. The procedure, as discussed in the previous chapter, is comprised by two parts, Independent Freeway Segment (IFS) calibration and network-wide (NW) calibration.

5.1 Independent Freeway Segment Calibration

IFS calibration involves the refinement of the microscopic simulation model parameters responsible for producing realistic driving behavior and traffic flow patterns. These parameters are global, meaning their values are the same at all points of the freeway segment, and local describing the effect roadway geometry and other local features have on driving behavior. All of these parameters are relevant only to the specific simulation software although their physical equivalent may be the same. The following table outlines the local parameters pertaining to the AIMSUN microscopic simulator while table 5.3 outlines the global ones along with their calibrated values. Regarding the parameters included in table 5.1, the actual definitions can be found in the AIMSUN simulator manual. We include a number of comments and clarifications we believe are useful to a modeler.

¹ In this document there is frequent use of the words "segment" and "section". Section is usually refer to a particular, continues piece of road that has one entrance and one exit. Sections are the building blocks of the AIMSUN network geometry. Segment is a term the author chose to use to describe a piece of the greater freeway network. So, a segment is a collection of several sections and includes entrance and exit ramps as well as sections of the freeway proper.

Table 5.1 Local Simulation Model Parameters

	Comments & Clarifications
Maximum Section speed (mph)	This is incorrectly considered as the section posted speed limit. In terms of the car following model this is the maximum speed of the stream during free flow conditions. In Minnesota in straight sections it is in general 10-15 mph higher than the posted speed limit. Lower values need to be selected in locations with special geometry.
Maximum Section segment speed (mph)	Each section is divided to a user specified number of segments and each of these can have a different speed. The above comment applies here also.
Maximum Section lane speed (mph)	Each section lane can have a different speed. The above comment applies here also.
Distance to zone 1 (sec)	These parameters control the distance (in time) from an exit a driver starts to initiate required lane changes. An important comment here is that the length of these zones is affected by the look ahead model global parameter and the lengths of the zones in the upstream sections. In complex interchanges these parameters may not be enough to emulate realistic traffic behavior and further fine-tuning is necessary on the node geometry.
Distance to zone 2 (sec)	
Distance to on-ramp (sec)	
Reaction time variation	These two parameters are primarily global but the user can define section level modification factors. Very dangerous parameters to use since they affect driving behavior a lot. In the case where an existing geometry is replicated it is ok to use but if the goal is to evaluate a hypothetical geometry for a reconstruction project the modeler must have very good knowledge why a particular section affects driver's reaction time different than others.
Max Give-way time variation	

One of the cardinal rules of IFS calibration involves the selection of the extent of the geometry to be calibrated. The boundaries of the segment must always be under uncongested conditions. There should be no recurring congestion extending into the simulated segment from the downstream boundary while it is not advisable to select an upstream boundary where a queue in the model extends beyond it. In the first case the simulation model is invalid, while in the second the results are biased and there is the possibility that upstream entrance demand is erroneous.

5.1.1 IFS Calibration Methodology

There are two major stages in this calibration procedure, volume-based and speed-based calibration. Measures of goodness-of-fit are implemented to examine the adjustment of parameters in the models, and the discrepancies between the simulated data and real data are used to improve the results. The aim of IFS is to calibrate the driving behavior model. Before these two stages of calibration, the modeler needs to verify the boundary traffic conditions. No matter how excellent the model is, the boundary traffic condition should be close to reality, since all traffic demand is from the boundary sections into the freeway system. If the boundary traffic conditions are incorrect, the model will have significant problems. Calibration can be performed after this preparation is finished. For details about volume-based and speed-based calibration, one can refer to “A Practical Procedure for Calibrating Microscopic Traffic Simulation Models” (Hourdos et al., 2003), which is the major procedural guide used in this study. As volume-based calibration is less complicated, it is usually performed first. However, these two stages are not in a definite fixed sequence. They are part of an iterative process and these two stages can be alternatively performed. In most of cases, after volume calibration is done, the speed calibration might change the model parameters in such a way that satisfies the speed accuracy but reduces the reliability of volume calibration. In such cases, the modeler needs to perform volume calibration again until these two stages agree with each other.

Volume calibration is primarily performed in the direction of traffic, focusing on upstream detector locations first and proceeds downstream. In difference, speed calibration focuses on known bottlenecks and proceeds upstream against the direction of traffic. While in volume calibration definite GOF measures are used, speed in a model will never be as well matched with real measurements. Therefore, it is better to rely on speed time/space contour plots to visually inspect the fitting of the model. Elements to focus on are the location of known bottlenecks, the speed downstream of the bottleneck, the rate congestion spreads upstream of a bottleneck, and the congestion duration.

Calibration is an iterative process that requires hundreds of simulation runs to obtain reliable results. If the execution of one simulation takes a long time, it will significantly reduce the efficiency of the calibration. In addition, it is important to create an environment where the cycle involving the selection of parameter values, execution of simulation runs, inspection of output, and redefinition of parameters, is facilitated in as an automated way as possible. Considering the number and extend of the freeway segments requiring calibration in this project substantial effort was spent to streamline this procedure and at the same time simplify it so undergraduate students under the supervision of an experienced modeler can accomplish the task. One element making the IFS faster than the general calibration of a freeway segment is the fact that eventually all pieces will have to work together. Although the effort in calibrating local parameters is not different, the effort in calibrating global conditions is incrementally reducing. The driving behavior parameter must be the same in all freeway segments therefore after a few segments global parameter calibration turns more to validation of earlier selected values.

5.1.2 Extend of IFS Calibration and Result Example

It was clearly stated in the project workplan that it will not be possible to conclude this step during this phase of the project. Regardless, a large number of segments were successfully calibrated and we hope support for this works conclusion will become available soon. Table 5.2 presents the freeway segments and boundaries that have been successfully calibrated.

Table 5.2 Freeway Segments Calibrated

Freeway segment	Boundaries
I-94 WB and WB	Entire length
I-35E NB and SB	I-494 to I-694
I-35W NB and SB	Hennepin Ave to I-694
I-494 EB and WB	I-94 (west end) to I-94 (east end)
I-694 EB and WB	I-35W to I-94 (east end)
TH-36 EB and WB	Entire length
TH-169 NB and SB	I-494 to I-694
TH-62 EB and WB pre-UPA geometry	I-494 to TH-55
TH-100 NB and SB	Entire length
TH-10 EB and WB	Entire length

The calibration process has reached the point where we anticipate only minor refinements in the values of the model global parameters. Table 5.3 presents the final global parameter values selected. These parameters can be further divided into two sets, one general applying to everything and one for each vehicle type, in this case three such sets are defined but SOV and HOV are identical since both are considered to be passenger vehicles. In regards to the local parameters, it is difficult to present the full set of parameters since they change almost for each section of the geometry, instead we can discuss the rationale behind their calibration and clarify through examples. Figure 5.1 shows the section dialog box of the application. The most important parameters are:

- Maximum Speed
- Distance to Zone 1, 2, and On Ramp
- Reaction Time Variation
- Detailed Speeds by Segment and/or Lane (segment here refers to a piece of the section and not the definition used in this document)
- Slope

Section: 287 (Layer: Network)

Main Lanes Attributes

Name: External Id:

Road Type: 174: Freeway Maximum Speed: 120 km/h

User Defined Cost: 0 Second User Defined Cost: 0

Third User Defined Cost: 0 Capacity: 4200 PCUs/h

Dynamic Models Static Models

Use Capacity as Attractiveness 4200

Micro

Distance Zone 1: 20 sec. Distance Zone 2: 3 sec.

Distance On Ramp: 5 sec. Yellow Box Speed: 10 km/h

Visibility Distance: 25 meters Reaction Time Variation: 0

Inherent Speed: 0 km/h Max. Give Way Time Var.: 0 sec.

Meso

Jam Density: 200 veh/km Reaction Time Factor: 1

Look Ahead Distance 500 meters

Altitude (Slope percentage: 0.00 %)

Initial: 0 meters Final: 0 meters Calculate Intermediates

Length: 1002.63 meters

OK Cancel

Section: 287 (Layer: Network)

Main Lanes Attributes

Lane Width: 3 meters

Lane Types

Lane	Lane Type
1	
2	

Lane Type Options (Only for Reserved Lanes With More Than One Segment)

Reserve the First Lane Segment Reserve the Last Lane Segment

Detailed Speed by Segment and/or Lane

Segment	Lane	Speed
1	Any	80

Add Delete

Shoulder

Right: None Width: 0

Left: None Width: 0

Length: 1002.63 meters

OK Cancel

Figure 5.1 Section Dialog Box with Local Calibration Parameters

Maximum Speed can be conceived as the average speed the modeler wants the flow to have in this section. This may not be the speed limit since different populations of drivers have different habits. For example in Minnesota most road users drive at least 10mph above the speed limit. This speed is applicable to the entire section unless specified differently by the segment speed described in the second dialog box. The reason the latter is needed is because the simulator does not understand about road curvature or any other geometric feature that causes drivers to slow down. Therefore, if the section contains a sharp turn a lower speed is assigned to the segments before and on the curved part of the road. Similarly the modeler can assign speed per lane. On I-94 this was needed in order to control the selection of lane in the downtown Minneapolis weaving area. In difference to other locations, driver at this section tend to drive as far on the left as possible to avoid frequent congestion on the right lane. To replicate this behavior a higher speed is assigned to the leftmost lane attracting vehicles. Normally vehicles tend to drive on the rightmost lane unless it is congested.

Distance to Zone 1 and 2 are the parameters that control lane changes in AIMSUN (version 6 and older). Basically the model assumes two types of lane changing behavior, normal and aggressive. Zone 1 encompasses zone 2 both starting at the end of the section where a decision point is located require vehicles to be on the correct lane. A vehicle that is outside zone 1 is not aware of the decision point and therefore does not perform lane changes to reach the correct lane. As soon as it enters zone 1 it evaluates its position and begins to perform lane changes to reach the right lane. During these lane changes the selected gaps are large enough for the vehicle to change lanes without affecting neither the flow on the original nor the receiving lanes. If the vehicle enters zone 2 while it still hasn't reached the correct lane the lane changing behavior becomes more aggressive, selecting gaps that require the vehicle in the receiving lane to slow down as well slows down on the original lane to catch a gap that is still upstream. Distance to on ramp is the equivalent of zone 2 but applies only in cases of acceleration lanes from on-ramps. These parameters are critical to the weaving operations on major interchanges and are the main parameters used to calibrate flow at a freeway bottleneck. Reaction Time Variation is a new addition to the model and was not used in this study (yet). Slope, if not used as is in reality can be used to fine tune the acceleration/deceleration behavior of vehicles at specific sections.

It is not efficient or helpful to the reader to include all the results of the aforementioned segment calibration. Therefore as an example, the calibration results from I-94WB are presented. One reason we selected this segment to present is because it includes one of the most difficult and unique areas in the entire system. Specifically, the author has spent considerable time investigating traffic conditions on I-94 WB between Riverside Ave and TH-55 north of the I-394 exit. This area includes the highest crash freeway location in the state, and these crashes are in large extend the result of specific local traffic patterns that also generate the recurring congestion in this segment. In terms of mainline volume validation, the R-square values achieved for the I-94WB mainline detectors are between 0.86 and 0.99, which indicate that the linear dependence between simulated volumes and real volumes is strong. The RMS, being between 0.04 and 0.14, show that the discrepancies between simulated volumes and real volumes are small.

Figures 5.2 and Figure 5.3 show the speed contours of real and calibrated speeds on I-94WB. The color-map of the figures is from 0 to 100 mph. The y-axis is the detector ID (space) and the x-axis is the time from midnight to midnight (time). The red areas indicate low speeds and concentrate at the bottleneck around 3rd Ave in downtown Minneapolis. Usually, the congestion

extends upstream to the entrance from HW-280, and the congestion period lasts until 7 pm. In Figure 5.3, the bottleneck occurs approximately at the same location, but a secondary bottleneck on the exit to I-394 is more pronounced as compared to reality. In general, the congestion in this area in the model is stronger than the one observed in the real data but the extent is approximately the same. One element that has not been captured is the morning congestion in this area. This congestion is generated primarily due to the 11th street exit. In this location a long queue from the traffic light extends into the freeway mainline. Given the IFS geometry this is not possible to emulate but it should be successfully emulated in the network level since that part of the surface street is also included in the model.

Table 5.3 Calibrated Global Simulation Model Parameters

Model Parameters	Final Calibrated Values
General model parameters	
Car following model	Deceleration estimation (sensitivity factor)
Reaction time	0.75 sec
Reaction time at stop	1.2 sec
2-lane car following model	
Number of vehicles	4
Max distance	984 feet
Max Speed Difference	18.6 mph
Max Speed Difference on Ramp	31 mph
Lane changing	
Percent Overtake	98%
Percent Recover	93%
Maximum number of turnings	4
Per vehicle type model parameters	
SOV and HOV	
Max Desired Speed	77 mph
Max Acceleration	9.18 ft/s ²
Normal Deceleration	13.12 ft/s ²
Max Deceleration	29.52 ft/s ²
Speed Acceptance	1.1
Min Distance between Vehicles	4.92 ft
Sensitivity Factor	0.65
After overtaking stay on fast lane	30%
Undertaking cases	60%
Imprudent lane changing cases	40%
Sensitivity for imprudent lane changing	5
Trucks	
Max Desired Speed	55 mph
Max Acceleration	6.88 ft/s ²
Normal Deceleration	9.84 ft/s ²
Max Deceleration	16.40 ft/s ²
Speed Acceptance	1
Min Distance between Vehicles	1.64 ft
Sensitivity Factor	1
After overtaking stay on fast lane	35%
Undertaking cases	10%
Imprudent lane changing cases	0%

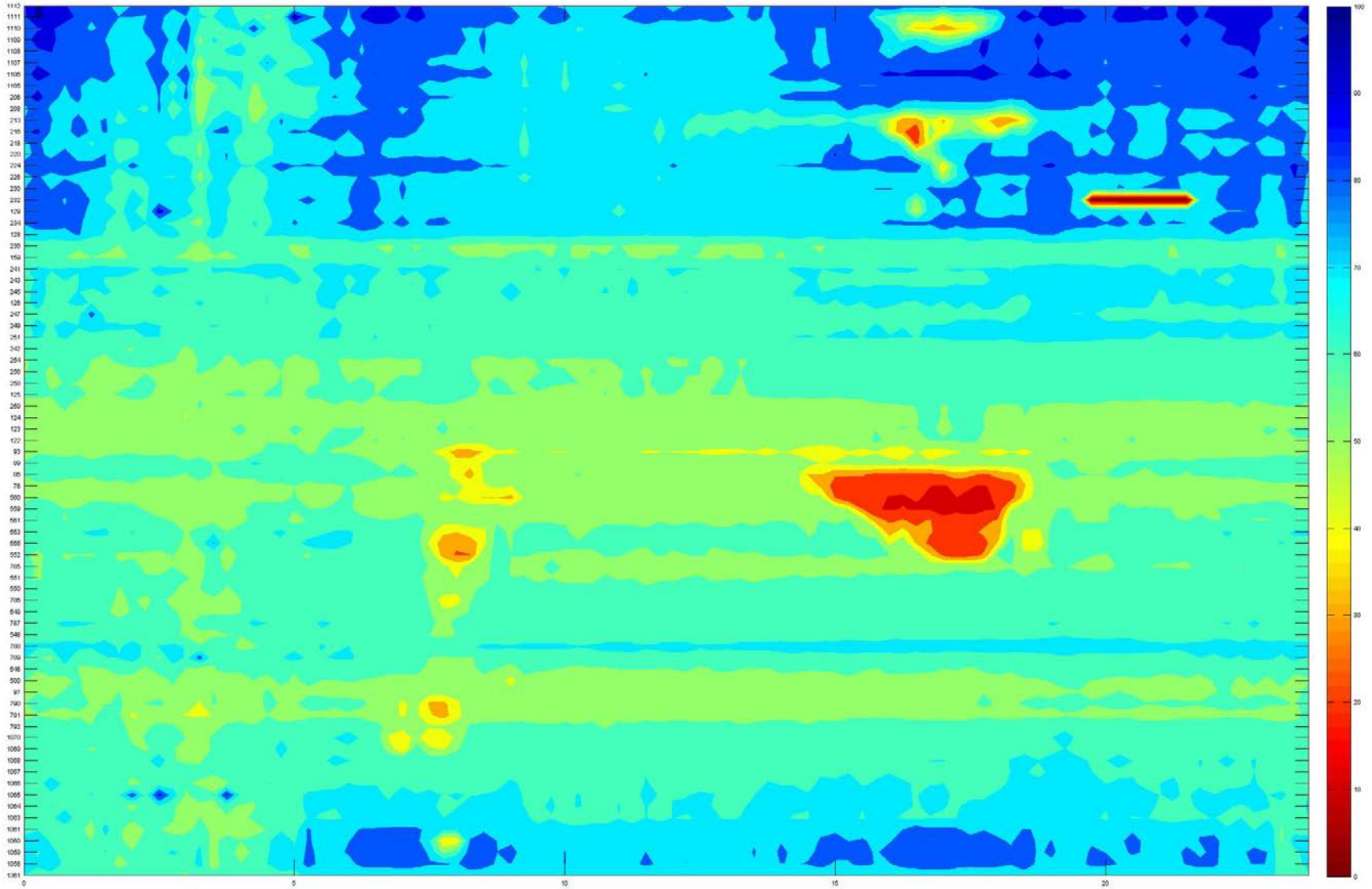


Figure 5.2 Contour of Real Speeds on I-94 WB

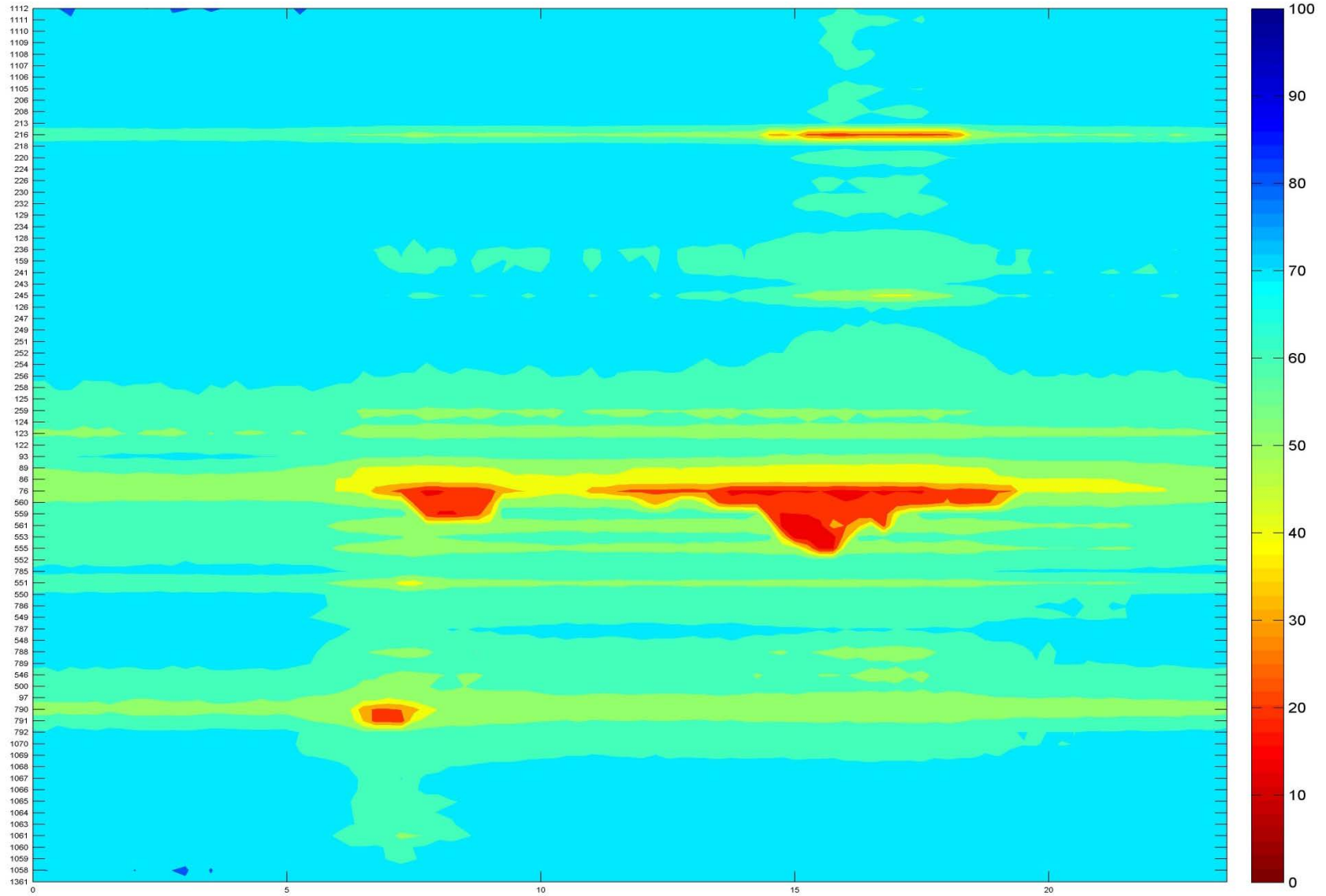


Figure 5.3 Contour of Simulated Speeds on I-94 WB

5.2 Network-Wide Calibration

Although in this phase of the project network-wide (NW) calibration is premature, it would leave the report incomplete if a description of the current methodology is not included. When dealing with such large models, there is no established state-of-the art or practice. Prior work by Sacks et. al, 2002 and Bayarri et. al, 2004 has set the foundation for a formal statistically calibration methods of roadway networks. In these efforts the theoretical aspect of real measurement availability and uncertainty but the networks used were relatively ordered grids and small. Regarding the calibration of networks covering an entire metropolitan area, very little information can be found in the literature and even that is biased by the data and effort available for the task. It is our intention to use the Twin Cities freeway-wide simulation model, with its rather unique amount of available data to develop a comprehensive methodology that will guide modelers in future projects. In the rest of this chapter we describe the current state of this development and the results reached from its implementation in a subarea of the Twin Cities network. This effort was completed on a parallel project (Hourdos et. al, 2010). This is a practical methodology aiming in guiding the user in the organization of the task. The statistical rigor is lacking from this approach and is certainly needed.

NW calibration is needed to obtain reliable results for traffic assignment. The reliability of the traffic assignment results is based on the accuracy of traffic demand, link costs function, and the route choice models. NW calibration is conducted to obtain better O/D demand and valid route choice models for traffic assignment. Network calibration has five key steps: the details are presented as follows.

Step One: Preparation of the Data

The first step in network calibration is to prepare the basic input data for the model and prepare the data for the calibration.

a. Basic inputs

The basic input data for the model include the network information, traffic control plans, traffic demand, and data for route choice.

- The network information includes information about network geometry, layout of roadways and intersections, and location of traffic equipment (e.g., loop detector and variable message sign).
- The traffic control plans contain information about signal designs for signalized intersections and priority information for un-signalized ones. Such information can be available from various resources, like the agency records (i.e., DOTs and Counties), measurement or collection from the field, the historical data from other projects, and the design by the users.
- The traffic demand is in terms of O/D matrices, which is required by microscopic simulation models for traffic assignment. Such information can be available from a regional planning model or estimated based on traffic counts. These O/D matrices can be seen as seed matrices and can be used for estimating time-dependent O/D matrices for dynamic traffic assignment.

- Data for route choice models needs to be prepared before network calibration. Such data include the parameters for route choice models (i.e., model alternatives and corresponding parameters) and the link costs parameters (e.g., link capacity, link speed, travel time, user defined costs, toll, etc). The parameters for the link costs vary based on different link costs functions used in traffic assignment.

b. Data for calibration

Network calibration needs freeway data as well as arterial data. Freeway volume data can be available from loop detectors while arterial data might be limited due to less capital investment. However, in general, Annual Average Daily Traffic (AADT) and Automatic Traffic Recorder Data (ATR) can be available for analysis. Such information might not have the same resolution level as detector data. The selection of the available data is based on the needs of the network.

Step Two: Boundary Condition Verification

After all input data for the model and data for calibration are prepared; the simulation model can be used for boundary condition verification. This step examines whether the imported O/D matrices have errors. Errors might happen during the extraction of the traversal O/D matrices from the O/D matrices of the larger network. By verifying the boundary condition, errors can be found and corrected to obtain a better start for the calibration.

Step Three: Preparation for the Calibration

This step is to obtain the better default values for the parameters of the models. There are various kinds of parameters in the microscopic simulation model that affect the driving behavior and route choice behavior of the vehicles. Users can define the values for the parameters based on engineering judgment, historical data, data from similar projects, and data from other programs or methods. However, these values might not be well estimated before the network calibration, which is a time-consuming trial and error process for traffic simulation. On the other hand, if some of the parameters can be better estimated before the network calibration, such a process might be more efficient and require less effort.

In this step, the values for parameters can be estimated based on several runs of the simulation. For example, according to the traffic count data for arterials (e.g., AADT, project-oriented measurements, ATR, etc.), the attraction of the roadways can be analyzed. The user can adjust selected link costs parameters (e.g., capacity and section speed) to increase or decrease the attraction. Although the link costs parameters might be calibrated in next steps, the adjustment of these parameters here is to obtain a better start for later calibration. In addition, the default traffic control plans, which are designed by the users, might need fine-tuning. The improper traffic control plans for the particular intersections, can cause lots of delay. Users need to examine those locations and redesign the traffic control plans to decrease the delay before the network calibration, since high delay in the intersections affects the route choice in dynamic traffic assignment, in which case vehicles following an initial shortest route might divert to another route to avoid the delay. After preliminary fine-tuning of traffic control plans, as well as parameters for the model, O/D adjustment can be considered.

Step Four: O/D Adjustment

This is an important step to obtain better O/D demand for the model. Time dependent O/D matrices are required for a dynamic approach to traffic modeling. They are simulated as the time variability of traffic demand in the microscopic simulation model. Such O/D matrices can be adjusted from seed O/D matrices relying on the traffic count through optimization algorithms. Usually, the estimation is a static process instead of a dynamic process, since the latter does not have an effective method to obtain the solution (Cascetta et al., 1993).

As described in the previous chapter the seed O/D matrixes for this project were extracted from the RPM. This set of 24 matrixes per vehicle type has matrix durations of 45 minutes during peak periods, one hour during midday, and two-hours around midnight. Even the 45 minute ones are long for the purposes of microscopic simulation. Due to the rapid change in demand at the borders of the peak periods, abrupt jumps in demand will be generated if the matrixes are used as they are. Instead, it is more appropriate to divide these matrixes into smaller pieces, 15 minute in our case. The division is not uniform but it follows the demand change trend observed from the detector data. Eventually, the estimated OD matrix will be generated for that time interval, which can be used for dynamic simulation. The comparison of global OD and sub-matrix is shown in Figure 5.4.

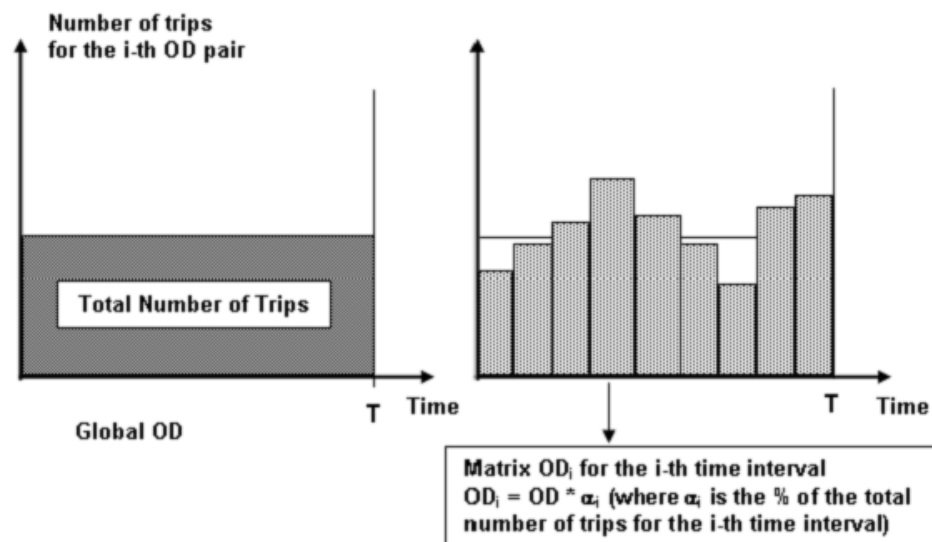


Figure 5.4 Time Depend O/D Matrices Calculation (AIMSUN Manual 2008)

In order to obtain the reliable new matrices, link costs parameters (i.e., capacity, travel time, speed, etc.) might be adjusted to obtain reliable static traffic assignment results during the adjustment process. Measure of goodness-of-fit can be used to decide whether new O/D matrices after adjustment are acceptable based on the discrepancies between simulated link volumes and real data. If the matrices are not acceptable, a link costs parameters calibration is still needed.

Link costs parameter calibration is to calibrate the link costs for static traffic assignment. Based on the discrepancy between the simulated volume and real volume, the parameters are adjusted until the fit of the simulation is acceptable. If the new O/D matrices are accepted as the best

estimation in this process, O/D adjustment can be finished, and the new O/D matrices can be used for route choice model calibration.

Step Five: Route Choice Model Calibration

Route choice model calibration is the fine-tuning process for calibrating the entire network. This step includes three sub-steps which are described as follow.

a. Route choice model parameter calibration

Model alternatives and corresponding parameters are calibrated. These parameters should be calibrated first, since they are global parameters that can affect the entire network.

b. Redesign of traffic control plans

If traffic control plans for the intersections are from real data (i.e., records from agencies and measurements from the field), the traffic control plans cannot be changed. Otherwise, if the traffic control plans are designed by the users, proper adjustment is needed for reducing the delay in the intersections. The traffic control plans affect the link costs in dynamic traffic assignment. If the improper traffic control plans increase the travel time in the link, the link costs will increase so that vehicles might avoid choosing it. The accuracy of the traffic control plans is difficult to decide on, due to the limitation of the real data.

c. Link costs parameter calibration

This sub-step is similar to the link costs parameters calibration in O/D adjustment. The link costs parameters of two models might be the same, have some parameters in common, or be completely different. If the parameters are different in two models, the parameter calibrations in the O/D adjustment process do not affect the results in route choice model calibration. However, the corresponding link costs parameters in the microscopic simulation model can be calibrated based on the experience in O/D adjustment process. For example, if one link has high attraction and the parameters are adjusted to reduce the attraction of the roadway in the O/D adjustment process, the corresponding link costs parameters in the microscopic simulation model should be adjusted in the same way to decrease the attraction of that link. Similarly, the experience in this step can be useful in deciding whether O/D re-adjustment is needed. If the link costs parameters for particular links are significantly adjusted in this step, and the results are still not acceptable, O/D matrices might need to be re-adjusted after calibrating the corresponding link costs parameters.

During the fine-tuning of the link costs parameters, the measure of goodness-of-fit is used to compare the simulation results to the real traffic volume. Two decisions should be made based on the comparison. First, whether O/D adjustment is needed again, since link costs parameters for that model can be improved based on the experience in this step. If O/D adjustment is needed, then users need to go back to step four; otherwise, the route choice model is calibrated again, following the three sub-steps until the accuracy of the simulation is judged to be acceptable by comparing the simulated volumes and real data.

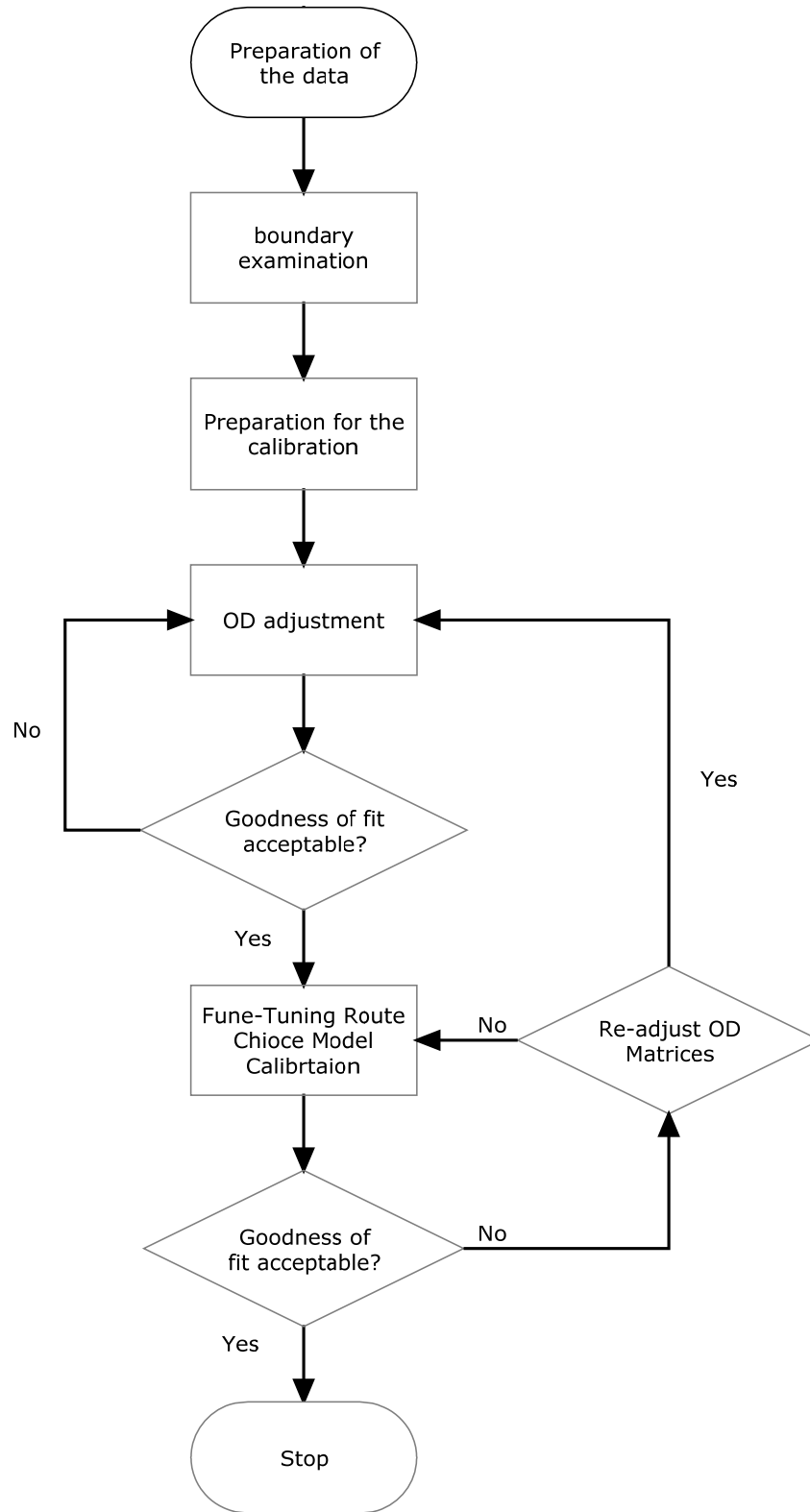


Figure 5.5 Flowchart for Network Calibration

Chapter 6: Conclusions and Future Work

As stressed already in the introduction, the task of developing a simulation model of the Twin Cities roadway network is very large and best approached by dividing it into smaller more tractable steps. The first division was made by separating the work into two pieces, a mesoscopic model of arterials and a microscopic model of freeways. Even the development of the freeway-wide microscopic model was not able to be accomplished in one phase due to funding restrictions. This report focused on the results of the first phase of this development. The tasks accomplished during this phase are the following:

- Import the geometry of all relevant roadways into the AIMSUN simulation application.
- Develop a methodology and extract from the RPM a set of O/D matrixes describing demand on the Twin Cities network over 24 hours.
- Calibrate approximately 60% of the freeway segments in the network.
- Develop a methodology for network-wide calibration. The methodology was first tested on a subarea of the TC network (about $\frac{1}{4}$ of the whole).

One task that was planned in the workplan but has not reached completion is the integration of the Twin Cities freeway-wide model with the MnDOT's IRIS software to activate network-wide ramp metering. The foundations for this task have been laid out to be completed in the next phase of the project.

Depending of the available funding the next phase or phases will complete the following tasks:

- Complete IFS calibration of all remaining freeway segments. The geometry of these segments will remain the one existing in the summers of 2008-2009. The geometry of the network has to agree with the geometry calibrated in the RPM for the extracted demands to have any correspondence. It will not be until 2012 until a newly calibrated RPM becomes available. Regardless, only the UPA corridor of I-35W north of TH-62 is the one that has the most significant change.
- Transfer into the model, information required for NW calibration. Such information includes link capacities, recorded travel times, and AADTs. This combination of measurements along with loop detector measurements will form the basis for the calibration of the route choice parameters.
- Extend the methodology described in chapter 5 regarding NW calibration to integrate all three levels of model resolution, macroscopic, mesoscopic, and microscopic. This will allow for the calibration of the model to achieve proper static and dynamic user equilibrium (macro, meso). Through these states, historical or habitual routes will be determined for use in the microscopic model Dynamic Traffic Assignment process.
- Complete the NW calibration of the freeway-wide model and validate it by simulating one or more known incidents that had network-wide impact. One of these incidents will be the collapse of the I-35W Bridge.

During the next phase(s) of the development of the Twin Cities freeway-wide model we hope to form avenues of communications with MnDOT and other organizations to guide us on the current questions and issues this model can assist with. This way we can make sure that the form of the network will be the appropriate one and that the right amount of information is extracted from it. It is anticipated that at some point several versions of the model will be created describing the network at different stages in the past, present and future.

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