TRANSIMS - the next generation planning/simulation model

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Abstract

The revolution in computer technology, which has doubled the computer speed every two years and has recently provided abundant computer memory, has forced the transportation professionals to rethink how they should model the events and the entities in the current planning and simulation models. TRANSIMS represents the next generation planning/simulation that has adopted the revolution in the information technology to represent the demand and the supply in a transportation network.

TRANSIMS is based on representing each person in an urban area including his and her daily activities, and on modeling his and her travel movements on a detailed represented transportation network. A major TRANSIMS technical feature is that the identity of individual synthetic travelers is maintained throughout the entire simulation and analysis architecture. All synthetic travelers are generated as part of a synthetic population developed for a specific metropolitan region using a variety of data sources including census, surveys, etc. Activity times and locations are computed for each individual. The plans generated by the Route Planner maintain individual identities, as does the Traffic Microsimulator. The resulting simulation output can provide a detailed, second-by-second history of every traveler in the system over a 24-hour day. A variety of impact analyses can be conducted using these results.

1 Introduction

TRansportation ANalysis SIMulation System (TRANSIMS) represents the next generation of travel demand modeling tools that bring the recent advances in the computer hardware and software to the field of transportation modeling. At the

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core of TRANSIMS is an agent-based simulation system capable of simulating second-by-second movements of every person and every vehicle through the transportation network of a large metropolitan area.

TRANSIMS technology was developed under US DOTs and EPA funding at the Los Alamos National Laboratory (LANL) over the last eight years. It is a result of an effort to develop new transportation and air quality modeling methodologies required by the Clean Air Act, the Transportation Equity Act for the 21st Century (TEA 21), and other regulations. (www.TRANSIMS.net)

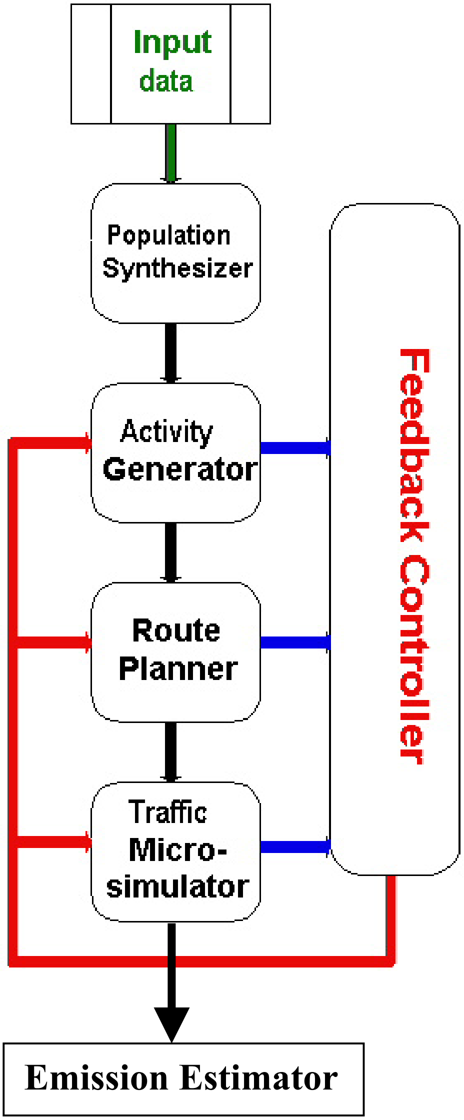

Figure 1: TRANSIMS framework.

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2 TRANSIMS framework

TRANSIMS is composed by a series of Modules, Population Synthesizer, Activity Generator, Route Planner, Traffic Microsimulator, and Feedback Module, which could be executed in any desired order by a set of scripts. Besides, Emission Estimator and Output Visualizer are two other modules for analyzing and displaying TRANSIMS output data. The framework is shown in Fig.1.

2.1 Population synthesizer

The Population Synthesizer module creates synthetic households that represent every real individual household in the metropolitan region under study. These synthetic households have synthetic persons that match the Census Block Group population demographics obtained from the census bureau.

A metropolitan area is comprised of many PUMA. Each PUMA is comprised of many block groups. The complete census records (long forms) are sampled for the households within the PUMA and are called PUMS. The PUMS usually consists of a 5% representative sample of all the households in a PUMA. Each block group has it own summary of marginal demographic data for all the households referred to as STF-3A. The STF-3A does not provide the cross tabulation of the demographic data. The Iterative Proportional Fitting (IPF) procedure is implemented to create a detailed cross-tabulated demographic data, whose marginal values correspond with STF-3A summary statistics for each block group from the PUMS data.

Table 1: STF-3A data for a Block Group.

	Householder's Age							
Workers	15-24	25-34	35-44	45-54	55-64	65-74	>74	**Total**
0	?	?	?	?	?	?	?	**30**
1	?	?	?	?	?	?	?	**57**
2	?	?	?	?	?	?	?	**224**
>2	?	?	?	?	?	?	?	**14**
Total	**32**	**82**	**72**	**54**	**33**	**24**	**28**	325

Table 2: PUMS data for a Census Tract.

	Householder's Age							
Workers	15-24	25-34	35-44	45-54	55-64	65-74	>74	**Total**
0	3	12	14	11	21	51	54	**166**
1	9	47	63	44	59	45	14	**281**
2	18	56	113	83	45	17	6	**338**
>2	2	17	70	88	55	17	3	**252**
Total	**32**	**132**	**260**	**226**	**180**	**130**	**77**	1037

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To generate synthetic persons for future scenarios, STF-3A forecasting marginal statistics need to be used.

STF-3A and PUMS data are shown in Table 1 and Table 2, respectively; whereas the question marks are detailed cross-tabulated demographic data that need to be obtained from the process.

Next, we need to match each household in the STF-3A cell to an actual-sampled household in the corresponding PUMS cell with similar demographics. Once the match is finalized, the full properties, and characteristics of the sampled household in PUMS are assigned to the synthetic household in STF-3A. The matching could be conducted by randomly selecting or based on some kinds of weights.

The synthetic households are located on the network using land use data. There might be more than one activity location in a Block Group. The probability to choose an activity location will depend on its land use data. For example, the activity locations that have greater residential area should have greater possibilities to be chosen to locate household locations.

Each synthetic household is created with a number of vehicles assigned to it. The number of vehicles owned by each household is given in the PUMS and is therefore transferred to the synthetic households through the matching process. The vehicle type assigned to each vehicle is determined at random according to a national distribution of vehicle emission types. The last step to generate a synthetic population is to assign a unique number to each household and person in the population.

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2.2 Activity generator

The Activity Generator module creates activity lists for every synthetic person by matching synthetic households with survey households, whose travel and activity participation information for each household member is known, based on similar demographic characteristics.

Firstly, the survey households are classified according to their demographic data using CART algorithm.

The CART algorithm is a technique for modeling a regression relationship between one or more dependent variables Y and independent variables X1, X2, …, XK.. A classification tree is constructed using the total times a household spends in some activity types, obtained from the skeletal activity patterns, as the dependent variables Y1, Y2, …, YK. For example, Y1 = total time spent by the household in working, etc. An additional variable YK is used to represent the total number of trips made by the household over the specified 24-hour horizon. The independent variables Xk identify various household demographic attributes that are obtained from the survey household demographic data.

Survey households will be put in the terminal nodes of the classification and regression tree in a way total variance in the value of dependent variables over the entire survey population is minimized at the end of CART algorithm.

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Next, each synthetic household (obtained from the Population Synthesizer Module) will be assigned to a unique terminal node of the tree built from the survey households based on the same demographic data.

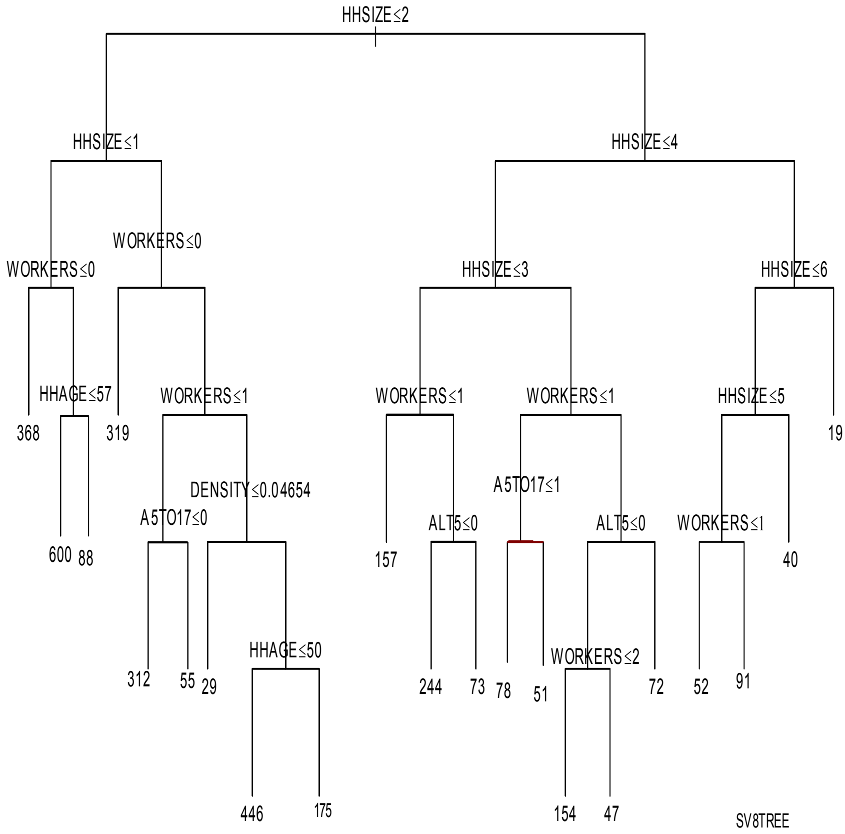

Figure 2: An example of the classification and regression tree generated by CART algorithm.

A survey household within the terminal node will be selected to match with the given synthetic household that is assigned to this node. The selection of the survey household could be done randomly, or weights could be assigned to survey households for flexibility. The next step in Activity Generator is to match the assigned synthetic household members with the selected survey household members based on the following four demographic variables: relate, work, gender, and age. The synthetic persons can then take over the activity patterns from the matched survey ones. Each activity of the synthetic person is given a preferred start-time, end-time, and duration based on skeletal patterns of the survey person.

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Each activity of the synthetic person must have a specific location within the region under consideration. First, a discrete choice model is used to select an appropriate zone for each activity. This is carried out based on the zone data that specifies the attractiveness of each activity type within each zone. The selection of zones for work activities is conducted before that of the zones for all other types of activities. Second, a location for each particular activity is randomly specified within the selected zone using the weights given in the activity location table.

An example of the classification and regression tree obtained by CART An algorithm is shown in Fig. 2.

2.3 Route planner

The Route Planner Module develops the route plans for each traveler based on the demand represented in the Activities data file. A time-dependent label-constrained shortest path for each trip executed by a traveler in the system is developed.

The technique adopted by TRANSIMS to identify a suitable travel route for any user is a variant of Dijkstra's procedure for finding shortest paths, which is suitably modified to accommodate time-dependent travel times and label sequence constraints. The underlying problem is referred to as Time-Dependent Label-Constrained Shortest Path Problem (TDLSP) and is unique to TRANSIMS applications.

In TDLSP, the admissible mode strings are examined and corresponding transition graph GL is constructed first. The transition graph GL is a graph that shows all the possible sequences of the travel modes by which we can reach the destination node from the starting node.

Then, we examine the Internal Network, consisting of nodes, links, time-dependent travel time function on each link, and the possible travel mode on each link, as well as the transition graph GL and accordingly determine the shortest path that satisfies the mode string. An example of the Internal Network and transition graph GL is shown in Fig. 3.

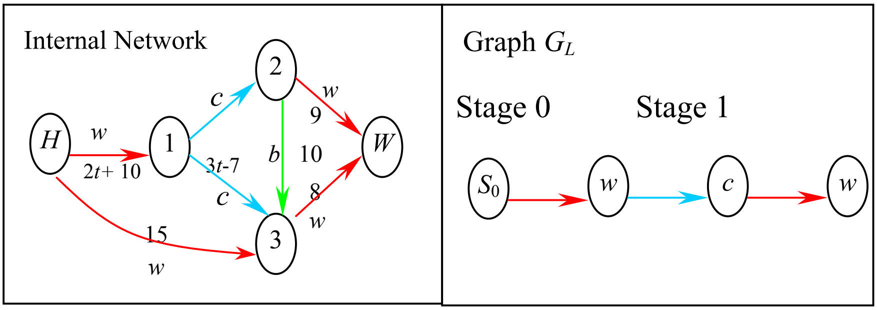

Figure 3: An example of the Internal Network and Transition Graph G_L.

Once the plans are generated for all the travelers, they are simultaneously fed into the Traffic Microsimulator Module.

If no path is found that obeys the mode constraints of the traveler (Path Anomaly), or that satisfies the time bound constraint (Time Anomaly) or the Invalid Shared Ride Time anomaly, then the traveler and the trip request are marked for a Path/Time/Shared Ride Time Anomaly feedback to the Feedback Module.

2.4 Traffic microsimulator

The TRANSIMS Microsimulator module executes individuals' travel plans as provided by the Route Planner module at the start-time specified by the plan. Plans that overlap in time are executed simultaneously by the Microsimulator, resulting in overall transportation dynamics.

The TRANSIMS Microsimulator module simulates the movement and the interactions of travelers in the transportation system of the study area. In this module every traveler tries to execute his/her travel movements, link by link along the intermodal networks, according to the plans generated from the Route Planner Module.

The TRANSIMS Microsimulator is capable of handling intermodal travel plans, multiple travelers per vehicle, multiple trips per traveler and vehicles with different operating characteristics. Realistic traffic behavior is simulated in Microsimulator by making decisions about lane changes, passing slow vehicles and evaluating interactions with other vehicles.

The Microsimulator first reads in the network data, which includes details such as links, nodes, lane connectivity, parking locations, etc. In the next step, the vehicle type, location and traveler plans are read. Then, travelers and vehicles are placed on the network. Step three includes the movement of the travelers and vehicles on the network in tandem with their travel plans using the Cellular Automata approach.

The amount of computation necessary for simulating a large transportation network at a level of detail down to an individual traveler and an individual vehicle is huge. Hence a coarse simulation approach entitled "Cellular Automata" (CA) is used to keep up with the fast computational speed necessary to simulate a whole region.

The Cellular Automata approach essentially divides every link on the network into a finite number of cells. At every time step each of these "cells" is scanned for a vehicle presence. If a vehicle is present, the vehicle position is advanced to another cell using a simple rule set. These rules are concerned with vehicle movements in the same lane, performing lane changes, turn pocket lanes and vehicle movements at intersection. The rule set is made simple to increase the computational speed necessary for a large simulation.

Reducing the size of the "cell", expanding the rule set and adding vehicle attributes increases the fidelity of the Microsimulator but would greatly affect the computational speed. The size of 7.5 meters length and a traffic lane's width is chosen as a default value for the "cell".

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TRANSIMS Microsimulator also provides the capability of using multiple computer processors (CPU'S) to support a large number of travelers and a considerable size transportation network.

2.5 Output visualizer

The output from TRANSIMS can be pictorially represented and viewed by the Output Visualizer. The Output Visualizer enables the user to display various input and output sets. It also provides tools to facilitate the analysis of the data sets. The tools encompass plotting, GIS, statistics, and animation. The Output Visualizer displays include those of travel plans, vehicles, signals, and intersection queues, among other data types.

The graphical user interface (GUI) of the Output Visualizer allows the user to manipulate the three-dimensional objects and presents the output in a graphical way. A user could be interested in the travelers' plans (single, aggregated or filtered) that could be overlaid on a network as shown in Figure 2.4. As can be seen from the figure, such a representation would clearly help in the understanding of the plan data characteristics as overlaid over the network.

Apart from the above-mentioned features, the Output Visualizer is capable of animating the simulation as it progresses. Essentially, the snapshot data (that is output from the Microsimulator) feeds the frames for animation. It should be noted that an animated simulation for the whole network would include a lot of data in the form of Snapshot and would result in very huge files which require a lot of memory space. (Fig. 4)

IBM Business Consulting has created a commercial version of TRANSIMS Visualizer, which is a state-of-the-art 3D visualization and animation software package. Using the Visualizer, users can view network attributes and TRANSIMS output data in 2D and 3D formats. The Visualizer also supports the animation of vehicle movements and other user-selectable, time-dependent data.

2.6 Emission estimator

The Emissions Estimator module translates traveler behavior into consequent energy consumption and pollutant emissions of nitrogen oxides, hydrocarbons, carbon monoxide, carbon dioxide, and particulate matter.

The Emissions Estimator, in the present version of TRANSIMS, produces estimates for:

1) tailpipe emissions from light-duty vehicles (LDVs),
2) tailpipe emissions from heavy-duty vehicles (HDVs), and
3) evaporative emissions

as a function of vehicle fleet composition, fleet status, and fleet dynamics. This section explains tailpipe emissions from LDV, and HDV. The evaporative emissions will be explained in a separate section.

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Figure 4: The Output Visualizer displaying vehicles on the network of Blacksburg case study in a zoomed in view.

The Emissions Estimator module thus requires information regarding:

1) the fleet composition developed from the Population Synthesizer,
2) inspection and maintenance test results obtained from local and national databases, and
3) traffic patterns produced by the Traffic Microsimulator module.

The emission inventory obtained from TRANSIMS form the basis for the computation of pollutant concentrations in a metropolitan area based on atmospheric conditions, local transport and dispersion, and chemical reactions.

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