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Simulating a Four-Step Model OD Table: The First Step in Implementing a TRANSIMS Regional Simulation

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Abstract

This paper presents an approach of transforming an existing origin-destination trip table and network from a traditional urban travel demand model (commonly referred to as a four-step model) into activity and location based time-dependent plan files that can be used for regional microsimulation in TRANSIMS. This generation of the activity and location based time-dependent plans represents the recommended first steps in deploying TRANSIMS an at MPO level. This paper summarizes portions of the forthcoming guidance manual for MPOs and other agencies on how to best implement TRANSIMS. The findings come from a research project sponsored by the USDOT and conducted by NJIT in collaboration with Rutgers University, which consisted of developing a TRANSIMS model for a portion of Central New Jersey (predominately Middlesex and Monmouth Counties). The TRANSIMS model covers an area with a population of 1.4 million and has approximately 700,000 trips during morning peak two hours and approximately 4.4 million trips in typical weekday. Differences between the four-step model and TRANSIMS data needs are discussed, as are difficulties in validating the simulation.

TRANSIMS Overview

TRANSIMS (TRansportation ANalysis and SIMulation System) is a regional agent based activity modeling system that is comprised of a set of open source algorithms and programs. It is designed to provide sensitive and accurate results that are relevant to transportation planning and emission analysis. TRANSIMS was originally developed by the Los Alamos National Laboratory as a part the Travel Model Improvement Program sponsored by USDOT. The system was designed to implement new transportation and air quality forecasting procedures.

TRANSIMS Modules

TRANSIMS consists of four primary modules: Population Synthesizer, Activity Generator, Route Planner, and Traffic Microsimulator. Using these modules in conjunction with feedback routines, TRANSIMS is able to create a synthetic population of households, estimate activities for each person in each household, plan trips during a simulated time period, assign trips to the transportation infrastructure, reroute trips around congested conditions on the network to improve travel times, and perform a microscopic simulation of all vehicles and transportation systems that are incorporated into the model.

Implementation of TRANSIMS from a Four-Step Demand Model

If the modeler does not have sufficient data from a recent household travel survey with which to calibrate the TRANSIMS Activity Generator Module (or another existing activity based trip generation model), TRANSIMS will not be able implement a true activity-based model. However, data that exists in most four-step travel demand forecasting models can be converted into TRANSIMS formats. The assignment step (and possibly mode choice) from a traditional four-step model can then be accomplished by TRANSIMS using the Route Planner and Microsimulator modules. This allows discrete tracking of vehicles and individuals in both time and space through the network, and allows for better estimate of queue and signal timing and phasing impacts on travel times and congestion in the network. This is in contrast to the aggregate formulas that estimate link speeds based on volume and capacity ratios in four-step models. The conversion of a four-step model into the TRANSIMS format includes conversion of the network and the conversion of the origin and destination (OD) matrices.

Network Conversion

A TRANSIMS network consists primarily of nodes, links, parking locations (entry or exit points from the highway network for vehicles), activity locations (where an activity takes place and where all trips begin and end), and process links that connect activity locations to the network. Additional details regarding intersection controls, including stop / yield controls, signalized locations (including timing and phasing details), and turn lane configurations also need to be defined. Transit facilities (rail links and timetables, bus routes, bus schedules, park and ride lots, etc.) also need to be provided to simulate transit trips in TRANSIMS.

Much of this needed information is already contained in the network of a four-step model. The link and node information can be directly converted from the four-step model network. Further information about the links (functional class, number of lanes, number of pocket or turn lanes, speed limits, link capacity, etc.) and nodes (signal type, timing plan, phasing plans, stop controls, turn restrictions, intersection approach lane channelization, etc.) can be pulled from the four-step model if they are available, but some often are not. This missing data, especially intersection controls, can often be synthesized using TRANSIMS utilities if not readily available in other GIS or traditional databases. Interchanges need to be coded to the level of individual ramps, a detail level that does not exist in some four-step model networks. Lower level roadways (collectors and locals) might not be included in the four-step model network or might be represented in theory by centroids connectors. A TRANSIMS network certainly does not need to include all roadways, but roadways that might serve through traffic under congested network conditions or roadways that provide access to major trip generators should be included in the TRANSIMS network. These roadways may need to be manually added to the TRANSIMS network, or adapted from existing GIS databases.

By comparison to a four-step model, activity locations in the TRANSIMS model replace the Traffic Analysis Zone (TAZ) centroids. However, in the TRANSIM model, an activity location is tied to one particular point on one link, and sometimes only one direction of that link. Therefore, TRANSIMS has many activity locations that represent one TAZ. The activity locations should be carefully determined to represent actual (or forecast) land use along the roadways. If the specific land use information is not available to the block face level to define where activity locations should be placed, they can be generated at regular distance intervals (depending on the functional class) along the TRANSIMS links. By coding a TAZ number to that each link, all activity locations located along that link will be associated with that TAZ. Parking lots and process links connecting to the activity locations are also created and paired with the created activity locations. More sophisticated techniques that define a TAZ by a GIS polygon can be used to associate activity locations with TAZs, but for this to work properly the GIS TAZ database must be quite geographically accurate due to the small offset distance of the activity location to the streets, a common divider between TAZs.

Trip Table Conversion

An origin – destination trip table (OD table) from a four-step model defines trips between TAZs within the region and serves as the basis for trips in TRANSIMS where no activity based model or insufficient household travel surveys exist. The more detailed the trip tables from the four-step model, the better. This includes trips tables segmented by time periods (time of day four-step models), trip purposes, and vehicle classes. Regardless of how detailed or segmented the OD trip tables, the use of a four-step OD matrix as the basis of TRANSIMS simulation requires that the OD trips be disaggregated in both space and time into individual travelers. For example, the OD table may specify that 132 trips go from TAZ 1 to TAZ 2 in the AM peak period. TRANSIMS needs to disaggregate that into 132 individual trips, each between a specific activity location within TAZ 1 to a specific activity location within TAZ 2. Each trip is also assigned a specific time within the time period (to the second) at which the trip will start.

To disaggregate the trip in space, each trip must have an activity location selected within each of the origin and destination TAZs to serve as the starting and ending points of the TRANSIMS trip. The selection of an activity location within each TAZ can be done completely randomly, or can be assigned through probabilities defined by the coding of different weights to the activity locations. Different weights can be used for selecting activity locations for different trip purposes. For example, general employment could be used for the selection of the work end of a trip, retail employment for the shopping end of a trip, population for selecting a residential end of a trip, and so on. Once activity locations are chosen for each individual trip in the OD matrix, a vehicle is created for each auto traveler to use on their trip and is place in the parking lot adjacent to the selected starting activity location.

To disaggregate the trips in time, diurnal curves must be provided that define the probability of a trip starting at a specific time of the day. This diurnal data can come from a household travel survey, traffic counts, or other data sources. Different diurnals can be provided for different trip purposes, should the data exist to support this level of analysis. A different diurnal curve is provided for each of the four-step model time periods and is used to proportionally distribute the trips within the time period to a specific start time for the TRANSIMS trip. To do this, OD tables are processed in such a manner that the TRANSIMS utility reads the trip time file by selecting the specified time period records and normalizing to a cumulative distribution between 0 and 1. The specific second assigned to the start of the trip is set by interpolating between the start and end time of the selected time period by the cumulative share at the beginning and end of the time period. A multi-iteration moving average procedure is used to estimate the probability of each minute of the day given the control parameters defined in software by the user. The program then smoothes these values to create uniform transitions between each time period and maintains and monitors trip targets for each minute.

As an output of the TRANSIMS utilities, a Household file, Population file, Vehicle file, and Trip or Activity file are generated. These are the same files that would be produced from the Population Synthesizer and Activity Generator modules of TRANSIMS. These files contain descriptive information about each traveler, their starting location for the day (i.e. household), activities during the day, and the modes of transport to use. In a conversion of four-step OD tables, all trips are treated as simple single person households with two activities within the day, one at the origin TAZ, and one at the destination TAZ. The trip is then defined by the need to travel from the first activity to the second. An important distinction between a four-step model and TRANSIMS models is that intrazonal trips are routed and simulated on the network just as interzonal trips. This means intrazonal trips that are not assigned or including in link volumes in a typical four step model will be routed and included in volumes and traffic flows on a TRANSIMS model.

Assignment Process

The TRANSIMS network and activity sets are fed forward to the Route Planner and Microsimulator, two of the core modules of TRANSIMS. The TRANSIMS assignment is based on the assumption that each traveler will route themselves through the network to minimize their own travel time (or generalized cost). Iterations are performed to allow each individual traveler to see the travel times on the network and are then allowed to seek their own personal best travel path. This optimization behavior is accomplished through iterative feedbacks of travel times and assignment procedures. Since the TRANSIMS model simulates travel times for all links and turns through the network dynamically in very small slices of time (default 15 minutes but can changed), the possibility also exists for the modification of a traveler's trip in time (peak spreading) in order to accomplish a better travel time. Feedback identifies the best route and time for each traveler to complete their daily activities, know in the TRANSIMS system as plans. Ultimately, the iterative feedback loops would approach Nash equilibrium; however, the stochastic effects of the simulator prevent a true equilibrium from ever being reached.

There are three steps that are followed in the iterative assignment feedback loops. The first step is a comparison of the current travel plans against those using the travel times from the Microsimulator from the last iteration. In the second step, a subset of those households or travelers with better routes is selected and their plans are changed to the new plan with a better travel time. The improved plans are then merged with the all other unchanged plans into a master set of plans for all travelers. The third step is to simulate all the travelers' plans with Microsimulator. Results are then obtained from output files, and new dynamic travel times for each link and turn are summarized to perform the feedback iteration.

Model Validation

Realistic demand estimation and assignment is very important in the simulation of the movement of people in time on large network. In a four-step model when demand exceeds capacity for a link, a higher penalty of travel time is simply calculated and used to dampen demand for that link on the next iteration. In a simulation model, the throughput of a link is limited to capacity, and higher demands create queues. When demand is unrealistically high (from poor routings and/or demand estimations), the queues can form quickly and cascade upstream in the network which bogs down the simulation calculations and can slow the iterations to a halt. To validate the trip distribution and assignment of trips, the analysis of trips in both time and space must be performed. If the OD demands obtained from the four-step model is overestimating the amount of trips using the network a particular time period, then a realistic simulation of trips will never be realized.

In the case study of the TRANSIMS model for Central New Jersey, a satisfactory simulation of vehicles proved to be very difficult to achieve, despite significant debugging of the network to improve capacity (primarily involving signal timing and phasing modifications) and iterations to distribute traffic around congested locations, a realistic simulation of vehicles was never achieved. When TRANSIMS routed volumes were compared to observed counts, some significant differences emerged. The solution to this was to factor the input OD table to reflect the differences to observed counts. A select link analysis for several key and problematic links in the network was performed to arrive at an OD table for trips traveling each of the selected links. These routed volumes were then compared to counts (see below for count source discussion). The selected links included both external links to the TRANSIMS model as well as a sampling of links within the network. Counts were been obtained from the following sources:

- NJTPA validation screenlines: Traditional screenline counts were available from the calibration of the four-step model. Unfortunately, the data was only available as a total daily volume estimate, and separate estimates were not made for the AM or PM peak periods, let alone individual 15-minute time periods. Since the temporal distribution of traffic on these roadways varies significantly (both in directional distributions and peak period / hour percentages estimates), a factoring process to estimate 15 minute volumes from the daily volumes was not pursued.

- Observed counts: Some ATR counts were available for some study area roadways. Unfortunately, a limited amount of observed counts were available. Older counts (maximum 5 years old) were increased by observed growth rates to arrive at a base year count estimate. In addition, those counts that were available typically only reported volumes on an hourly basis, not the 15 minute basis that is commonly used in the actual data collection. Available turning movement counts were also examined. These do typically include the 15 minute level of precision needed, but are limited and when available are usually limited to the peak periods.

- NJCMS volume estimates: The NJDOT sponsored New Jersey Congestion Management System (NJCMS) is a suite of computer software (PPSuite-based) and observed data. Among other outputs, the system estimates weekday hourly volumes on roadways based on input AADT volumes and a wide range of temporal distribution tables that estimates hourly volumes on each link. These modeled volumes then undergo a peak spreading algorithm on links that experience V/C ratios above 1.00, and the resulting output volumes estimate for each hour of the day. The NJCMS volumes were used as a supplement to the ground counts.

A matrix factoring process that compares the routed TRANSIMS demand volumes to the observed counts was then applied to modify the four-step model OD table to better reflect ground count conditions and reduce links with high V/C ratios that prevented a reasonable simulation run. While using the synthesized or modeled hourly flow data from the NJCMS system is not a preferred data source to use for validation of the TRANSIMS simulations, little options existed without performing a significant and costly data collection effort. Much of the data needed for validation of the TRANSIMS model, including observed traffic flows in discrete 15 minute time segments, is measured in the field but may be subsequently lost in the data summary process.

Conclusions

This paper summarizes the methods and findings from a recent USDOT project, part of which created a TRANSIMS model of Central New Jersey based on the network and OD demand tables from the MPO four-step model. The majority of the data needed to build a TRANSIMS network is either contained within a typical four-step model network or can be synthesized using TRANSIMS utilities. The first step of simulation of traffic flows over a TRANSIMS network can also be conducted using the OD demand tables created by a four-step model, although doing so eliminates the study of trip chaining behaviors and the interrelationship of trip making patterns of household members. The true difficulties in converting a four step model into TRANSIMS lies in the availability of the more robust data sets needed to validate a TRANSIMS simulation versus time of day four step models.