SimAGENT
TRANSIMS &MATSIM | 5

TRANSIMS and MATSIM Experiments in SimAGENT

Konstadinos G. Goulias, Nathanael A. Isbell, Daimin Tang, Michael Balmer, Yali Chen, Chandra Bhat, and Ram Pendyala

May 18, 2012

Phase 2 Report Submitted to

SOUTHERN CALIFORNIA ASSOCIATION of GOVERNMENTS

GeoTrans Laboratory, 1832 Ellison Hall, University of California Santa Barbara, Santa Barbara, 93106-4060

TRANSIMS AND MATSIM EXPERAMENTS IN SIMAGENT

Table of Contents

PREFACE

In this report we present a comparison of the TRANSIMS and MATSIM microsimulation software for SimAGENT. TRANSIMS and MATSIM use the output of SimAGENT's CEMDAP module as the input data to drive their dynamic assignment microsimulations. This report discusses the simulation frameworks of both TRANSIMS and MATSIM and the resulting simulation results. The SCAG 4-step (static assignment) model is compared with the results from both modeling environments. Mean link volumes and paired samples t-tests are used for the comparisons. Most of the TRANSIMS work was done by Daimin Tang with help for Yali Chen and Karthik Konduri for Arizona State University. Most of the MATSIM work was done by Michael Balmer of senozon through a contract with UCSB and Nate Isbell. We selected this type of input and comparison with the four step model because we will perform a similar exercise with a subcontract with Yi-Chiang Chu using DynusT by June 2012. The experience documented here will help us decided on the most appropriate method for traffic assignment and interface with emissions predicting software.

1. SOFTWARE OVERVIEW

TRANSIMS

The Transportation Analysis SIMulation System (TRANSIMS) is a microsimulation package that attempts to model all transportation related aspects of human behavior (Nagel et al., 1999). Historically, the amount of data needed and computational requirements to execute such a model have limited the applications of such microsimulations in large regions. TRANSIMS has been used in many transportation studies including, signal timing in Chicago, Illinois (Chang and Ziliaskopoulos, 2003), and the Portland, Oregon area transportation network (Barrett et al. 2002). TRANSIMS uses transportation infrastructure, demographic, land-use, and human decision making data to generate a realistic model of traffic and congestion. TRANSIMS represents road design in a microscopic manner, as well as, incorporating such things as the number of lanes, controlled intersections, as well as other traffic control details. Each agent in TRANSIMS represents a person in the real world. These agents operate on the transportation network making plans about what to do throughout the modeled day. Agents can also choose different travel modes. Once the network is defined, agents have travel plans and are assigned transportation modes. The router in TRANSIMS decides what transportation links to utilize for each trip for each agent. This routing is done by implementing a version of Dijkstra's shortest path algorithm that has regular language constraints and solves problems with time-dependent edge delays using a general first-in-first-out model (Barrett et al., 2002). This is an iterative process that allows for re-planning because the routes are simulated by determining optimal mode choices based on the demographic and geographic characteristics of the population, forward causality is artificially introduced. In order to bring the system to a "relaxed state" TRANSIMS implements re-planning. Link delays observed in the simulation are sent to the route planner to iteratively re-plan a fraction of the agents. For example, if an agent runs into too much congestion, the agent will try another route. This interaction between the plans-making models and the microsimulation is repeated until expectations during plans making and conditions during plans execution are consistent (Nagel and Barrett, 1997).

MATSIM

The Multi-Agent Transportation Simulation Toolkit (MATSIM-T or MATSIM) is written in Java. MATSIM was developed to handle many different varieties of input data at a variety of spatial aggregation levels. MATSIM has the capability of adding new custom models and algorithms and is adaptable to interface with models outside of the MATSIM framework. MATSIM models each agent with completely individual settings. MATSIM has been used in conjunction with activity based models to supply the dynamic modeling environment in Tel Aviv (Bekhor et al., 2011). Similarly, MATSIM was used in Canada to link an activity-based model for the Greater Toronto Area with dynamic traffic assignment to allow for dynamic emissions modeling of agents and households (Hatzopoulou et al., 2011). Other applications of MATSIM include modeling private cars and commercial vehicle traffic on a large scale (Joubert et al., 2010), and combining a microsimulation to model location choices for shopping and leisure activities with time geography concepts and practices (Horni et al., 2009).

MATSIM creates/optimizes demand in four steps: 1) creates the scenario, 2) models the initial individual demand, 3) iteratively optimizes the demand, and 4) offers output for a post process analysis. Creating the scenario in MATSIM, steps 1 and 2, transforms, parses, and writes the transportation network, facility locations, and their respective attributes, and population data with individual demands into their appropriate XML formats. This is all done modularly, meaning that if more detailed or more current data become available, you can replace the existing data module with the more detailed module in a seamless fashion. Step 3 optimizes the demand for each individual in the modeled scenario making sure that these agents obey the constraints of the scenario and they interact appropriately with the other agents in the region. Instead of using the "relaxed" state like TRANSIMS uses for route choice described by the Wardrop equilibrium, MATSIM optimizes the complete daily plan (routes, times, locations, sequence of activities, activity types, etc.) of each agent. This is done by maximizing each agent's daily utility, depending on infrastructural constraints (i.e. capacity of links, opening times, of businesses, etc.) and the plans of other agents in the simulation. Therefore, the utility of any given daily plan can only be determined by the interaction of all agents in the simulation. This is done by implementing a co-evolutionary algorithm (see Balmer et al., 2009). A traffic flow simulation model handles the daily plans and agent interactions. Plans with high utility scores will remain while plans with low scores are removed (Balmer et al., 2009).

TRANSIMS AND MATSIM

MATSIM differs from TRANSIMS in a number of areas. First, agents in MATSIM completely contain their individual attributes and data throughout the modeling process. This allows for agents to access demographic characteristics or time pressure while that agent is moving about the network. TRANSIMS stores this type of data amongst many modules and files. Secondly, MATSIM utilizes XML for network and agent input and output data. This allows for files to contain different levels of data, and insures that the same file format is used throughout agent data exchange between modules. This means that arbitrary modules can be joined to supply agent information. Conversely, TRANSIMS implicitly gives the module's capabilities by the file formats. Furthermore, MATSIM requires only one document type definition (DTD or schema) for all agent data files. Finally, because of the MATSIM agent design, it is relatively easy to store multiple plans for each agent. This allows for the iterative part of MATSIM to be much more easily interpreted as a co-evolutionary algorithm in which every agent draws on the population of plans to find more optimal solutions.

2. METHODOLOGY

PREPARATION

The entire TRANSIMS application flow chart is shown in Figure 1. The MATSIM flow chart in Figure 2. They are divided into two parts, data preparation and the model simulation. For both TRANSIMS and MATSIM, synthetic schedules are provided by the CEMDAP module of SimAGENT. The rest of the traffic contributors in the region (trucks, port/airport traffic, and external traffic) are provided as OD matrices.

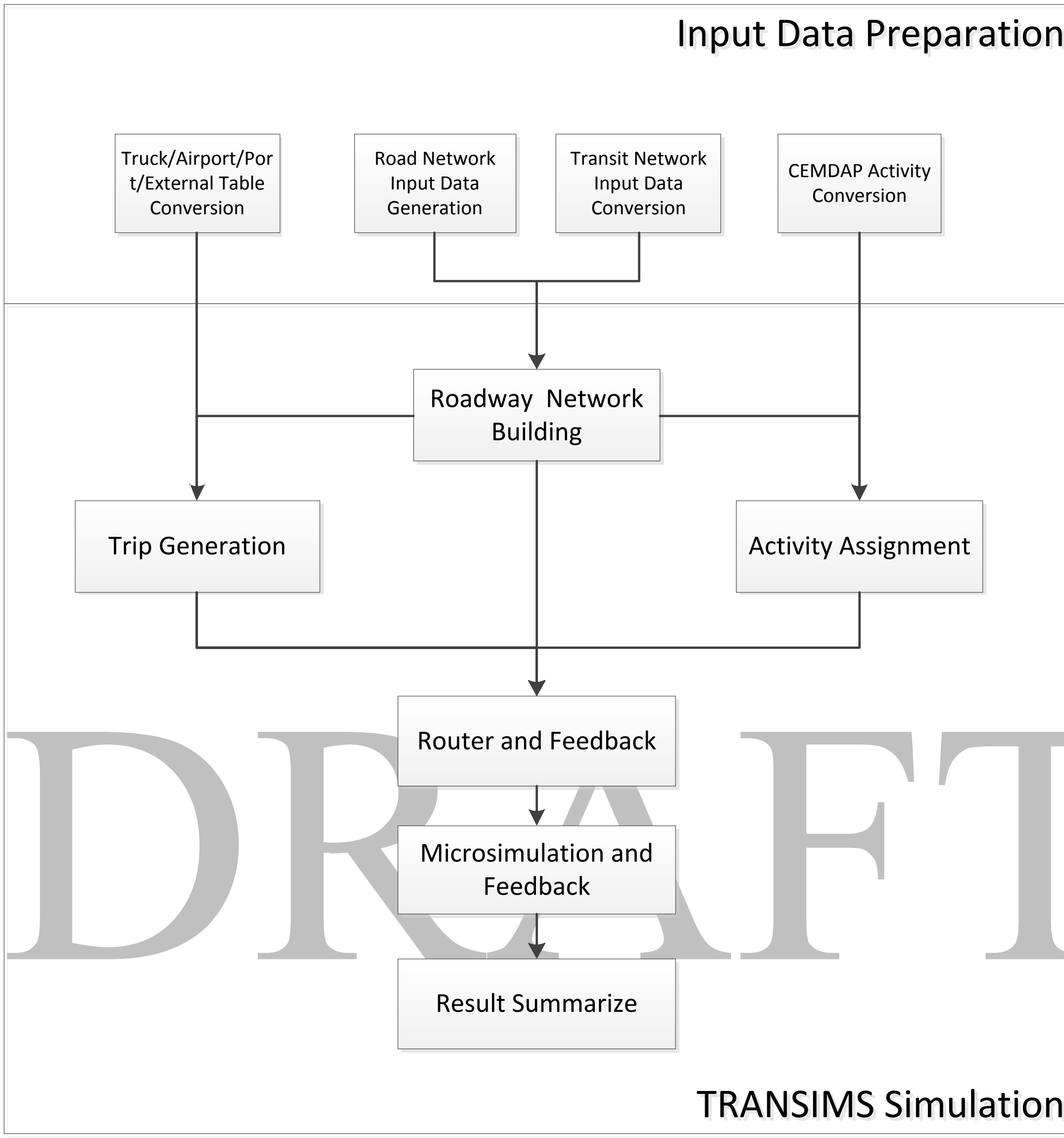


FIGURE 1 Flowchart of TRANSIMS application.

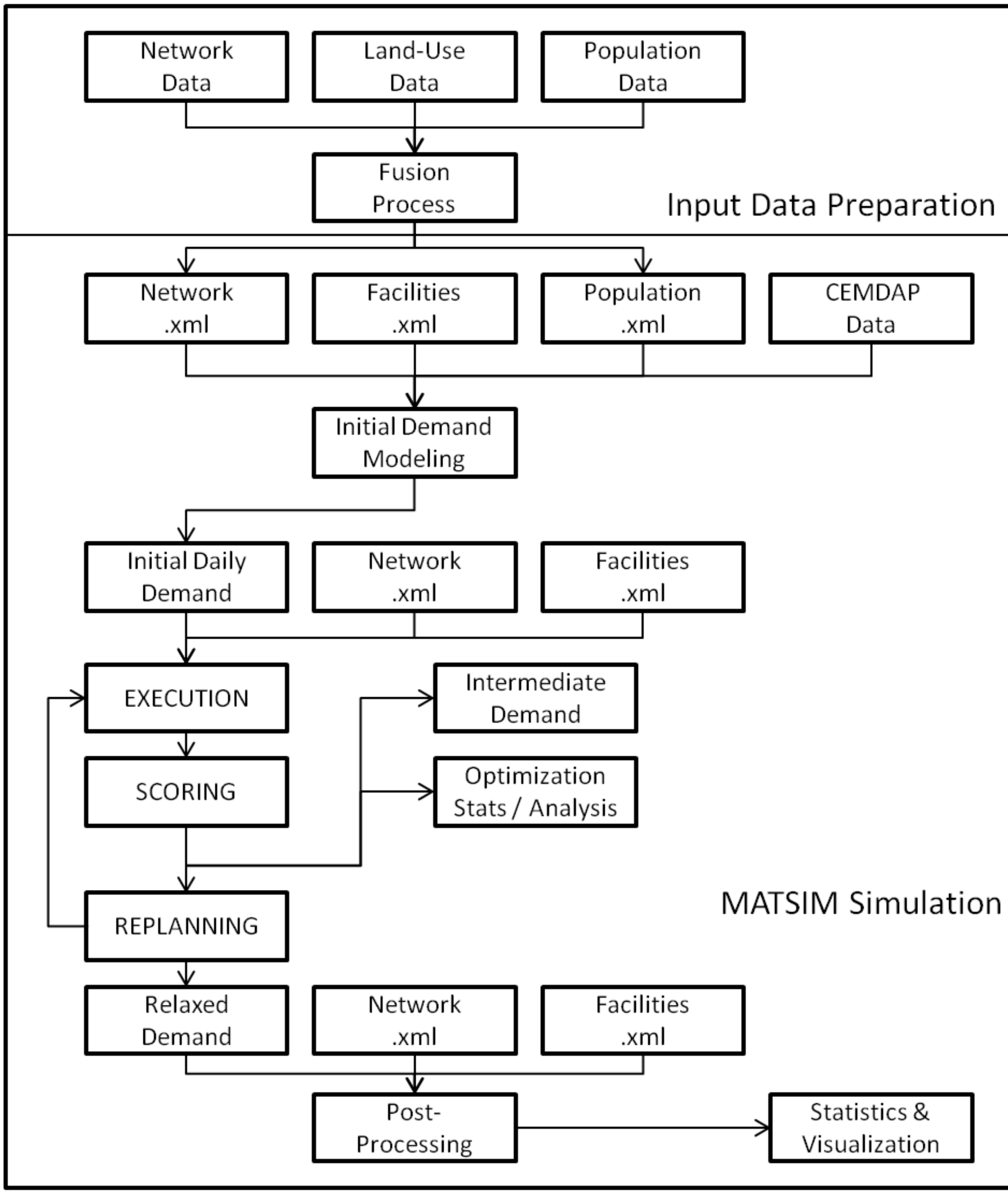


FIGURE 2 Flowchart For MATSIM Application.

TRANSIMS and MATSIM input data includes: the SCAG road network, transit network, activity schedules of the SCAG residents, and truck/airport/port/external trips in TAZ to TAZ Origin-Destination (OD) matrices from the SCAG four-step model. Roadway and transit networks come from SCAG regional transportation planning package. Daily activity data of people are the output from Comprehensive Econometric Microsimulator of Daily Activity-travel Patterns (CEMDAP) module and truck/airport/port/external trips are from traditional four-step traffic demand model that was used for the 2008 regional transportation plan. All data were converted to the TRANSIMS input format using C# in Visual Studio 2010. Data were converted to the MATSIM input format using Java.

ROAD NETWORK PREPARATION

The network used is from the SCAG Regional Planning Model, including road nodes and links. Nodes are points with XY coordinates while links are lines that connect nodes. Each roadway link also has some basic descriptive attributes, such as node_AB, node_BA, road length, road name, road type, number of lanes, etc. All road data have been stored in ArcGIS shapefiles.

TRANSIMS road network conversion was done using GISNet.exe to directly convert GIS nodes and links from shapefiles into TRANSIMS input file.

MATSIM road network conversion was done using SCAGShp2Links.java and SCAGShp2Nodes.Java.

A key difference between TRANSIMS and MATSIM is that MATSIM generates a link for each direction of travel. TRANSIMS however, for links other than major roadways, utilizes one link for both directions of travel.

TRANSIT NETWORK PREPARATION

Transit data also need to be converted to the formats required by TRANSIMS and MATSIM. TRANSIMS requires two files for the transit generation process: a transit route header and a transit route node. The route header file contains information about route number, transit mode, headways and offsets throughout the simulation time period, while the route nodes file contains a series of sequential road nodes that indicate the road path of each transit route. In the SCAG transportation planning package, transit data include the transit routes and the geo-coded transit stops along the routes. The stops and route lines are associated by their route IDs. However, the routes and stops are not attached to the SCAG road network so that they cannot be directly converted to route node file and used in TRANSIMS application. According to this, identifying the road links and nodes that transit routes are laid on is the key approach to transit - network integration. Figure 3 below shows the major conversion steps in the process.

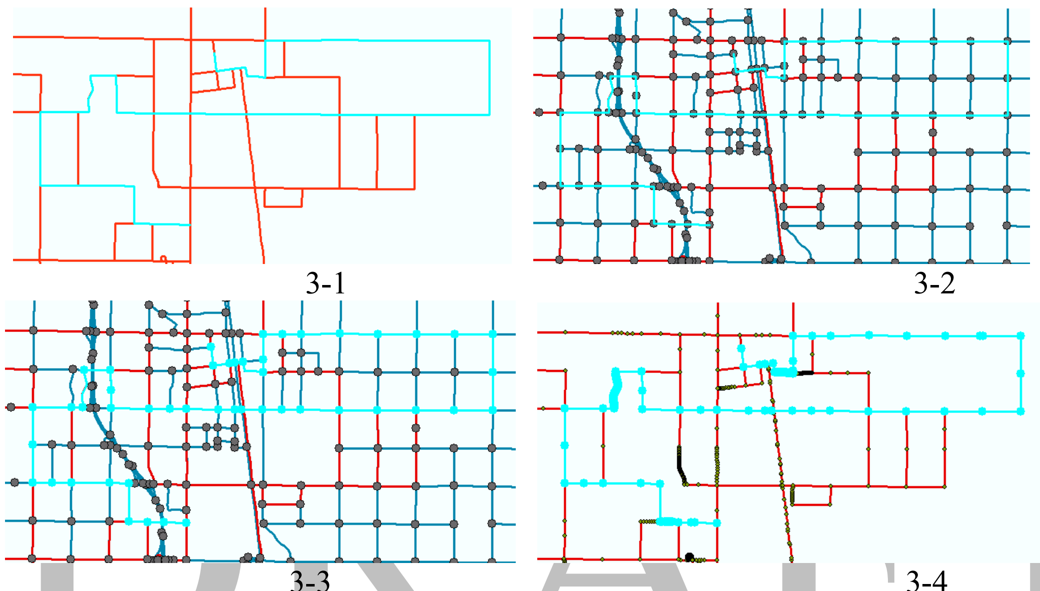


FIGURE 3 Transit Route Conversion.

In preparation for generating transit input data, we use ArcGIS software with spatial join method for this process. In figure 3-1, the red lines are the transit routes. We select one bus route from the transit route file as an example. First, we add the road nodes and links to the map so the link, node and route could lay on each other shown in figure 3-2. Second, we use the spatial join tool to join the nodes and routes together in order to find all the roadway nodes which are intersected with the route. After that, as shown in 3-3, we can find a collection of node points associated with each transit route. However, all the nodes are not in the right sequence. As we know, the transit route is a polyline file, in which each route is composed by a series of line segments, and they are connected by points so that the points of each route line are in the right sequence from start to the end. According to this, as shown in 3-4, we split and convert each route line to a series of sequential points and use spatial join tool again to find the nearest route line point of each road node which we should have found in the last step in order to obtain the right order of network nodes.

With the way we converted the network above, the transit route node file is ready for TRANSIMS. In addition, transit route header file also needs to be converted from the SCAG transit route file. In SCAG application, we include ROUTE, NAME, MODE, TTIME, HEADWAY, and OFFSET in route header file. If the transit network includes guideways, their links and nodes should exist in the network Node and Link files prior to starting the transit conversion process. In our SCAG region study, we included all the transit links and connection links in the input link file which served as input to the TransimsNet program. Tables 1 and 2 are the sample data from transit input files.

TABLE 1 Sample of Transit Node File

Route	Node
3	39730
3	16365
3	18932
…	…
3	39730
4	18959
4	27173
…	…

TABLE 2 Sample of Transit Route Header File

ROUTE	NAME	MODE	DISTANCE	ROUTE_HEAD	DIRECTION	HEADWAY_1	HEADWAY_2	HEADWAY_3	OFFSET_1	OFFSET_2	OFFSET_3
3	Route 7	BUS	11.3	CAL STATE METROL	AM	0	70	0	0	23.67	0
4	Route 9	BUS	7.18	GREEN-CLOCKWISE		25.71	105	25.71	11.9	29.71	11.9
5	Route 10	BUS	7.18	GREEN-COUNTERCLO		25.71	84	25.71	11.9	26.33	11.9
12	Route 33	BUS	16.51	LANCASTER	NORTH	31.76	24.71	31.76	13.92	11.57	13.92
15	Route 43	BUS	16.17	EAST LANCASTER	EAST	31.76	30	31.76	13.92	13.33	13.92

After all these preparatory steps, TRANSIMS transit related network files can be generated by its transit tools called TransitNet which will be discussed later in the methodology section.

MATSIM also requires the transit network (links and nodes) and schedule. These are created from the SCAG data using PtNetworkParser.java and TransitScheduleCreator.java. MATSIM has encountered some problems using the converted network from the spatial join. Creating a transit network that places traffic on to the network created in the road network preparation step has not been achieved. Currently transit is modeled on its own network that does not interact with the road network. Efforts are currently underway to resolve this issue and requires additional work beyond the TRANSIMS tasks.

MATSIM ACTIVITY DATA PREPARATION

The daily travel activities of each person in each household come from the new version of the Comprehensive Econometric Microsimulator of Daily Activity-travel Patterns (CEMDAP) model dated March 2011. CEMDAP is used as the modeling engine that simulates activity-travel patterns of all individuals in the region for a 24 hour period along a continuous time axis. The CEMDAP model provides a series of data about daily activities, including simulated person, tours, activity stops during a day and vehicles used by households. The person data contain all the characteristics of synthetic persons: age, gender, work status, age, and so forth. The tour table gives the duration, number of stops, and travel mode of each tour. The activity stop file contains the stops of each activity of each person. For each activity stop record, there is a start time, travel time, travel duration, travel mode (drive alone, share ride passenger, share ride driver, walk, transit, and any other data required by the users), type of activity (shopping, social/recreation, personal business, eat out, and any other activity types included in the specific application), traffic analysis zone (TAZ) of origin, TAZ of destination, distance, etc.

Vehicles are stored for each household and their records contain household id, vehicle id specific to each household, make, body type, years in use, primary driver for the household, annual mileage, etc.

Table 3 shows the activity file information. The conversion of activity stop and vehicle files from CEMDAP output to the TRANSIMS format is done in the following way. Vehicles should be converted first because the activity files are associated with vehicles under conversion. According to the TRANSIMS vehicle format, new ID of each vehicle is coded by combining the household id with the vehicle id. For example, if the vehicle id is "01" and the household id is "2002", the new vehicle id would be "200201". Next the CEMDAP stops file is converted to the TRANSIMS activity file. There are two steps for the complete conversion, a data format conversion and activity location assignment. Since TRANSIMS requires that all activities start from the beginning of the day and CEMDAP activities start from the first activity when traveling outside, a home activity for each person is added before the conversion. During the format conversion process, only the useable information for the TRANSIMS activity file is kept. Most data fields are the same or similar between TRANSIMS and CEMDAP and they are converted based on the corresponding data fields such as household id, person id, purpose, trip start time, end time, duration. For travel mode, CEMDAP model uses "Drive Alone", "Share Ride Passenger", "Share Ride Driver", "Walk", "Transit" and "School Bus". While in TRANSIMS, travel mode is categorized as "Walk", "Drive", "Bus", "Rail", "Park-&-Ride Outbound", "Park-&-Ride Inbound", "Bicycle", "Magic Move", "School Bus", "2 Person Carpool", "3 Person Carpool", "4 Person Carpool", "Kiss-&-Ride Outbound", "Kiss-&-Ride Inbound." In addition, the MATSIM modes are "car", "ride", "walk", "pt", "driven by parent", "driven by other", "driven by school bus", and "shared ride driver". The correspondent mode pairs in Table 4 for travel are used for the travel mode conversion.

TABLE 3 CEMDAP output Variables

Column No	Variable Name	Variable Description
1	HID	Household identification number
2	PID	Person identification number
3	TID	Tour identification number 2
4	SID	Stop identification number
5	ActType	Activity type at the current stop
6	StartT	Start time of travel to the stop (minutes from 3 a.m.)
7	TravelT	Travel time to stop (minutes)
8	Duration	Stop duration (minutes)
9	ZoneID	Stop location (zone) identification number
10	OZoneID	Previous (origin) stop location (zone) identification number
11	Distance	Trip distance (miles, calculated as zone to zone centroid distance)
12	PActType	Activity type at the previous stop
13	ArriveT	StartT + TravelT
14	StartT15	Start time of travel to the stop (n^{th} 15-minute interval from 3 am)
15	HmStayDu	Home/work stay duration before tour (minutes)
16	Mode	Tour mode
17	Tourdun	Tour duration (minutes)
18	N_stops	Number of stops in tour
19	IsWorker	1 if adult goes to work on that day, 0 otherwise
20	MakeWrel	1 if adult undertakes work-related activity, 0 otherwise
21	MakeDrop	1 if adult drops-off children at school, 0 otherwise
22	MakePick	1 if adult picks-up children from school, 0 otherwise
23	MakeJDis	1 if adult undertakes joint discretionary activities with children, 0 otherwise
24	MakeShop	1 if adult undertakes shopping activity, 0 otherwise
25	MakePers	1 If adult undertakes household/personal business activity, 0 otherwise
26	MakeSoc	1 if adult undertakes social/recreational activity, 0 otherwise
27	MakeEatOut	1 if adult undertakes eat-out activity, 0 otherwise
28	MakeServe	1 if adult undertakes other serve-passenger activity, 0 otherwise
29	AdultChild	1 if adult, 2 if child
30	IsSch	1 if child goes to school on that day, 0 otherwise
31	MakeIDis	1 if child undertakes independent discretionary activities, 0 otherwise
32	NonSch_Tours	MakeJDis + MakeIDis
33	WrkStart	Work/school start time (minutes from 3 a.m.)
34	WrkEnd	Work/school end time (minutes from 3 a.m.)
35	NumBW	Number of before-work tours
36	NumWB	Number of work-based tours
37	NumAW	Number of after-work tours
38	Works	1 if worker
39	NumToursWork	NumBW + NumWB + NumAW
40	WrkStart15	WrkStart into 15 minute intervals (e.g., I if 3:00-3:15 AM , 2 if 3:15-30)
41	WrkEnd15	WrkEnd into 15 minute intervals
42	N_tour	Total number of tours made
43	Nonwork	1 if nonworker
44	SchStart	School start time (minutes from 3 a.m.)
45	SchEnd	School end time (minutes from 3 a.m.)
46	DropSch	1 if child gets dropped off at school by parent, 0 otherwise
47	PickSch	1 if child gets picked up from school by parent, 0 otherwise
48	ChildStu	1 if child student
49	SchStart15	SchStart into 15 minute intervals
50	SchEnd15	SchEnd into 15 minute intervals
51	Worker	1 if works=1 or childstu = 1
52	NonWorker	1 if nonwork=1 or IsSch = 0
53	N_Act_Stops	N_stops - 1
54	Activity	ActType
55	PActivity	PActType
56	TripTypeB	
57	TripType	1 if Adult and TripTypeB =1, 2 if (Child and TripTypeB=1) or TripTypeB=2, 3 if TripTypeB=3
62	Mode_new	DA = 1, SR_driver = 2, SR_pass = 3, Walk = 4, Transit = 5, Schbus = 6

Table 4 Travel Mode Conversion

Travel Mode Conversion		
CEMDAP	**TRANSIMS**	**MATSIM**
Drive Alone	Drive	car
Share Ride Passenger	2/3/4 Person Carpool	ride
Share Ride Driver	2/3/4 Person Carpool	ride
Walk	Walk	walk
Transit	BUS	pt
School Bus	School Bus	ride

In the second step, each activity in TRANSIMS is assigned to an exact location where it happens, otherwise people cannot be routed on the network. However, activities in the CEMDAP model are at the zonal level. People travel from the centroid of one transportation analysis zone (TAZ) to another, which means trips within a TAZ all start from the same location to another. Therefore, an activity assignment approach has been done to distribute trips starting from different activity locations within each zone. The approach of activity assignment is based on a random assignment method. First, all the activity locations generated by TRANSIMS are sorted by TAZ. Second, activity records are read once per household. For each person in the household, we assume the locations of their first activities which we added at the conversion step are home activities. For all activities, random locations are chosen within the respective zones and set as that household's location. Third, after all trips of one household are assigned to the network, some locations need to be updated. There are two situations in which the locations need to be updated: First, if the last activity of a person ends in the same zone as its first home activity, it is assumed that it is a "back home" activity and change its location to the home location. Second, the locations of those passengers who travel together are updated along with the number of passengers in passenger field. After assigning all the trips to the network, the locations of vehicles in each household also need to be allocated. In order that people can get access to their vehicles when starting their trips, the locations of vehicles are set to their first activity locations. For share ride mode, to find out how many people travel together, all the people in the same household were searched to find the person who has share ride mode and as well as the same origin and destination. After that the travel mode and number of passengers in the vehicle were determined. Table 4 is a sample of a TRANSIMS activity file.

TABLE 4 TRANSIMS Activity Sample

HHOLD	PERSON	ACTIVITY	PURPOSE	PRIOTITY	START	END	DURATION	MODE	VEHICLE	LOCATION	ZONE	PASSENGER
2	1	1	12	9	0	15.3	15.3	8	20	218174	4013	0
2	1	2	5	9	15.3	18.267	2.967	10	20	218131	4013	1
2	1	3	12	9	18.35	24	5.65	10	20	218174	4013	1
3	1	1	12	9	0	4.4	4.4	8	30	222569	4013	0
3	1	2	8	9	4.4	13.35	8.95	2	30	227667	4065	0
3	1	3	9	9	14.233	14.467	0.233	2	30	282207	3574	0
3	1	4	12	9	15.567	24	8.433	2	30	222569	4013	0
4	1	1	12	9	0	10.167	10.167	8	40	222609	4013	0

Converting from the CEMDAP output to the MATSIM activity files is done similarly to the TRANSIMS conversion. Vehicles are assigned to households and given household vehicle IDs. Household characteristics are also assigned. Primary and secondary drivers, activity types and start/end times are also imported from CEMDAP. Household locations are also assigned within each TAZ by randomly assigning household locations within each TAZ. Leg-specific modes are chosen based on the activity type and the number of household members participating and their respective ages.

```
  <?xml version="1.0" encoding="utf-8" ?>
  <!DOCTYPE plans (View Source for full doctype...)>
- <plans xml:lang="de-CH">
    <!--  ================================================================   -->
  - <person id="1000002_4" employed="no">
    - <plan selected="yes">
        <act type="home" link="1054719999" x="385034.40819126327" y="3763116.2154275775" start_time="00:00:00" dur="07:41:0
          end_time="07:41:00" />
        <leg mode="ride" dep_time="07:41:00" trav_time="00:00:00" />
        <act type="educ" link="1057489999" x="385548.9054775411" y="3762326.2986720395" start_time="07:41:00" dur="04:17:00"
          end_time="11:58:00" />
        <leg mode="ride" dep_time="12:04:00" trav_time="00:08:00" />
        <act type="other" link="1050019999" x="384507.86079395394" y="3767208.571548837" start_time="12:12:00" dur="00:14:00
          end_time="12:26:00" />
        <leg mode="ride" dep_time="12:26:00" trav_time="00:07:00" />
        <act type="home" link="1647171" x="385108.23364623624" y="3762970.186369153" start_time="12:33:00" dur="14:27:00"
          end_time="27:00:00" />
      </plan>
    </person>
```


FIGURE 4 MATSIM Activity Plan Sample

Truck/Airport/Port/External Trip Preparation

In addition to the daily activity data of simulated persons in SimAGENT, we also have trips for goods movement, ingress and egress to airports and ports, and external trips. The data of truck/airport/port/external trips are the outputs from the four-step transportation planning model and stored in OD matrices for four time periods (AM/MD/PM/NT). TRANSIMS uses its convert trip tool to convert zone-to-zone trip tables to TRANSIMS trips by activity location and time of day. MATSIM uses Stops2PlansConverter.java to convert the OD matrices into activity plans by location and time of day. Table 5 below shows sample data from four-step truck table, number of truck trips are weighted traffic counts and summarized in three vehicle types by four time periods. In TRANSIMS, each trip table input to the trip table conversion process is assigned to a single travel mode and vehicle type for a whole day. So we create three sub-tables from the original truck dataset. We split all the OD trip tables for all the vehicle types and combine them for a whole day and input to TRANSIMS one by one. Because MATSIM coverts the OD trips to activity plans with vehicle types included this step is not necessary.

TABLE 5 Sample of AM Truck Trip Table

From	To	Light Truck	Medium Truck	Heavy Truck
1	1	6.37	3.23	0.02
…	…			
1	4114	0.02	0.21	0.4
…	…			
131	502	0.01	0.01	0.01
…	…			

TABLE 6 Converted All Day Truck Trip Tables

From	To	Heavy Truck
1	1	0.06
…	…	…
1	4114	1.38
…	…	…
131	502	0.05
…	…	…

From	To	Light Truck
1	1	13.78
…	…	
1	4114	0.05
…	…	
131	502	0.01
…	…	

From	To	Medium Truck
1	1	8.26
…	…	
1	4114	0.54
…	…	
131	502	0.02
…	…	…

Since the TRANSIMS and MATSIM model trips on a second-by-second basis, the trips included in the input trip tables and activity plans need to be distributed to a specific time of day. TRANSIMS requires a diurnal distribution file with each trip table. Diurnal distribution files are text files with at least three data fields (start time, end time, and one or more distribution fields). The first two columns of the file define the starting and ending time of the time period. The third column contains a number that represents the time period's share of trips. The values represent the relative probability of a trip within the time period given the sum of all values in the distribution. MATSIM applies these distributions in the activity plan generation step described above.

The first step is to get the percentage of trips travelled in each time period by simply adding trips among TAZs and divided by total numbers for the whole day. Then we use a tool called SmoothData.exe in TRANSIMS package to distribute the proportion of trips shared in four time periods into 15-minutes intervals. Table 7 shows the proportion of vehicle trips in each time period for light trucks. Figure 5 shows an example of the diurnal distribution.

TABLE 7 Light Truck Trip Distribution

START	END	SHARE
6AM	9AM	0.132
9AM	15PM	0.407
15PM	19PM	0.264
19PM	6AM	0.197

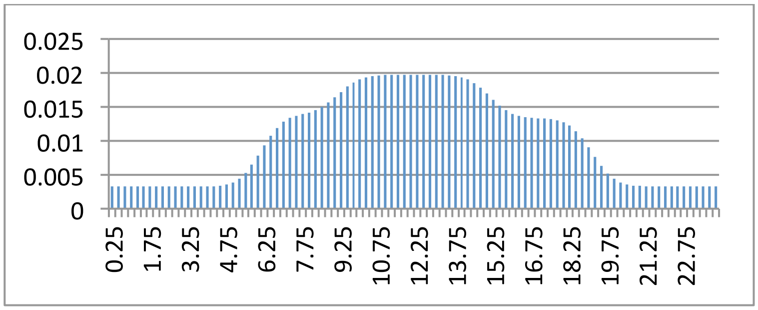


FIGURE 5 Light Truck Diurnal Distribution.

TRANSIMS Data Preparation Process	
Major Process	Description
SCAG_LinkConverter	Convert network links from regional planning package
SCAG_Trip_Converter	Convert trip tables and diurnal file from OD Matrices
SCAG_ActivityConverter	Convert CEMDAP activities and vehicles to TRANSIMS format
SCAG_TripAssignment	Assign trips and vehicles to activity locations within the network
SCAG_VehicleCombiner	Combine the trip vehicles and activity vehicles
SCAG_Household_Converter	Extract household from Activity file
SCAG_Household_Combiner	Combine the household of trips and activities
MATSIM Data Preparation Process	
Major Process	Description
SCAGNetworkConverter	Convert network links and nodes from regional planning package
SCAGSingleTripsConverter	Convert trip tables and diurnal file from OD Matrices
SCAGTAZ2Coord	Assigns persons within a TAZ to locations within that TAZ
SCAGStopsParser	Assign trips and vehicles to activity locations within the network
SCAGStops2PlansConverter	Combine the trip vehicles and activity vehicles
SCAGStops2PlansConverter	Extract household from Activity file
SCAGStops2PlansConverter	Combine the household of trips and activities

FIGURE 6 TRANSIMS & MATSIM Data Preparation Process.

With all the data preparation approaches discussed above, data that come from different sources are converted to the input requirements of TRANSIMS and MATSIM. Figure 6 shows the major processes that are used within each environment to prepare and convert the data.

.

Road Network Building

The TRANSIMS network is generated by TransimsNet program. The TRANSIMS network contains 20 or more road related components that define various aspects of the highway and transit facilities and operational characteristics. All components are created based on the input node, link, shape, and zone files. In particular, the attributes of links have a strong impact on the network generation. For example, setting up activity locations is based on the road type of each road link. Activity locations won't be generated on freeway, ramp and type of other roadway. In addition, transit stop nodes and connection links were also added to the network node and link file so that SCAG network also includes transit network as well. Other network building parameters such as pocket lengths for facilities, signal warrant for area type, and maximum connection angle are also set in the control file. Figure 7 shows the network components used in the TRANSIMS model.

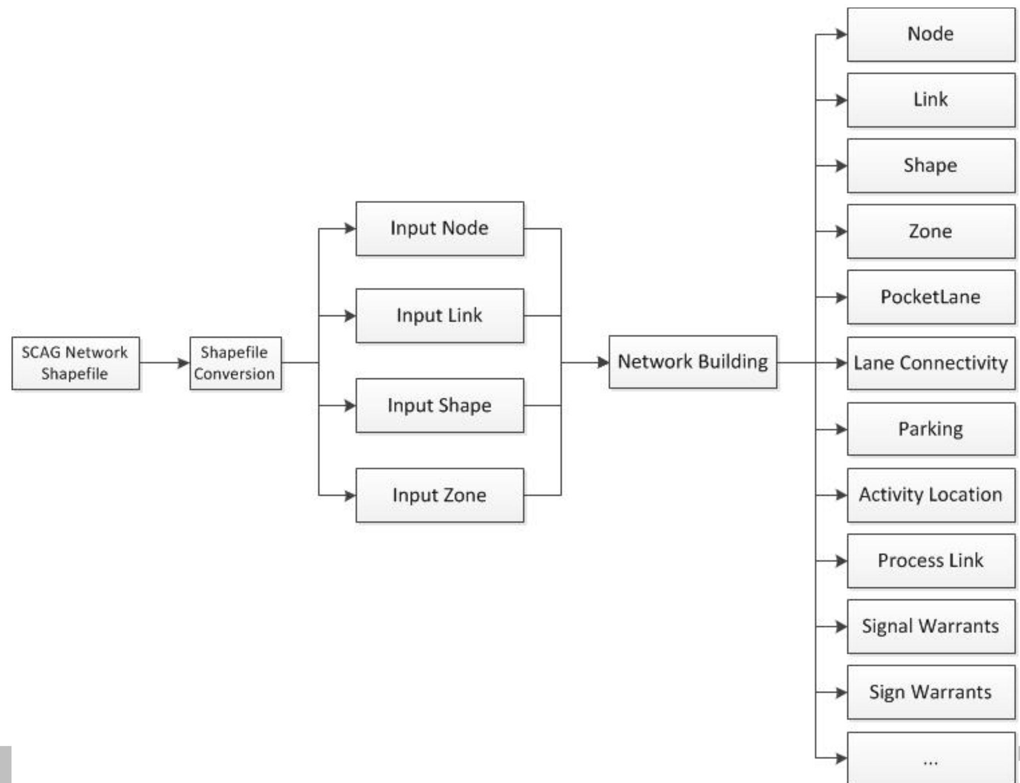


FIGURE 7 TRANSIMS Network Conversion

After a road network is established, the ArcNet program can convert the network to ArcGIS shapefiles to enable visualization on maps. However, the network data may still have some problems that need to be resolved. This includes the link connectivity problem and the missing data problem. With networks displayed in ArcGIS, we can easily edit the network elements to fix the problems and rebuild the TRANSIMS network. Figure 8 shows the entire TRANSIMS network. The route paths and operational characteristics of the TRANSIMS transit network are described in the Transit Stop, Transit Route, Transit Fare, Transit Driver and Transit Schedule files. The Transit Stop file specifies the physical locations, different from network nodes, along the network links where travelers can board or alight from a transit route. The Transit Route file specifies the list of stops and fare zones for a given route. The Transit Fare file includes the boarding and transfer fares by mode for a zone-based fare system. The Transit Driver file specifies the list of links traversed by the transit vehicle to service each route. Finally, the Transit Schedule file specifies the scheduled departure times from each transit stop. All the transit related data are generated by transit route node and header files.

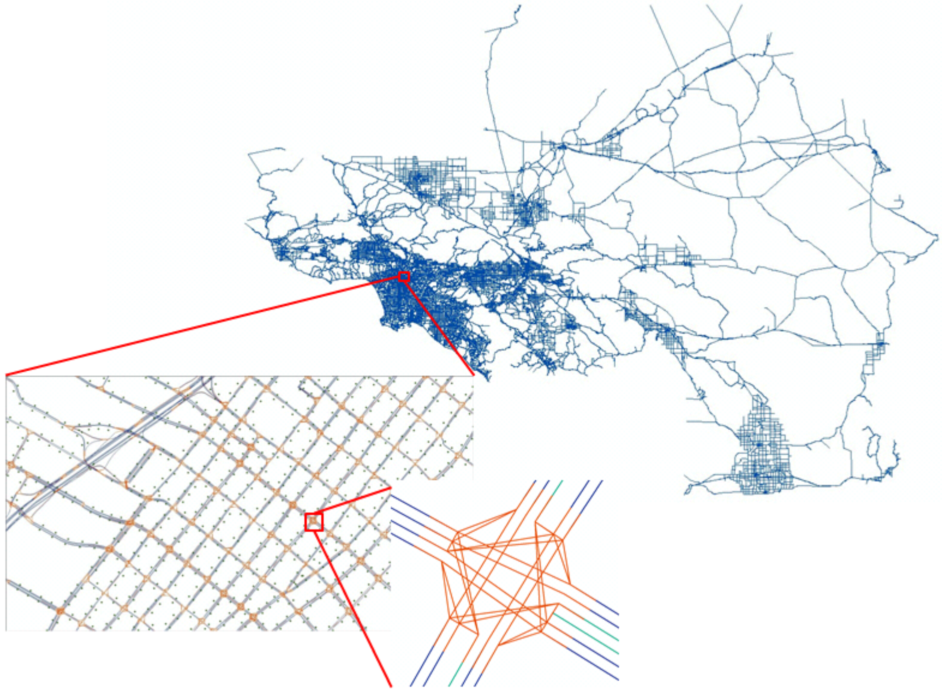


FIGURE 8 TRANSIMS Network.

The MATSIM road network is built using the error corrected shapefiles that were generated from the TRANSIMS ArcNet program. These shapfiles are then converted to the proper XML format using the SCAGNetworkConverter.java . Figure 9 shows the complete MATSIM network. Transit files are also generated in MATSIM. The transit network is created using the PtNetworkParser.java and the schedule is created using the TransitScheduleCreator.java. The network includes the transit stops and transit routes. While the transit schedules include the transit fares and transit schedule files, the vehicle type is also created here with fleet capacities, access and egress times and headways.

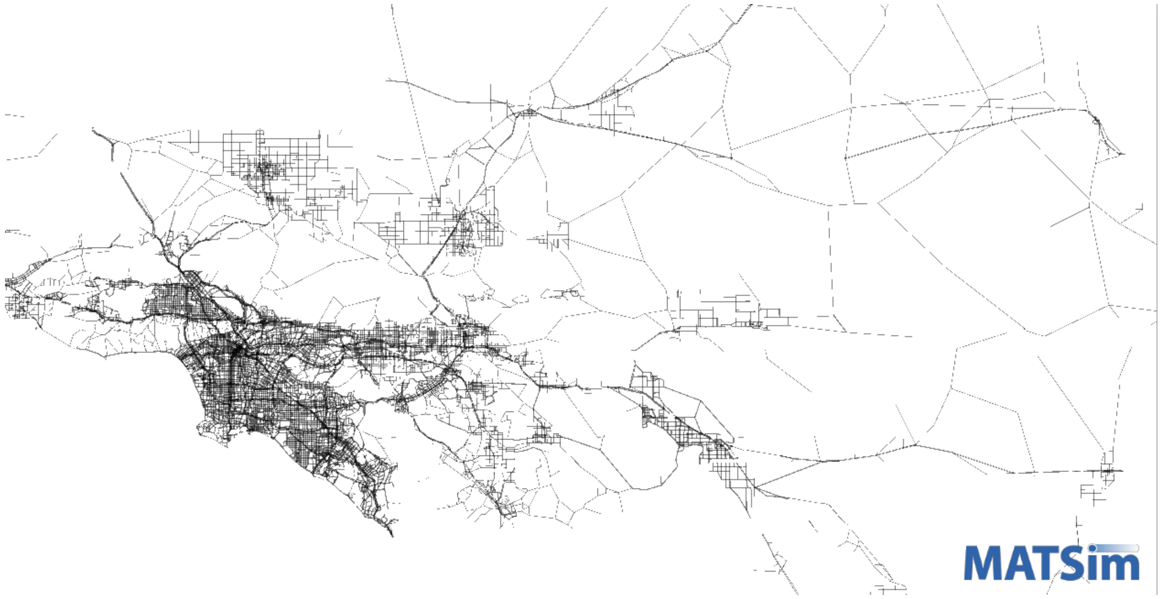


FIGURE 9 MATSIM Network.

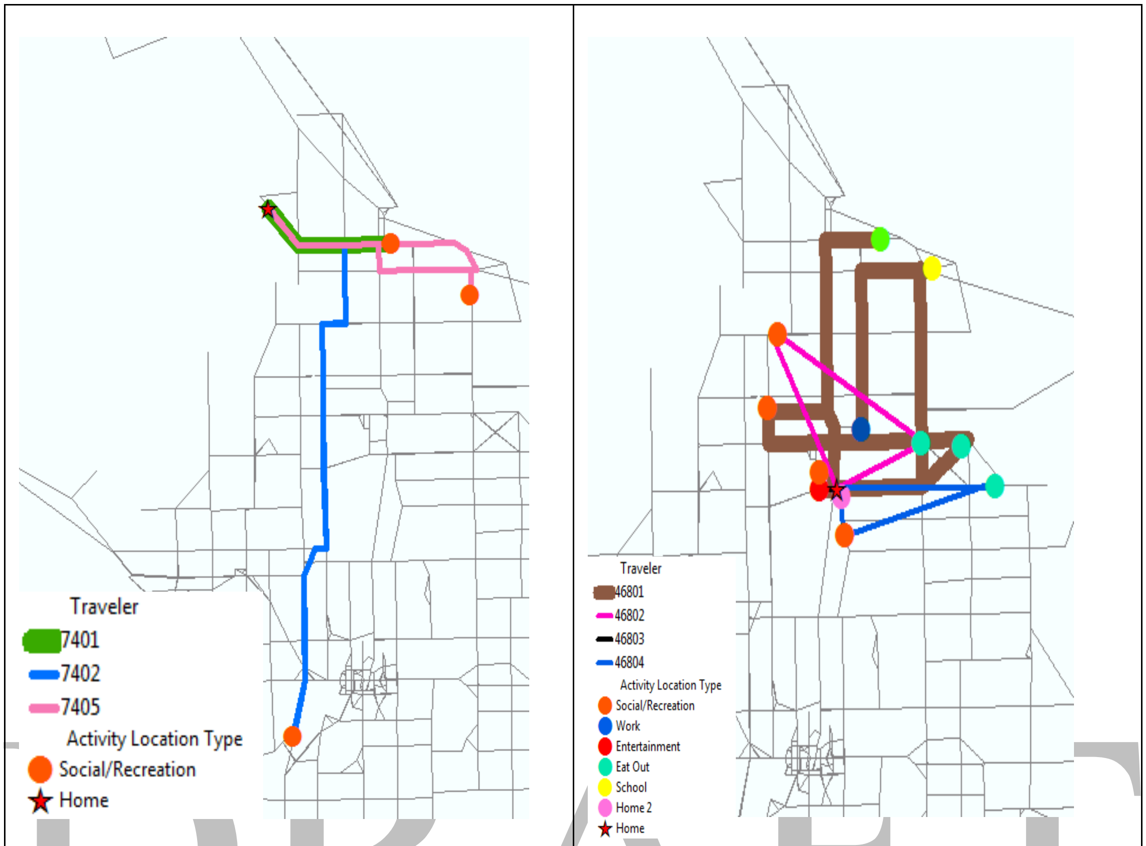
3. TRANSIMS PROCESS

Generally speaking, the TRANSIMS model mainly includes four processes: network building, trip generation, routing and feedback, microsimulation and feedback. A script control file, which sets parameters of the program and the directory of input and output file, is used in manipulating each program. The windows batch files are widely used for TRANSIMS applications that are run on a single CPU. However, the batch files are not well suited to parallelized applications since flow control and looping would require a myriad of "if" and "goto" statements. A good approach to control parallelized TRANSIMS applications is with scripts developed in Python. Python is well suited for TRANSIMS applications due to its good memory management function and threading module, which provides automatic management of multiple simultaneous tasks. According to the advantages of python above, we use python to control the entire TRANSIMS process.

Generating traffic trips from the combination of truck/airport/port/external OD matrices by time of day from trip tables (OD) is the first thing after network building. As mentioned in data preparation, we import every trip table with a diurnal distribution file to the ConvertTrips program, which also specifies the conversion parameters like trip purpose, travel mode, average travel speed, vehicle type and subtype for different trip tables. The ConvertTrip process will create trip records that start from one activity location and arrive at the destination with estimated travel times. Table 7 below shows the sample data of the ConvertTrip outputs.

TRANSIMS uses a router program that builds travel paths in the network for trips and activities. Given the origin and the destination activity location, the trip start time, and the primary travel mode, the router uses the shortest path algorithm to construct a minimum impedance path between the origin and destination based on travel conditions at the specified time of day. The whole travel path for a trip is called a travel plan. The plan for an automobile trip between home and work consists of three legs. The first leg represents the walk from the home activity location to the parking lot where the automobile is parked. The second leg represents the network links when driving from the origin parking lot to the destination parking lot. The third leg represents walking from the destination parking lot to the work activity location. The total impedance for all three legs is used to identify the optimal path for the trip. The output travel plan file includes a separate set of records for each mode-specific leg of every trip. After travel plans have been built, we can use ArcPlan program to convert travel plans to be viewed in ArcGIS in order to verify their validity or to check network travel times.

TRANSIMS router can handle both trips-based and activity-based travel data at the same time. But at first, vehicle file from different sources have to be combined together. After imputing trips of truck/airport/port/external generated from ConvertTrips and the converted CEMDAP activity data to the router and when both kinds of travel data are imported, trip-based tours are routed.



Household "74" Three persons with some overlap of paths	Household "468" Four persons with unassigned trips

FIGURE 10 Travel Plans for Households 74 and 468.

Figure 10 above shows the daily paths of two households. Household "74" has 5 persons (with ids 7401, 7402, 7403, 7404, 7405) but the 3rd and 4th persons are not included because they have no travel. The second household "468" has all its four persons (46801, 46802, 46803, and 46804) represented in the tables and paths of Figure 10. The TRANSIMS router uses the SimAGENT input data and generates a series of activity path records which are composed of travel mode, time period of travel, origin-destination locations, turning points on the path, and so forth. This information is stored in an Arcview® polyline file to show the travel path on the network. The entirety of paths for each household is a travel plan and the two travel plans of the households are shown in Figure 10. The household members of the right hand side sketch with ids "46802" and "46804" have trips that did not get routed on the TRANSIMS network and they directly move from an origin to the destination with a travel mode of "Magic Move". This is because the persons traveled by "School Bus" (Mode = "6") and "Driven by Parent (for child)" (Mode = "4") and VEHID = "-1" which could not be routed on the network. This is an example of the type of details that need to be post-processed in addition to a variety of other comparisons among different assignment algorithms and sensitivity analysis that are planned for the next phase in model development.

It is important to note that TRANSIMS model is based on the concept of iterative feedback. This means an iterative feedback process is used to update link travel times and adjust travel plans so as to generate realistic estimates of traffic volume and transit ridership. In this part, the PlanSum program to summarize the link demands and estimate link delays using volume-to-capacity relationships. The link delay file is used in the PlanSelect program for selecting a subset of household members to re-route their trips and adjust their travel plans. The PlanSelect process is based on the link volume-to-capacity ratio, time of day selection, percentage of household and differences between cumulative travel time and assigned time in a travel plan to determine if a household is eligible for re-routing. When a household is selected for the next routing process, the link delay file calculated for the previous loop is also imported for generating new routes. The new travel plans are built during this process and they are merged to the previous whole plans.

When new merged plans have been built, the first two loops of routing have been done. According to the TRANSIMS user document, the number of loops depends on the convergence criterion used and the method selected for achieving it. When the percentage of travelers who could improve their travel time by changing paths is less than 2% (about 40 iterations), we could consider the path building is stable. Additional iterations do not significantly improve this result. Figure 11 shows the flow chart of router and router feedback Iteration.

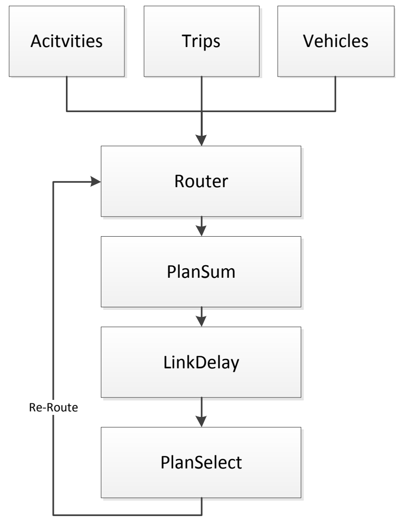


FIGURE 11 Route Planner and Feedback Iteration.

After building and adjusting travel plans for every household, it is time to start to simulate all the travellers on the network. TRANSIMS uses microsimulator program to run the simulation. It simulates the movement and interaction of persons and vehicles in a multimodal transportation network and it works in conjunction with the router to simulate the travel conditions experienced by individual travelers. The simulation is carried out in discrete, user-specified time intervals of one second or less over the course of a day. In every time step, the driving status of each vehicle based on its travel plans, vehicle type, road conditions, surrounding vehicles, and traffic signals It is also a dynamic traffic assignment process with iterative feedbacks. Before starting the simulation, PlanPerp program is used to sort all the travel plans by time of day. And then input time plans and vehicle type data to start the simulation.

During the simulation, each link in the network is depicted as a grid of cells, with each pocket and through lane containing its own set of cells. The cell size is typically set equal to the total space occupied by a passenger car when stopped in a queue. Each vehicle thus occupies one or more cells depending on its length. Relatively simple rules are used to move vehicles between cells in the network. The Microsimulator generates performance statistics based on cell movements per second that replicate fundamental flow-density-speed relationships. If congestion or network errors prevent a vehicle from changing lanes within a user-specified time period, the vehicle will be removed from the network and considered “lost.” Failure to remove such vehicles from the network has been found to generate unrealistic congestion that spreads into the off-peak time periods and deteriorates the quality of the simulation.

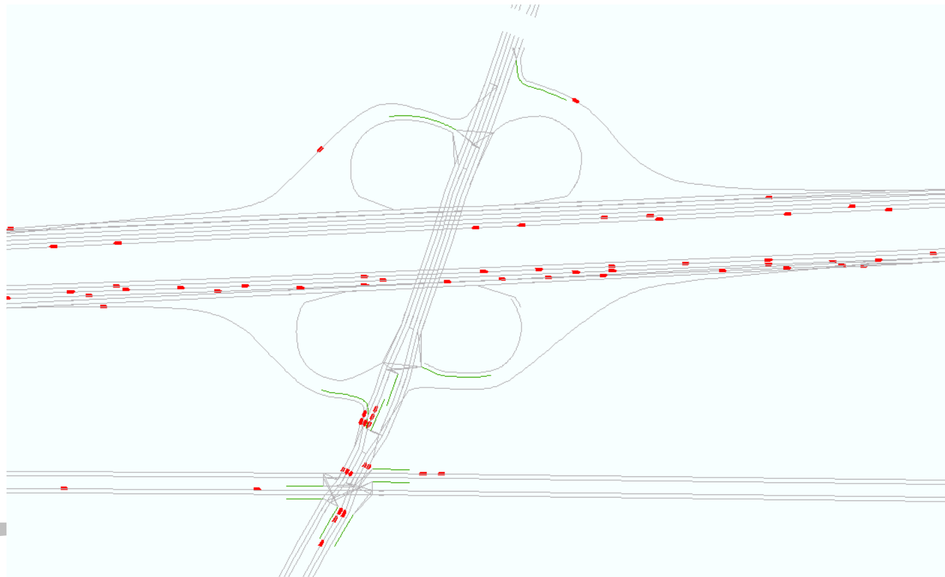


FIGURE 12 Simulation Snapshot.

The simulation result feedback concept is similar to the one described in the router. One itineration includes re-route households selection, trip re-route, travel plan merge, plan sort, travel plan summarize, simulation, and travel delay calculation processes. But during this itineration, the main factor for selecting household changes from estimation on volume-capacity ratio is the calculation of traffic-related link travel times. And PlanCompare program is used to find the travel time differences between current travel plan and the previous one and we can see if the process reaches user-equilibrium solution (2% differences or below).

4. MATSIM PROCESS

The demand of an agent is called a “ plan” in MATSIM. Figure 4 shows an example of one agent’s daily plan, written in XML. This structure stays the same during all modeling and simulation of the demand. In particular, the assignment of the traffic demand does not only take single trips into account, but the complete daily plans, including the activities, are executed. Figure 2 shows the scenario creation process, initial individual demand modeling process, iterative demand optimization process (including demand execution, scoring, and replanning), and post-process analysis. Since MATSIM-T is a modular approach, all parts shown in Figure 2 (fusion, initial demand modeling, EXECUTION, SCORING and REPLANNING) are given as interfaces such that users are able to plug in their own models.

The fusion and MATSIM processes rely on input data from SIMAGENT. Since the quality, quantity, and resolution of data can vary considerably from one scenario to another, the scenario creation and the MATSIM process steps in MATSIM can vary as well. MATSIM therefore provides in its core only the resulting data representation of the infrastructure (network and facilities) and the population including each person's individual demand, plus parsers and writers for the XML data representation.

Land-use data from SCAG region, work locations by industry type are combined in the fusion module that parses this information and creates one facility (including the number of workplaces) per census block. This gives a rough approximation of the existing work facilities and work places in the region.

The post-process analysis part of MATSIM works in the same way, with the difference that now the input data follows MATSIM standards (MATSIM XML formats of the network, facilities, population and demand) and therefore is useable for any given scenario. The iterative demand optimization process is the core of MATSIM. While all other steps are run once in a sequential order defined by the user, part three optimizes the demand for each individual synthetic traveler in the scenario such that they respect the constraints (network, facilities) of the scenario and the interaction with all the other actors of that region. MATSIM uses a relaxation method to find an equilibrium state. Not only the routes are optimized in MATSIM. The complete daily plan, including routes, times, locations, sequence of activities, activity types, etc. of each agent is optimized. Each agent tries to execute its day with highest possible utility. The utility of a daily plan depends on infrastructural constraints (capacity of streets, opening times of businesses, etc.) and on the daily plans of the other agents in the system. The effective utility of a daily plan can only be determined by the interaction of all agents. This is where MATSIM implements co-evolutionary algorithms. MATSIMS' evolutionary algorithm consists of the following steps:

1) Initialize / generate the daily plans for each agent in the system
2) Calculate the utility of the execution of the individual daily plans for each agent
3) Delete "bad" daily plans (the ones with a low utility)
4) Duplicate and modify daily plans
5) Make those plans the relevant plans for the next iteration; increase the iteration counter by one
6) Go to step 2.

It is important to note that the "individuals" of the evolutionary algorithms are the plans, while the synthetic travelers are the entities that *co*-evolve. Figure 2 shows this optimization loop. For each of the steps listed above, specific modules are available. The execution of the daily plans (EXECUTION) is handled by a corresponding traffic flow simulation module, in which the individuals interact with each other, i.e., individuals may generate congestion on streets of high usage. The SCORING module calculates the utility of all the executed daily plans. Plans with a high utility (high "fitness") survive, while plans with a low utility (e.g. caused by long travel times because of traffic jams) are eventually deleted. The creation and variation of daily plans (REPLANNING) is distributed among different modules that are specialized on varying specific aspects of daily plans. The modifications in the plan of a single agent are completely independent on the re-planning of all the other agents' plans.

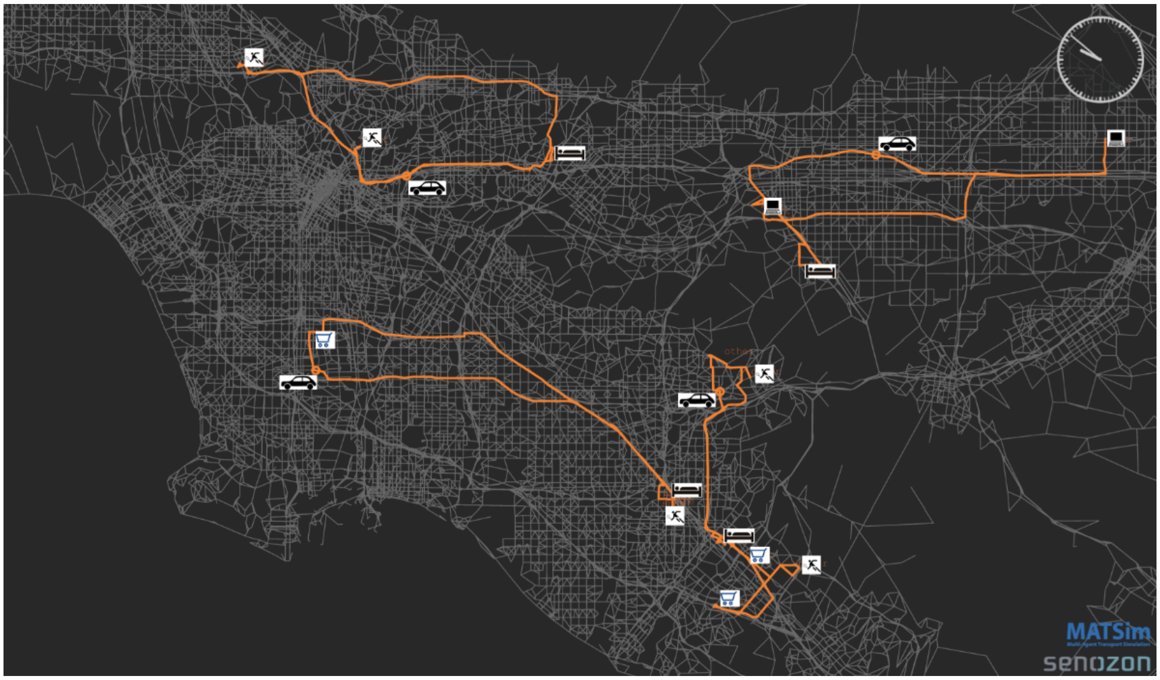


FIGURE 13 MATSIM Activities.

5. RESULTS

TRANSIMS modeled approximately 1.3 million goods movement trips and 65.8 million passenger trips. MATSIM modeled approximately 1 million goods movement trips and 50.8 million passenger trips. Figure 14 provides a summary.

	TRANSIMS	MATSIM
Goods Movement Trips	1,360,348	1,000,224
Passenger Trips	65,848,153	50,780,472

FIGURE 14 TRANSIMS and MATSIM Trip Breakdown.

TRANSIMS was run on a workstation with twelve 3.2 GHZ CPU cores and 24GB of RAM. The initial routing process was completed in 20 hours. Every iteration thereafter takes around 3 hours. TRANSIMS takes 20 iterations to reach user equilibrium.

MATSIM was run on a workstation with sixteen 2.93 GHZ CPU cores and 72GB of RAM. Every iteration thereafter takes around 40 min to complete. Similarly equilibrium is reached around 20 iterations. It should be noted that MATSIM was only able to run a 25% sample of the data. Because of the memory consumption of MATSIM a 100% run was not possible on the hardware available. For the analysis below a 10% sample is used and multiplied by 10 to compare with the 100% run from TRANSIMS.

Figure 15 shows the comparison of mean hourly network volumes from TRANSIMS, MATSIM, and Static Assignment. MATSIM volumes are significantly lower than the static assignment while the TRANSIMS volumes appear to be much closer

.

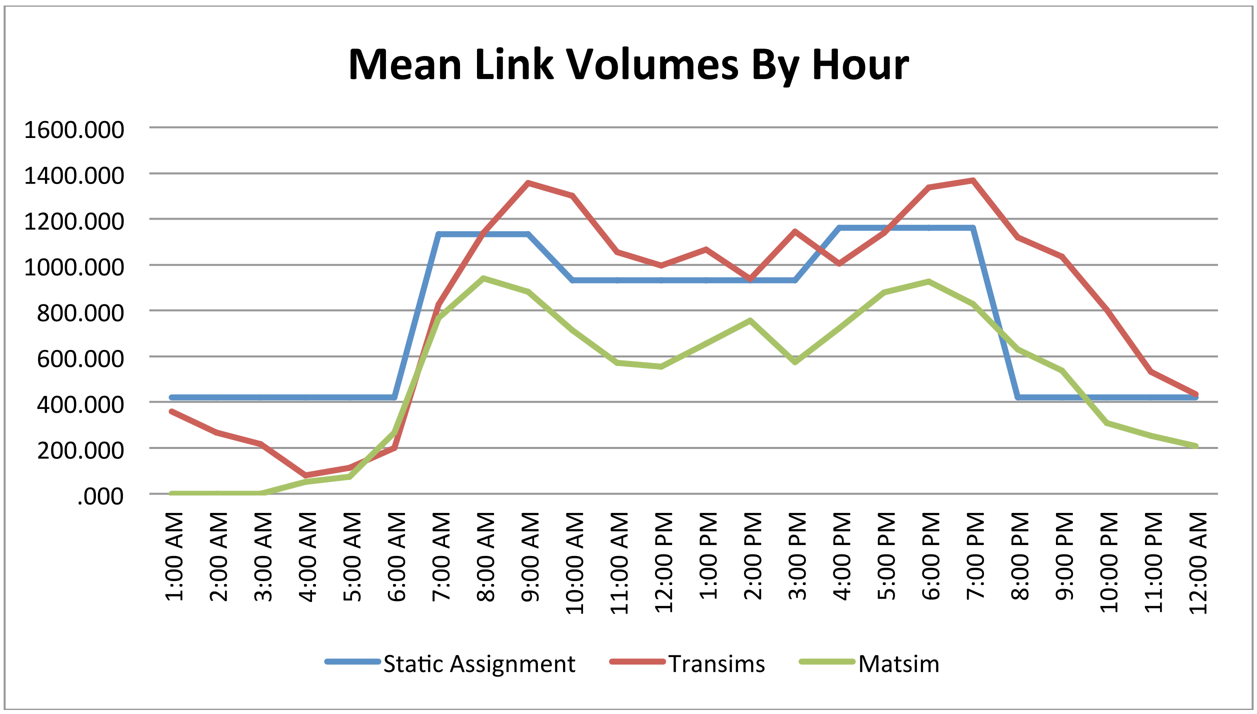


FIGURE 15 Mean Link Volumes by Hour

MATSIM has problems with modeling the 1:00AM, 2:00AM, and 3:00AM time periods. From Figure 15 it is apparent that the mean volumes for these three time periods are all zero. Extensive investigation as to why this occurs has taken place and is still underway. Currently, the cause of this is unknown. Because of the gross volume under estimation, for these three time periods, volumes from the rest of the time periods are not given much relevance.

The resulting outputs from TRANSIMS link volumes were compared with the static assignment volumes by time of day using a paired t-test. Hourly volumes were summed into the 4 time of day categories: AM, MD, PM, and NT. Similarly, the MATSIM volumes were compared to static assignment. See Tables 8 and 9. The t-tests conclude that at the 95% confidence level, both TRANSIMS and MATSIM are significantly different then static assignment across all time of day categories. Figure 16 shows the respective t-scores.

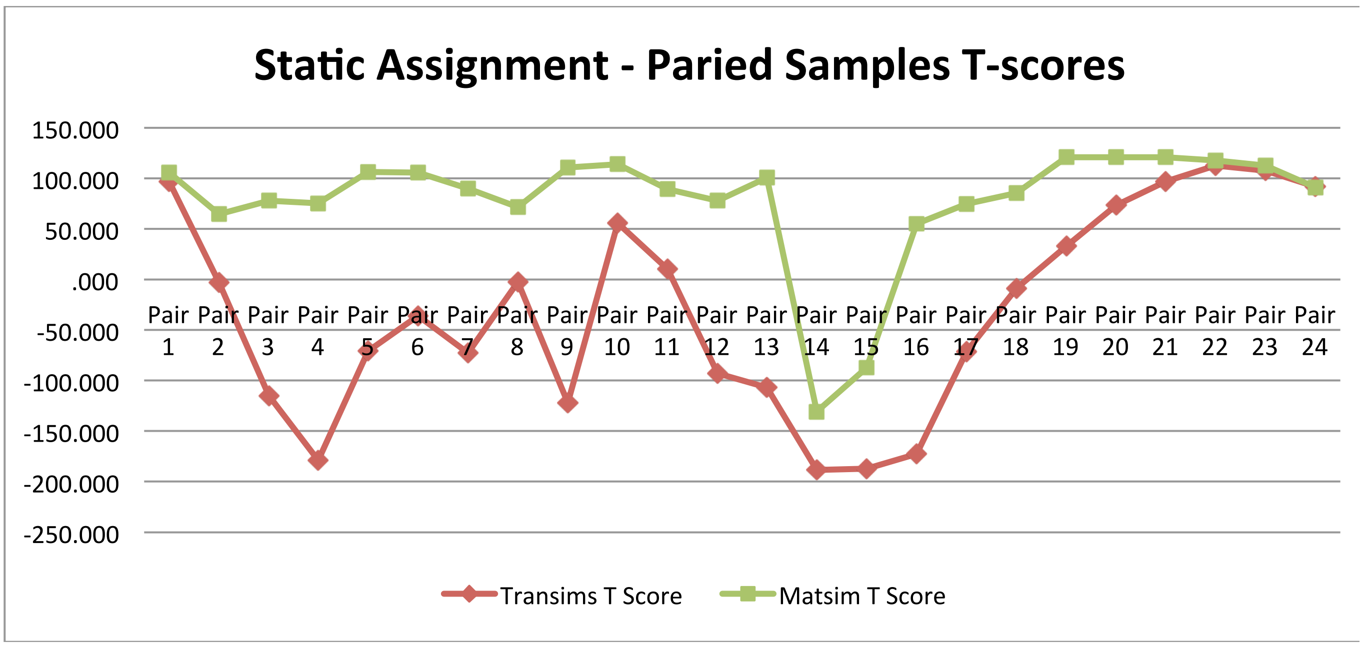


FIGURE 16 T-Scores Static Assignment and TRANSIMS and MATSIM

Figures 17 - 20 show a portion of the SCAG network that covers Los Angeles by time of day. These maps show the result of subtracting TRANSIMS link volumes from the static assignment volumes. Links that appear red, orange, or yellow are showing that the TRANSIMS volume on that link is higher than the static assignment volume. Conversley, links that are blue, turquoise, or green are showing that the TRANSIMS volume on that link is lower than the static assignment volume. Similarly, Figures 21-24 show the static assignment volumes minus the MATSIM volumes by time of day in the same region.

CONCLUSION

TRANSIMS and MATSIM were both used to implement microsimulations of the CEMDAP output. TRANSIMS while harder to work with provided a model that included 100% of the data and correctly routed transit and goods movement onto the network.

Problems occur when dealing with data inconsistency. For instance, in the CEMDAP activity files, some share ride passengers do not have vehicle information, which would be directly moved from origin to the destination. When building the network, some links may not connect to the whole network; links may lose connectivity lanes in some intersections, which leads to links unreachable during the routing process and simulation.

MATSIM was only able to provide a 25% sample (although a 100% sample should be possible with more random access memory). Significant problems were encountered with transit routing onto the road network. Furthermore, volumes were grossly incorrect for 3 time periods and lower then both static assignment and TRANSIMS for most of the other time periods.

6. FURTHER RESEARCH

The second by second vehicle speed and acceleration profiles from TRANSIMS are currently being implemented into the Comprehensive Modal Emissions Model (CMEM) to provide second by second emissions calculations. A problem exists from the nature of the data provided by TRANSIMS. TRANSIMS provides speeds and accelerations in 5 mph intervals as shown by the blue line in Figure 25. These jumps in speed result in very extreme accelerations. These extreme accelerations lead to emissions over-estimations by CMEM. Because of this, a polynomial smoothing is applied to the TRANSIMS trajectories. The red line in graph 3 shows the same trajectory with smoothing applied.

TABLE 8 Paired Samples T-test For TRANSIMS And Static Assignment

Paired Samples Test 4Step Transims

		Paired Differences					Transims T Score	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	AMflow - AM7t	308.1103142	702.6051274	3.1703606	301.8963705	314.3242580	97.185	49113	.000
Pair 2	AMflow - AM8t	-6.4428885	520.9468309	2.3506650	-11.0502194	-1.8355576	-2.741	49113	.006
Pair 3	AMflow - AM9t	-224.8413085	433.2809044	1.9550906	-228.6733090	-221.0093080	-115.003	49113	.000
Pair 4	MDflow - AM10t	-367.6469120	456.3137430	2.0590216	-371.6826183	-363.6112057	-178.554	49113	.000
Pair 5	MDflow - AM11t	-123.2976837	384.9720166	1.7371068	-126.7024332	-119.8929342	-70.979	49113	.000
Pair 6	MDflow - PM12t	-65.2209031	402.0435732	1.8141386	-68.7766360	-61.6651703	-35.951	49113	.000
Pair 7	MDflow - PM1t	-133.5703351	408.1508803	1.8416966	-137.1800819	-129.9605883	-72.526	49113	.000
Pair 8	MDflow - PM2t	-4.7433204	411.2903053	1.8558626	-8.3808327	-1.1058080	-2.556	49113	.011
Pair 9	MDflow - PM3t	-211.8949472	384.9417604	1.7369702	-215.2994291	-208.4904653	-121.991	49113	.000
Pair 10	PMflow - PM4t	156.9576793	621.3872502	2.8038817	151.4620384	162.4533201	55.979	49113	.000
Pair 11	PMflow - PM5t	22.9448316	489.6438989	2.2094170	18.6143485	27.2753147	10.385	49113	.000
Pair 12	PMflow - PM6t	-174.6145405	418.2940701	1.8874656	-178.3139951	-170.9150858	-92.513	49113	.000
Pair 13	PMflow - PM7t	-205.1969813	425.2745276	1.9189635	-208.9581722	-201.4357904	-106.931	49113	.000
Pair 14	NTflow - PM8t	-699.8997836	823.7787494	3.7171316	-707.1854049	-692.6141624	-188.290	49113	.000
Pair 15	NTflow - PM9t	-615.4088442	729.2399425	3.2905447	-621.8583502	-608.9593382	-187.023	49113	.000
Pair 16	NTflow - PM10t	-382.9697840	491.9527825	2.2198354	-387.3206873	-378.6188808	-172.522	49113	.000
Pair 17	NTflow - PM11t	-112.4054643	348.9760619	1.5746824	-115.4918603	-109.3190683	-71.383	49113	.000
Pair 18	NTflow - AM12t	-14.6074230	370.3658157	1.6711993	-17.8829931	-11.3318529	-8.741	49113	.000
Pair 19	NTflow - AM1t	60.4631271	406.3815663	1.8337129	56.8690284	64.0572259	32.973	49113	.000
Pair 20	NTflow - AM2t	152.5329443	459.4594431	2.0732159	148.4694170	156.5964716	73.573	49113	.000
Pair 21	NTflow - AM3t	202.8156539	463.9307154	2.0933916	198.7125820	206.9187258	96.884	49113	.000
Pair 22	NTflow - AM4t	340.0847014	667.5208187	3.0120499	334.1810485	345.9883544	112.908	49113	.000
Pair 23	NTflow - AM5t	307.2986730	633.2611930	2.8574604	301.6980173	312.8993288	107.543	49113	.000
Pair 24	NTflow - AM6t	221.6076684	534.8824405	2.4135466	216.8770889	226.3382479	91.818	49113	.000

TABLE 9 Paired Samples T-test For MATSIM And Static Assignment

Paired Samples Test 4Step Matsim

		Paired Differences					Matsim T Score	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	95% Confidence Interval of the Difference: Upper			
Pair 1	AMflow - AM7m	366.5067389	766.1489703	3.4570891	359.7308040	373.2826738	106.016	49113	.000
Pair 2	AMflow - AM8m	192.1859750	660.2982712	2.9794596	186.3461993	198.0257506	64.504	49113	.000
Pair 3	AMflow - AM9m	251.4468782	717.6862568	3.2384111	245.0995547	257.7942017	77.645	49113	.000
Pair 4	MDflow - AM10m	217.2786286	636.3495174	2.8713958	211.6506592	222.9065979	75.670	49113	.000
Pair 5	MDflow - AM11m	361.0926123	751.4757605	3.3908792	354.4464495	367.7387752	106.489	49113	.000
Pair 6	MDflow - PM12m	376.8626575	790.7891844	3.5682730	369.8688009	383.8565142	105.615	49113	.000
Pair 7	MDflow - PM1m	277.7569036	686.5325045	3.0978362	271.6851085	283.8286987	89.662	49113	.000
Pair 8	MDflow - PM2m	177.5940172	551.1707340	2.4870442	172.7193817	182.4686528	71.408	49113	.000
Pair 9	MDflow - PM3m	358.0706634	717.8573749	3.2391832	351.7218265	364.4195003	110.544	49113	.000
Pair 10	PMflow - PM4m	439.9492906	853.4241873	3.8509005	432.4014808	447.4971005	114.246	49113	.000
Pair 11	PMflow - PM5m	281.9625659	699.0653524	3.1543881	275.7799284	288.1452033	89.387	49113	.000
Pair 12	PMflow - PM6m	233.9681040	666.3141708	3.0066051	228.0751228	239.8610852	77.818	49113	.000
Pair 13	PMflow - PM7m	331.7412440	729.0844933	3.2898433	325.2931128	338.1893752	100.838	49113	.000
Pair 14	NTflow - PM8m	-209.3497775	355.4130558	1.6037280	-212.4931032	-206.2064518	-130.539	49113	.000
Pair 15	NTflow - PM9m	-116.4611918	297.2878887	1.3414502	-119.0904499	-113.8319337	-86.817	49113	.000
Pair 16	NTflow - PM10m	112.2550602	452.6943035	2.0426896	108.2513648	116.2587556	54.955	49113	.000
Pair 17	NTflow - PM11m	167.2092484	497.2734444	2.2438438	162.8112884	171.6072084	74.519	49113	.000
Pair 18	NTflow - AM12m	211.9840580	548.4194540	2.4746296	207.1337552	216.8343609	85.663	49113	.000
Pair 19	NTflow - AM1m	420.4559805	769.9611782	3.4742909	413.6463299	427.2656311	121.019	49113	.000
Pair 20	NTflow - AM2m	420.4559805	769.9611782	3.4742909	413.6463299	427.2656311	121.019	49113	.000
Pair 21	NTflow - AM3m	420.4559805	769.9611782	3.4742909	413.6463299	427.2656311	121.019	49113	.000
Pair 22	NTflow - AM4m	367.3825188	693.0847183	3.1274017	361.2527749	373.5122626	117.472	49113	.000
Pair 23	NTflow - AM5m	346.4383888	681.3162363	3.0742989	340.4127271	352.4640504	112.689	49113	.000
Pair 24	NTflow - AM6m	152.0382177	368.9646985	1.6648770	148.7750393	155.3013962	91.321	49113	.000

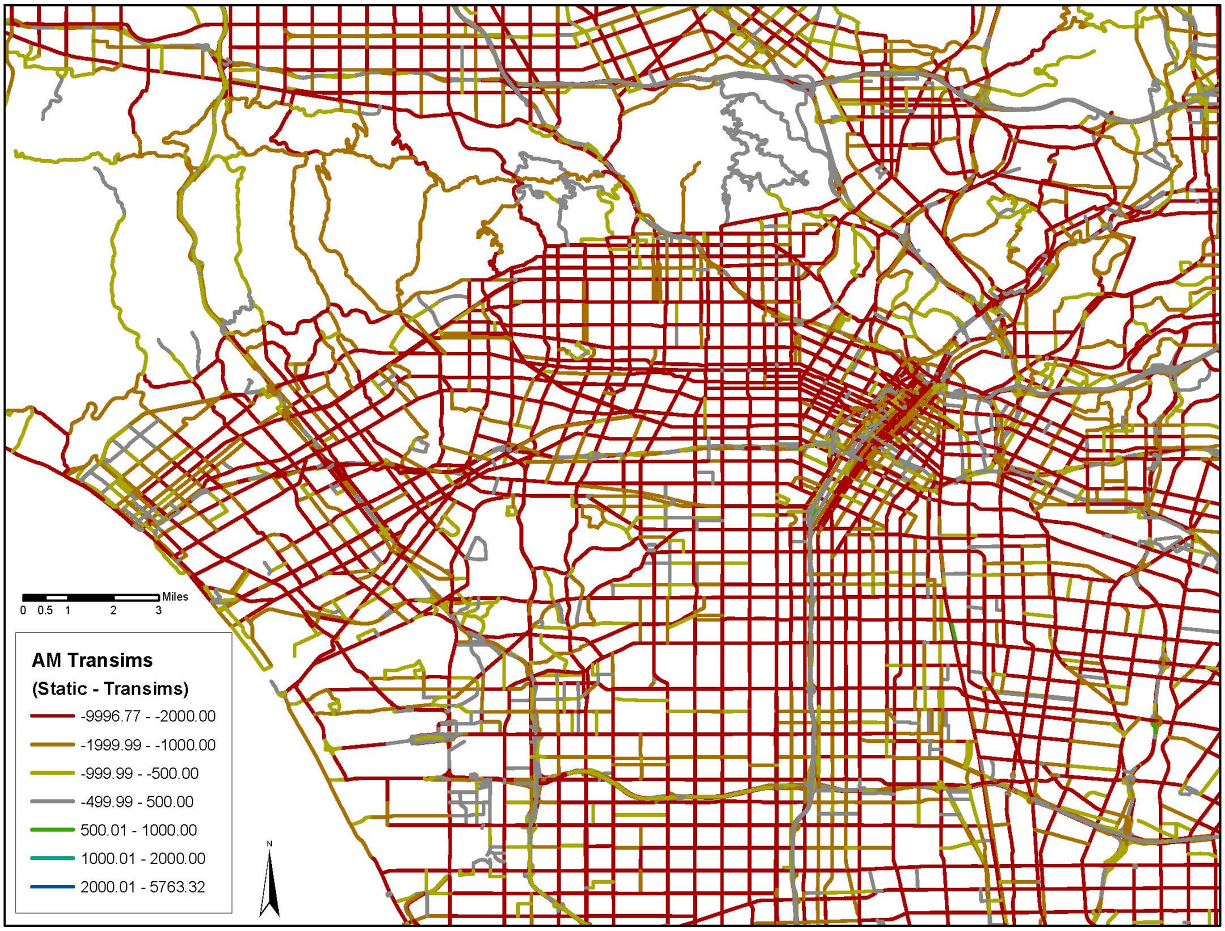


FIGURE 17 Static Assignment – TRANSIMS, AM.

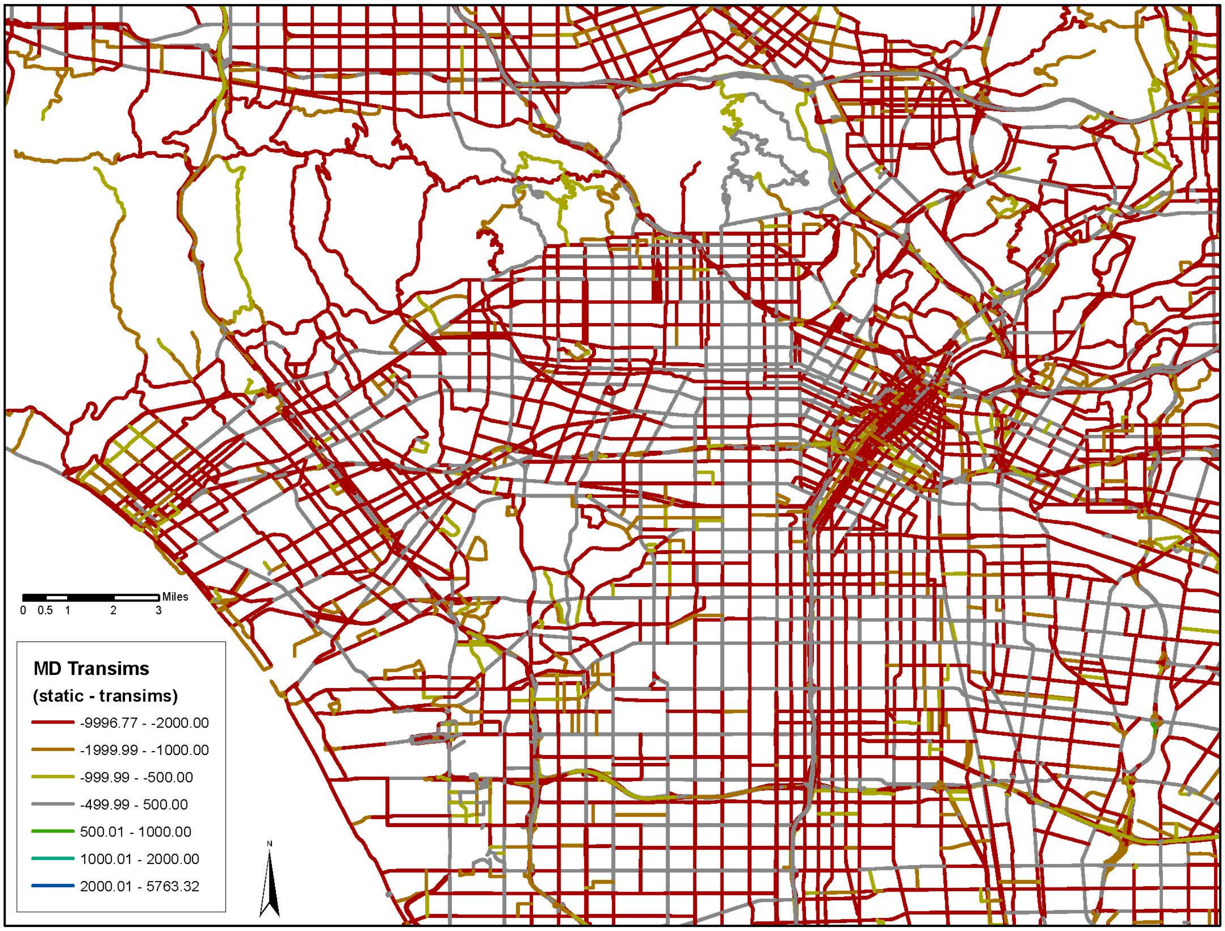


FIGURE 18 Static Assignment – TRANSIMS, Midday.

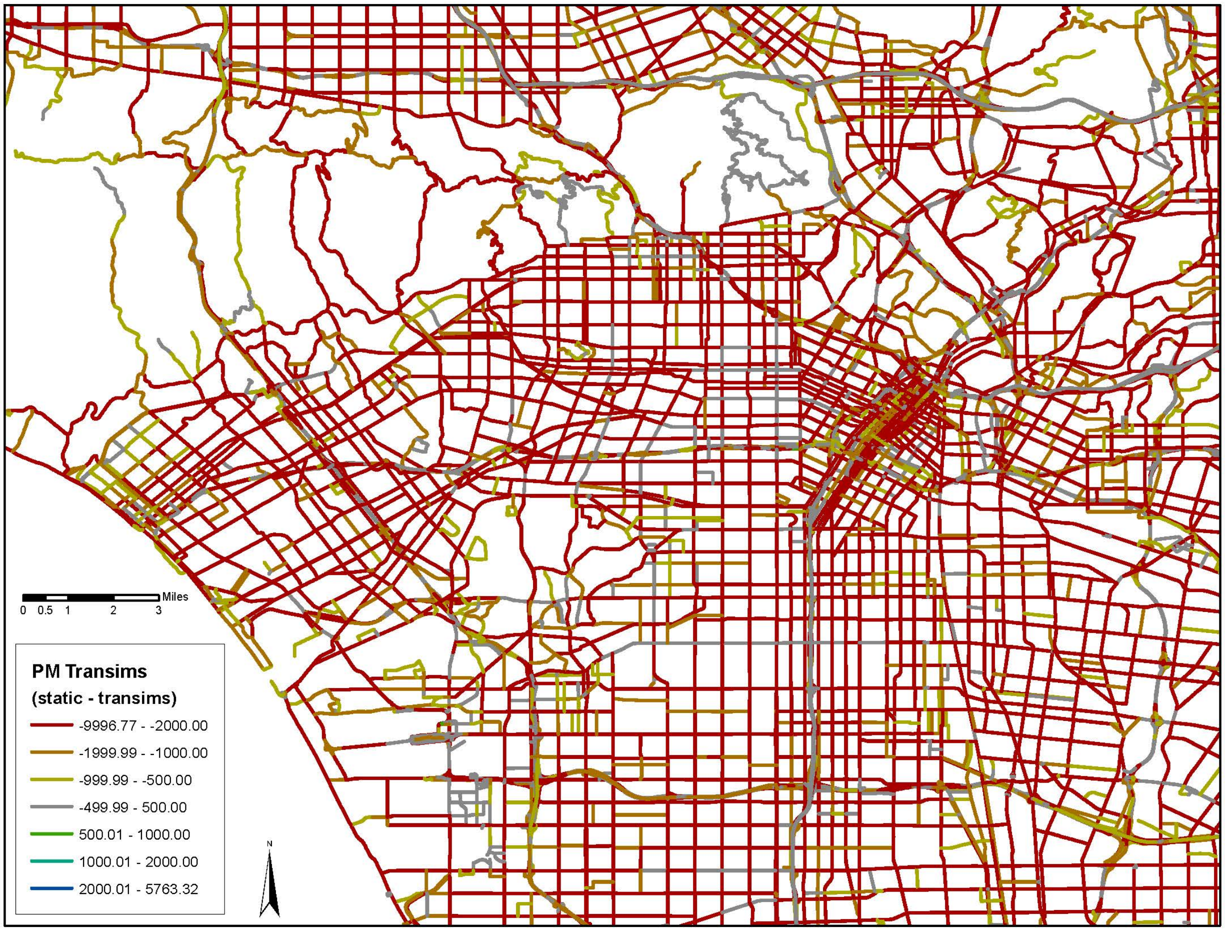


FIGURE 19 Static Assignment – TRANSIMS, PM.

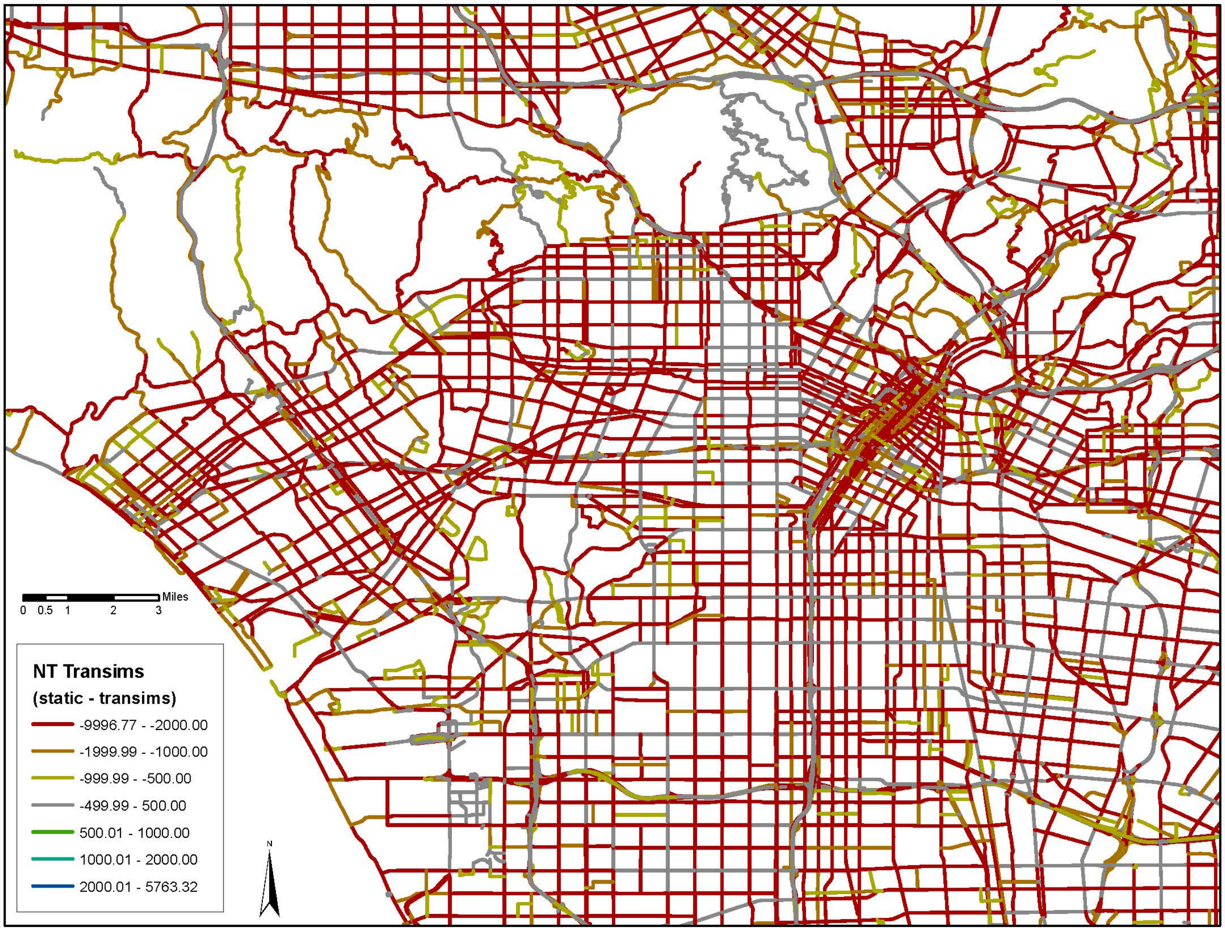


FIGURE 20 Static Assignment – TRANSIMS, Nighttime.

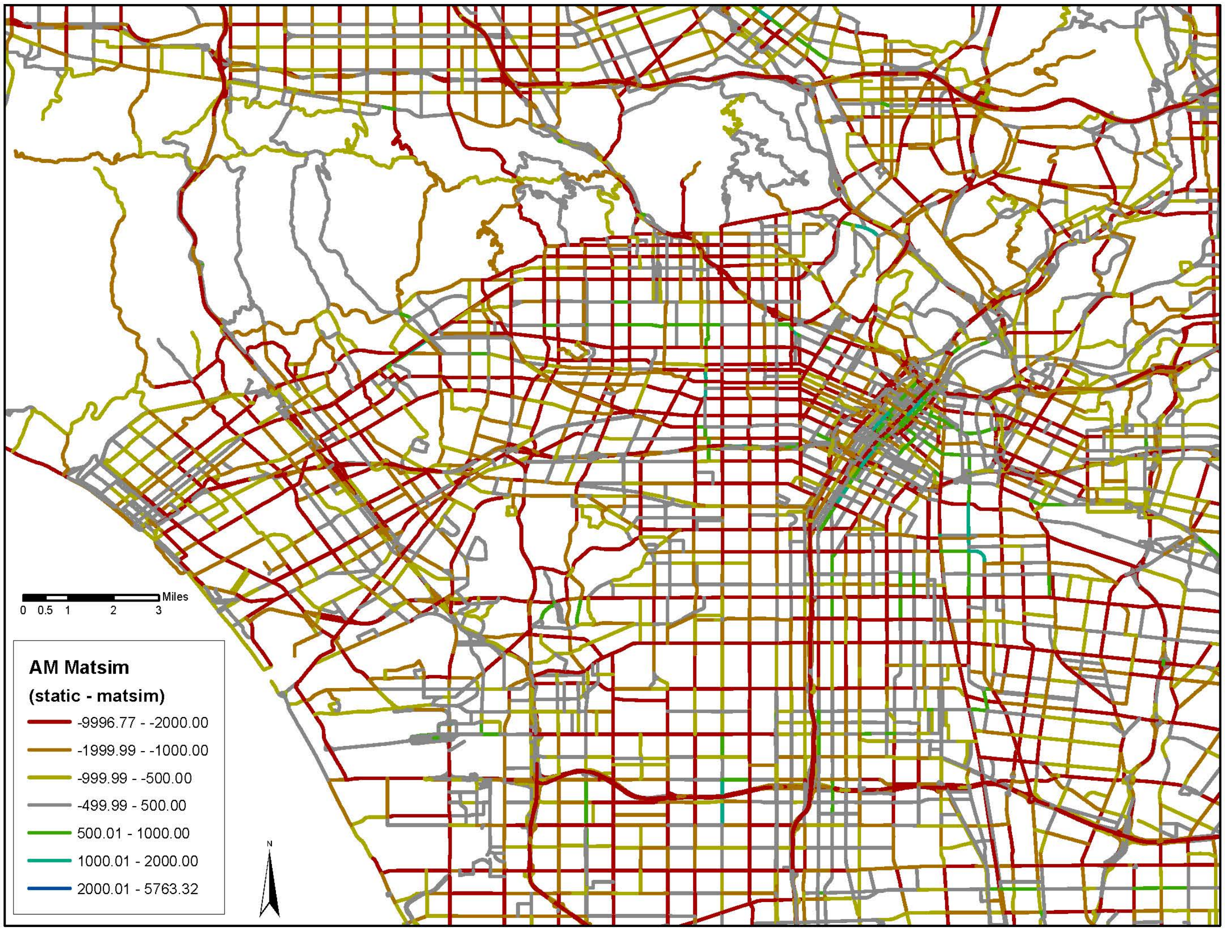


FIGURE 21 Static Assignment – MATSIM, AM.

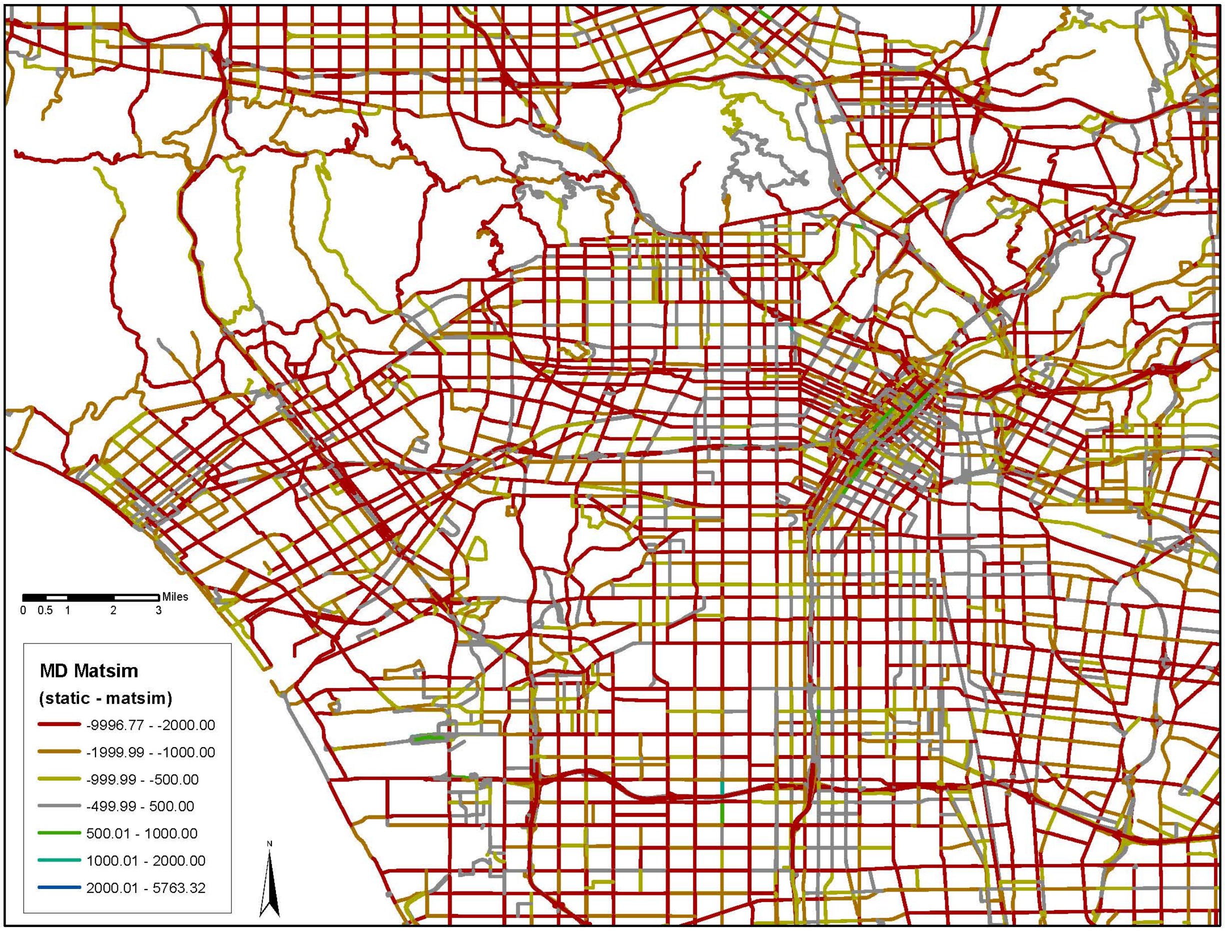


FIGURE 22 Static Assignment – MATSIM, Midday.

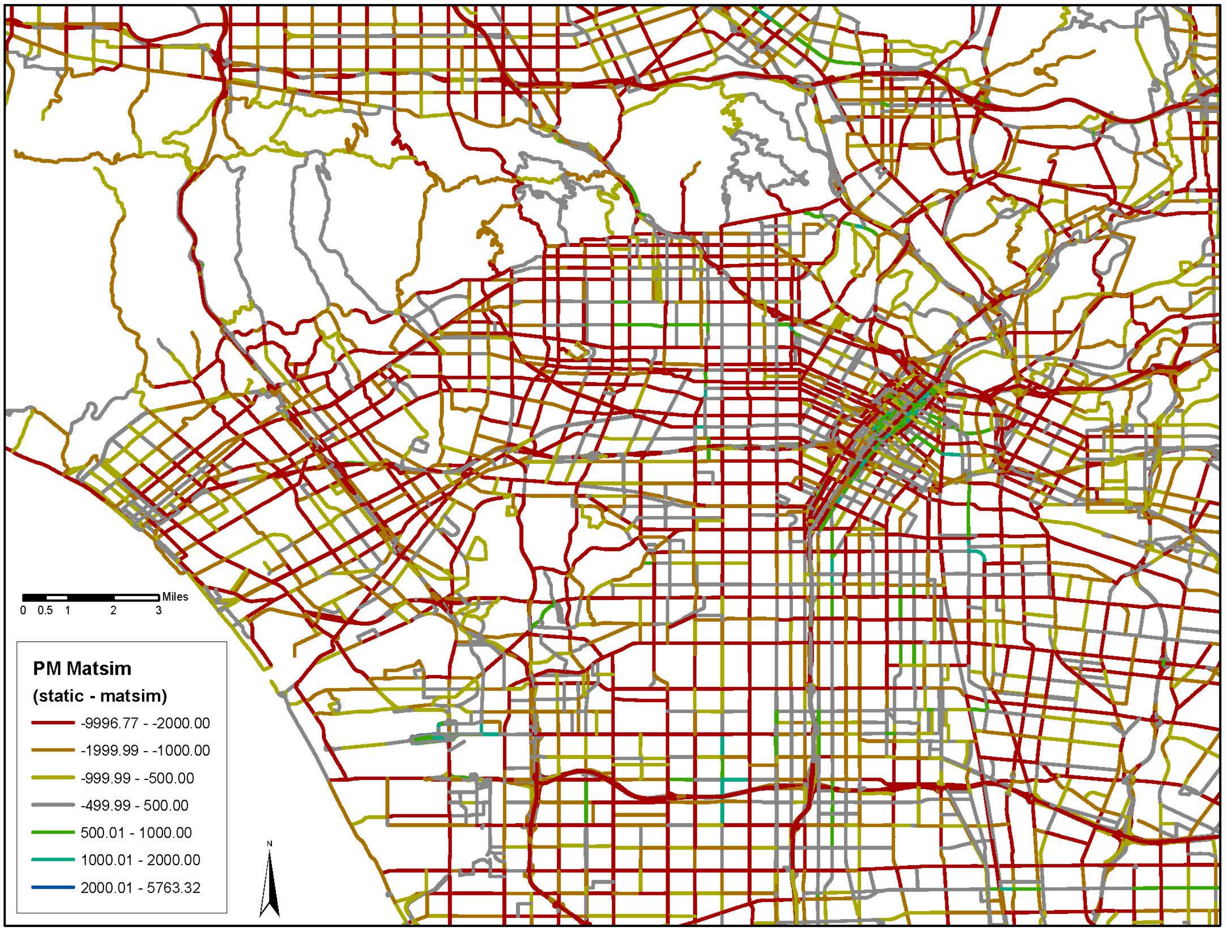


FIGURE 23 Static Assignment – MATSIM, PM.

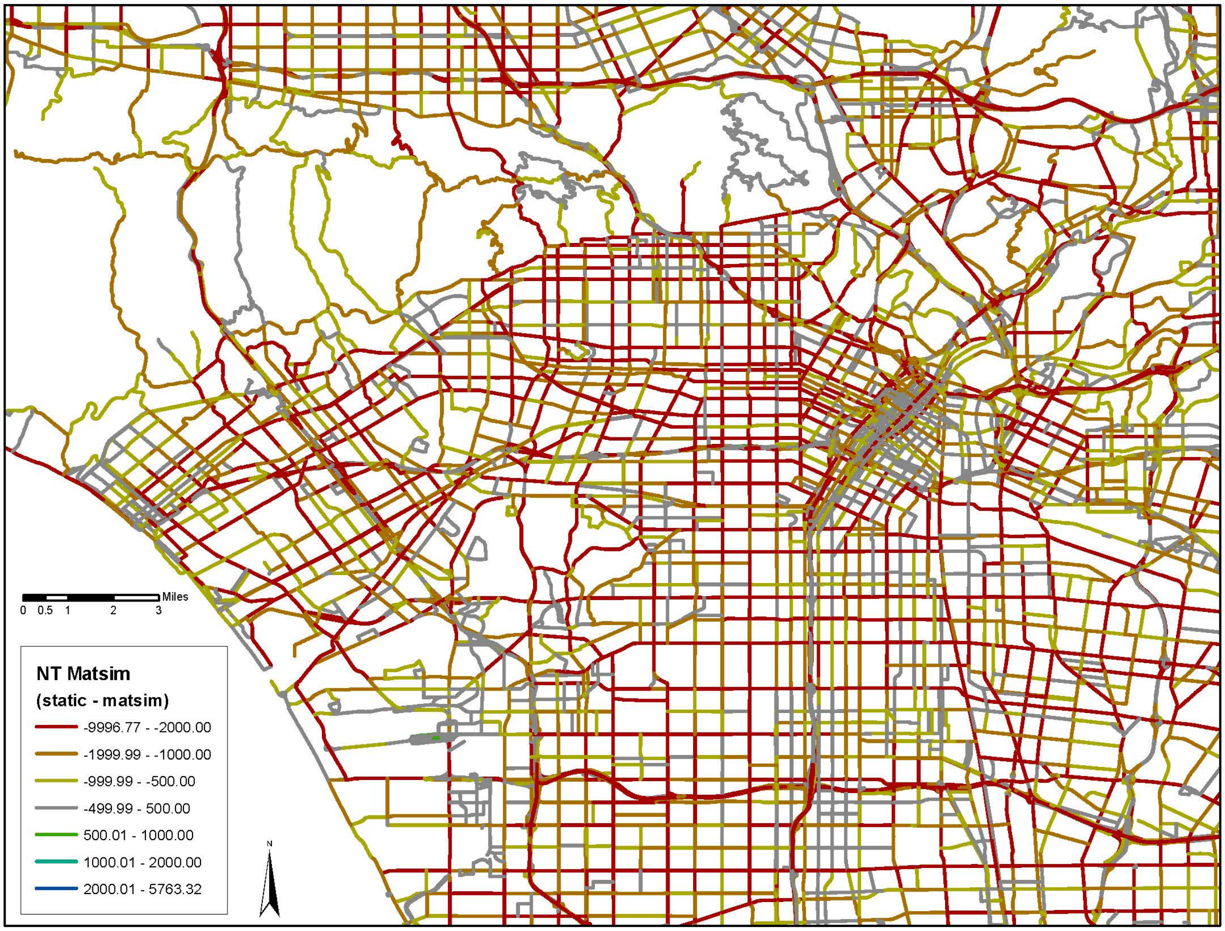


FIGURE 24 Static Assignment – MATSIM, Nighttime.

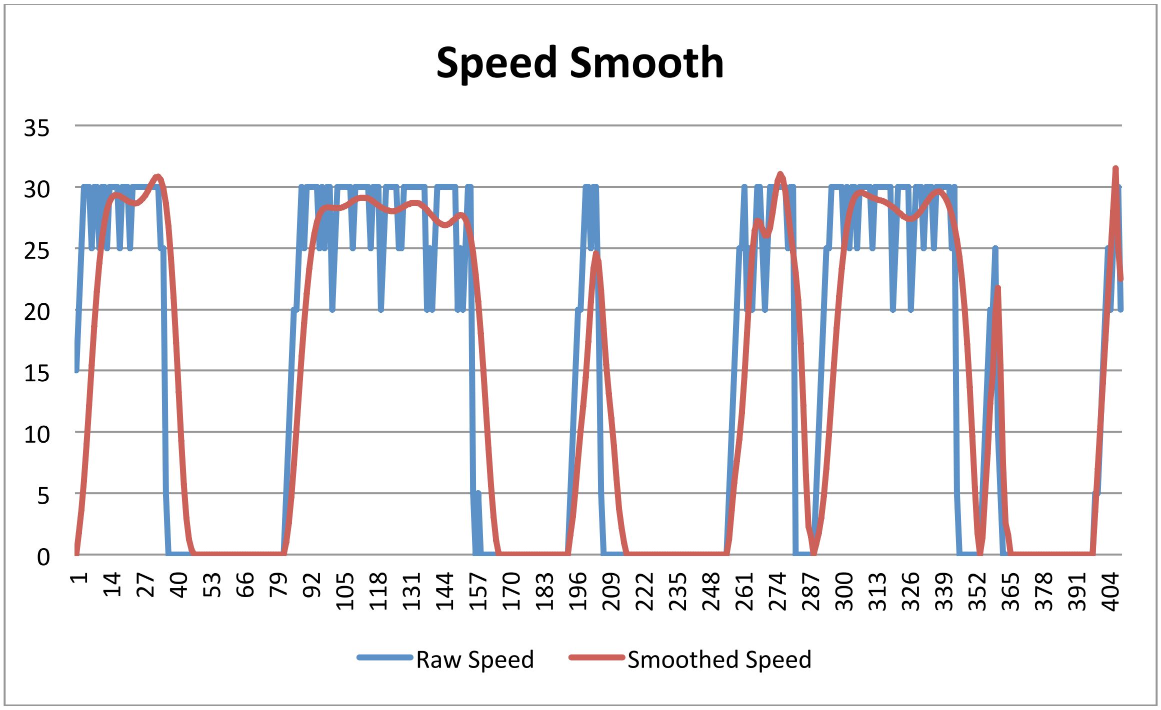


FIGURE 25 TRANSIMS Trajectory Smoothing

TABLE 10 Sample CMEM Output

VSP bin	CO2(g)	CO(g)	HC(g)	NOx(g)	Count	Percent
1	1.1771	0.0043	0.0034	0.001	19	4.6683
2	1.1703	0.0043	0.0054	0.0011	4	0.9828
3	1.167	0.0043	0.0064	0.0011	4	0.9828
4	1.1734	0.0043	0.0045	0.001	3	0.7371
5	1.167	0.0043	0.0064	0.0011	4	0.9828
6	1.167	0.0043	0.0064	0.0011	3	0.7371
7	1.1723	0.0043	0.0048	0.0011	3	0.7371
8	1.1702	0.0043	0.0055	0.0011	4	0.9828
9	1.167	0.0043	0.0064	0.0011	3	0.7371
10	1.167	0.0043	0.0064	0.0011	7	1.7199
11	1.1712	0.0043	0.0052	0.0011	4	0.9828
12	1.223	0.0048	6.00E-04	2.00E-04	149	36.6093
13	3.89	0.0421	0.0046	0.005	21	5.1597
14	4.9418	0.0646	0.0068	0.0063	40	9.828
15	6.0916	0.0934	0.0055	0.0113	30	7.371
16	7.3012	0.1279	0.0054	0.0152	26	6.3882
17	8.7508	0.1737	0.0078	0.0224	12	2.9484
18	9.9706	0.3435	0.0105	0.0266	8	1.9656
19	10.734	2.1875	0.0187	0.0401	6	1.4742
20	15.292	5.9401	0.0503	0.099	57	14.0049

7. REFERENCES AND CITATIONS

Barrett, C., Bisset, K., Jacob, R., Konjevod, G., Marathe, M., 2002. Classical and contemporary shortest path problems in road networks: Implementation and experimental analysis of the transims router. In: Möhring, R.H., Raman, R. (eds.) ESA 2002. LNCS, vol. 2461, pp. 126–138

Balmer, M., Rieser, M., Meister, K., Charypar, D., Lefebvre, N., and Nagel, K., 2009. MATSim-T: Architecture and simulation times. In: Bazzan, A., Klügl, F. (eds.) Multi-Agent Systems for Traffic and Transportation Engineering, ch. III. Information Science Reference (2009).

Bekhor, S., C. Dobler, and K.W. Axhausen, 2011. Integration of Activity-Based with Agent-Based Models: an Example from the Tel Aviv Model and MATSim, paper presented at the 90th Annual Meeting of the Transportation Research Board, Washington, D.C., January 2011.

Chang, E., and A. Ziliaskopoulos, 2003. Data challenges in the development of a regional assignment simulation model to evaluate transit signal priority in Chicago. CD-Rom for the 82nd Annual Meeting of the Transportation Research Board, Washington D.C. 2003

Hatzopoulou, M., H., Y. Jiang, Hao, and E. Miller, 2011. Simulating the impacts of household travel on greenhouse gas emissions, urban air quality, and population exposure, Transportation (2011) 38, pp. 871–887.

Horni, A., D. M. Scott, M. Balmer and K. W. Axhausen, (2009) Location Choice Modeling for Shopping and Leisure Activities With MATSim: Combining Micro-simulation and Time Geography, Transportation Research Record, 2135, pp. 87-95.

Joubert, W. J., P. J. Fourie and K. W. Axhausen, (2010) Large-Scale Agent-Based Combined Traffic Simulation of Private Cars and Commercial Vehicles, Transportation Research Record, 2168, pp. 24-32.

Nagel, K., R. Beckman, and C. Barrett, 1999. TRANSIMS for urban planning, Technical Report LA-UR 98-4389, Los Alamos National Laboratory.

Nagel, K., R. Beckman, and C. Barrett, 1999. TRANSIMS for urban planning, Technical Report LA-UR 98-4389, Los Alamos National Laboratory.