A METHODOLOGY FOR ESTIMATION AND CALIBRATION OF A CITY-WIDE MICROSIMULATION MODEL

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INTRODUCTION

With the rising profile of mesoscopic and microscopic traffic simulation models and higher fidelity, notably dynamic, traffic assignment methods in the planning community, there is little in the way of guidance or standards of practice in estimating, calibrating, or applying these models. Even as the experts struggle to define dynamic traffic assignment, there is little experience for a travel demand modelers to draw upon in the literature. This paper describes a methodology and case study for a successful application of both microscopic traffic simulation and dynamic simulation-based traffic assignment toward estimating and calibrating a traffic microsimulation model for the whole of the City of Eureka, California, and the better part of the Greater Eureka Area Travel Model, which includes smaller cities to the north and south.

Other methods that are more familiar to planners, including subarea analysis using the travel model and origin-destination matrix estimation using newly collected traffic count data, are also part of the methodology. Additionally, novel methods, as far as the history and state of the practice of traffic simulation are concerned, are used, including the leverage of geographic analysis with land use data to refine the trip table estimation.

The purpose of this project is to develop a traffic microsimulation model that extends and compliments the analytical capabilities of the Greater Eureka Travel Model, which spans Humboldt County. The microsimulation model relies heavily on the travel model to produce base estimates of the traffic demand for peak periods, but uses traffic count data to improve those estimates. Using local information about the predominant land use in each traffic analysis zone, the trip table estimation is constrained to produce a more probable solution. Dynamic simulation-based traffic assignment is then used to estimate the route choices of drivers and to further refine the estimated trip table. The calibrated model gives local planners and engineers better geared than the travel model for performing operations-level subarea traffic impact, access management, alternatives analysis, and other types of studies.

The case study not only represents a well-defined methodology for similar applications elsewhere, but also represents a departure from the normal modus operandi in traffic simulation applications. The Greater Eureka Area (GEA) micro-simulation model will be a living, maintainable traffic database for the city, county and state authorities in perpetuity in much the same way travel models are developed, calibrated, updated, and recalibrated over time.

PROBLEM STATEMENT

The methodology in this project is designed to answer two questions, the answers to which are inextricably linked and interdependent:

(1) What are the volumes of vehicles travelling between origin and destination zones in the network?
(2) What are the likely routes drivers take between those origin and destination zones?

The challenges in answering these questions effectively and accurately stem mostly from limitations in existing methodologies and in the data that is typically used to answer them. To truly understand the trip pattern and route choices of drivers in a region, it is imperative to directly observe the origins, destinations, and routes. This can be achieved with license plate surveys, for example. Other inventive methods have been used that track or match the identities of vehicles observed at different locations at different times, such as video recorded from airplanes circulating above a site.

TRAFFIC DATA

Traffic data used to estimate trip tables are largely limited to what can be inexpensively collected or has already been collected, namely traffic counts. This dependence on counts has a number of drawbacks:

(1) Counts reveal neither the origins and destinations of vehicles nor their routes.
(2) Poor coverage of the study area may leave links on key routes between origin-destination pairs countless, which degrades the quality of the origin-destination matrix estimation (ODME) solution.
(3) Analysts are tempted to combine counts from different days, or even years, to increase coverage, or to average counts together to reflect an "average" day.

These problems are sources of error and uncertainty in the trip table solution, and tend to be poorly understood or, at the very least, underappreciated.

ODME METHODS

Furthermore, ODME methods are imperfect. ODME methods use traditional static traffic assignments to load trips from a matrix onto a network. Loaded flows are compared with counted volumes in order to calculate an adjustment to the matrix that, when loaded again, improve the match between flows and counts. This procedure continues iteratively until the match between the flows loaded from the estimated matrix and the counts cannot be improved further. Two shortcomings with these methods are, like the shortcomings in the traffic count data described above, also not well understood:

(1) The solution is heavily influenced by the matrix used in the initial loading (i.e., the *seed* matrix).
(2) Volumes in a cell in the matrix are adjusted based on the flows and counts on links on the used path(s) between the corresponding origin-destination (OD) pair; crude heuristics must be used to estimate volumes between OD pairs when no counts are available on path(s) between those OD pairs.
(3) No unique solution can be proven to exist, meaning that any number of estimated matrices might match the counts equally well. In other words, a good match with the counts does not in and of itself prove a good estimate of the trip pattern.

The seed matrix that is of such critical importance to the quality of the ODME solution is usually produced by a subarea analysis in a travel demand model. Thus, a poorly calibrated travel demand model can be, alongside the traffic count data, yet another source of error in the ODME solution.

In summary, effective use of state-of-the-practice ODME methods requires a thoughtful consideration of these limitations. Experience applying the methods and the know-how to identify defects in the solution are almost a precondition for success.

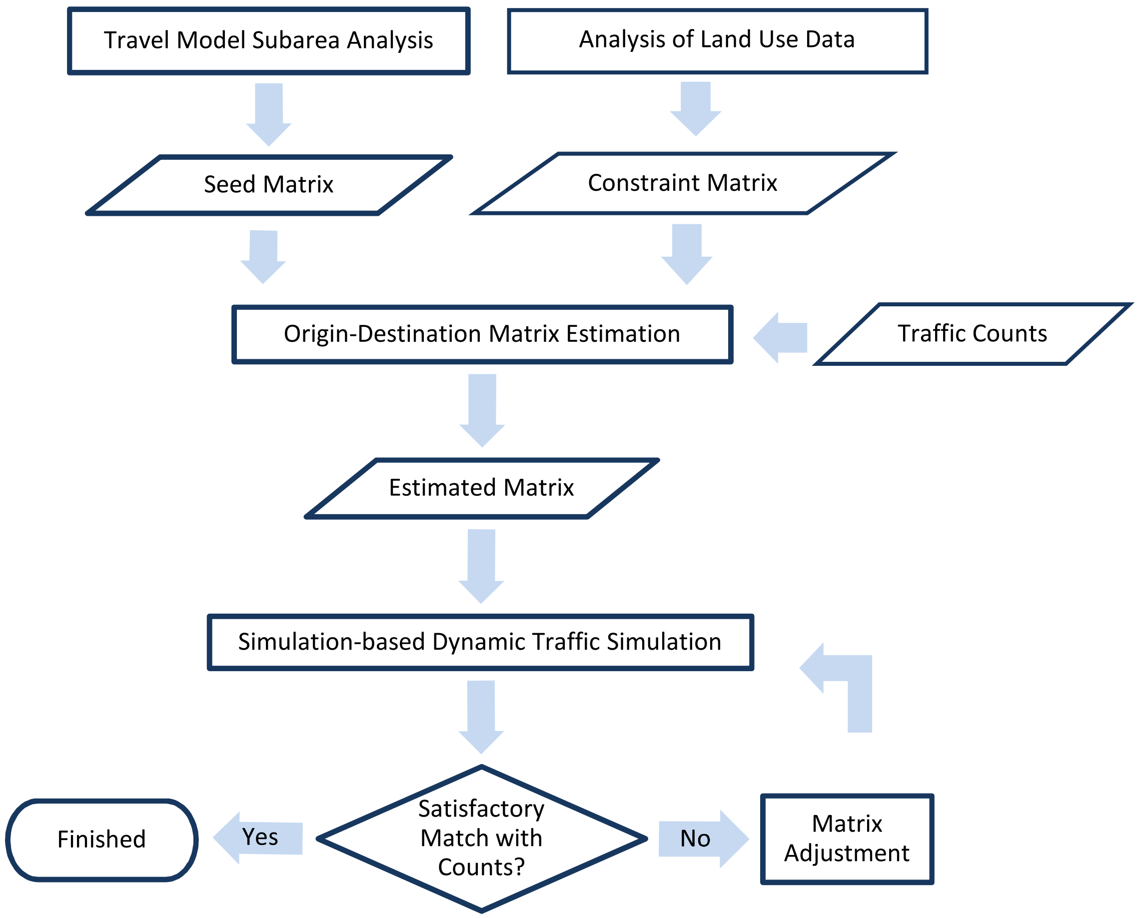
ROUTE CHOICE CONSISTENCY

Lastly, once a matrix is estimated, assuming it can be trusted to be representative of the real pattern of travel in the study area, traffic simulation models use route choice models to determine the paths vehicles choose to take. The more useful route choice models are behavioral, meaning that drivers choose a route that minimizes some perceived total travel time or generalized cost or that achieves some other objective. Each driver makes his or her decision out of self interest, independently of the decisions of others. The loading mechanism (e.g., user equilibrium) used in the ODME methods are thus inherently inconsistent with the route choice loading. In other words, even if the match between the loaded flows and counted volumes resulting from the ODME is very good, there is no guarantee that the route choice model will produce the same loading. The match between the simulated flows and the counts might possibly be worse than that achieved by the ODME. Only a simulation-based ODME, using a route choice loading consistent with the simulation, can overcome this inherent inconsistency.

The methodology presented in this paper recognizes these shortcomings and proposes alternative methods to help improve the estimation and calibration.

METHODOLOGY

The methodology used to estimate and calibrate a trip table for microsimulation of the city of Eureka, CA is summarized in the following diagram:



SUBAREA ANALYSIS

The first step in the methodology is to perform a subarea analysis in the travel demand model. The Greater Eureka Area (GEA) microsimulation subarea is an area roughly 3.5 miles by 3.5 miles and spans the city limits and covering parts of surrounding Humboldt County. Stretches of Route 101 several miles beyond that 3.5 x 3.5-mile core are included in the subarea. The subarea is performed in the most recently calibrated base year 2005.

The subarea analysis is a traditional static User Equilibrium traffic assignment for the AM and PM peak hours. It is run to a relative gap of 10^{-6}, beyond which only very minute changes in the flow vector occur over continued iterations. The output of this procedure is the matrix that will be used s the seed for the origin-destination matrix estimation.

ORIGIN-DESTINATION MATRIX (TRIP TABLE) ESTIMATION

Traffic count data was collected throughout the city in the Spring of 2009, the base year for the microsimulation calibration. So that all counts could be observed during the same hours of the same days for the purposes of consistency, cameras were used to record intersections so that turning movement count data observed during back-office data reduction. Elsewhere, manual turning movement counts and pneumatic tubes were used to collect traffic counts. These count data were processed and compiled into a geographic count database in TransModeler, the microscopic traffic simulation platform used in the project.

The minimum requirements to perform the origin-destination matrix estimation (ODME) are a seed matrix and traffic counts. However, it was found that, due to some of the issues with ODME methods described earlier, the ODME solutions based on these inputs alone were inadequate. Eureka has a fairly dense, mostly grid layout, which allows for numerous possible paths between many origin-destination pairs. Furthermore, the traffic analysis zones are fairly small, resulting in a rather dense geographic distribution of centroids at around 50 per square mile. The dense zonal structure and grid street network make for a particularly challenging ODME effort. As a result, the ODME solution could achieve excellent results in terms of matching counts by producing unreasonable volumes of trips traveling short distances between agricultural and low-density residential areas. Thus, to steer the ODME toward a more probable solution, geographic analysis was used to produce a matrix of constraints that would limit the volume of trips that can be produced in the ODME between zones a very short distance a part and having predominantly agricultural, low-density residential and other land uses not expected to be significant producers or attractors of trips.

Using the seed matrix from the subarea analysis, the traffic counts, and the constraint matrix, an ODME solution was produced for the AM and PM peak periods that matched counts with a root mean square error of less than 10% and that satisfied general a priori expectations about trip pattern in the city.

SIMULATION-BASED DYNAMIC TRAFFIC ASSIGNMENT

The ODME loading is based on a traditional static User Equilibrium assignment. Thus, the ODME loading does not account for the capacity and delay effects of traffic signals, stop signs, and other causes of interrupted flow that are prevalent in Eureka. It also allows volumes to exceed capacity. The loading in the simulation model based on route choice behaviour is thus expected to be different from, and inconsistent with, the ODME loading method. In order for reasonable route choices to be simulated, congested, or loaded, travel times on which the route choices are based must be estimated. This is the primary function of the simulation-based dynamic traffic assignment method in TransModeler. The full simulation is run iteratively, with the method of successive averages applied to output travel times each iteration. The route choices of each run are thus a function of the travel times simulated and averaged over prior runs. In Eureka, a 15-minute temporal profile in the demand was estimated based on 15-minute count data. Thus, dynamic, 15-minute travel times were used. Through the simulation-based dynamic traffic assignment, those dynamic travel times (and the dynamic route choices) are expected to stabilize. The assignment runs until it has converged to a target relative gap measure of User Equilibrium or until a maximum number of iterations is reached.

Very good results have been achieved using the simulation-based dynamic traffic simulation to estimate the route choices of trips generated from the estimated trip tables. Routes observed visually between origin-destination pairs and passing through critical links all satisfy expectations about the feasible routes drivers take. Unreasonable routes, such as those along corridors interrupted by stop signs every block, are effectively filtered out of the set of route choices. Furthermore, multiple route choice alternatives are frequently used between many OD pairs.

The methodology described up to this point produces very good results in Eureka given the complexity of the route choice problem in the city and the imperfections inherent in the traffic demand estimation methods. However, as expected, the quality of the match with the counts, the ultimate target of the calibration effort, degrades as the simulated loading diverges from the ODME loading. In Eureka, the root mean square error in the volumes increased from under 10% as determined by the ODME loading to as much as 35%. However, for any given application, this will vary depending on the scale and complexity of the model. This necessitates the final step of the methodology, which is to systematically refine the trip table based on the gaps between simulated volumes and counts.

TRIP TABLE REFINEMENT

A refinement of the trip table is the last step in the methodology, and may require a number of iterations before a desirable degree of match between the simulated and observed volumes is reached. Using a critical link analysis based on the path flows resulting from the simulated route choices, the dominant origin-destination (OD) pairs producing trips passing links where the match is poor are identified. The critical OD pairs in the trip table can be scaled accordingly to improve the match. If the changes are modest, another simulation-based dynamic assignment can be avoided. Rather, a single simulation can be run to determine the improvement in agreement with the counts. This can be repeated as many times as is necessary to improve the trip table and to reduce the error to acceptable calibration targets. This process is ongoing in the Eureka model and is expected to be completed within a month.

SUMMARY

This paper gives a methodology for estimating and calibrating a microsimulation model for an entire city using a combination of travel demand methods, geographic analysis, origin-destination matrix estimation, and dynamic traffic simulation. The Eureka case study demonstrates that such an approach can be successful in overcoming some of the more difficult challenges in the application of microscopic traffic simulation to wide areas, particularly in the planning context. Trip table estimation and calibration methods in the state of the practice can be significantly improved by exploiting geographic information and analysis and by using emerging dynamic traffic assignment methods.