

# Large-Scale Traffic Microsimulation From An MPO Perspective

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## Abstract

One potential advancement of the four-step travel model process is the forecasting and simulation of individual activities and travel. A common concern with such an approach is that the data and computational requirements for a large-scale, regional microsimulation may be so intensive that a successful application would be virtually impossible for a typical Metropolitan Planning Organization (MPO) or other agency to achieve. This paper and presentation will focus on the “big picture” issues surrounding traffic microsimulation, i.e., “is it worth the effort,” with the underlying theme being that the level and quality of detail needs to be in line with the particular application that is being addressed.

Much of the information is derived from the work the North Central Texas Council of Governments (NCTCOG), the MPO for the Dallas-Fort Worth region, is doing on the Transportation Analysis and Simulation System (TRANSIMS) project. TRANSIMS is a federally funded project being conducted by Los Alamos National Laboratory to develop a “next generation” travel model. The paper and presentation will include an overview of NCTCOG’s involvement in the Traffic Microsimulation Case Study, which represents the first interim operational capability of TRANSIMS. Issues surrounding the required detail and accuracy of network coding and travel data will be discussed, both for existing (observable) and forecast conditions. The need for (and procedures for) calibration and validation on both a micro- and macro- level will be described. Database management techniques for keeping track of all information and the computational and manpower requirements for a successful application will be discussed.

The North Central Texas Council of Governments (NCTCOG) is the Metropolitan Planning Organization (MPO) for the 5,000-square-mile, four-million-person Dallas-Fort Worth Metropolitan Area. Since 1995, we have had the opportunity to work with Los Alamos National Laboratory (LANL) on a case study application of the first interim operational capability of a “next generation” travel simulation and forecasting tool known as the TRansportation ANalysis and SIMulation System (TRANSIMS).

NCTCOG’s primary involvement has been with the Traffic Microsimulation module of TRANSIMS. This experience has given NCTCOG new insights about how a large-scale regional microsimulation can be eventually made a part of a typical MPO’s transportation planning and decision-making process. While the data requirements for running a microsimulation can be extensive, the underlying theme is that the level and quality of data detail needs only to be in line with the particular application that is being studied.

Following a description of TRANSIMS, the topics covered include the traffic microsimulation process; case study overview; network coding procedures; database management issues; TRANSIMS output analysis; what we have learned so far; next steps; and closing thoughts on microsimulation.

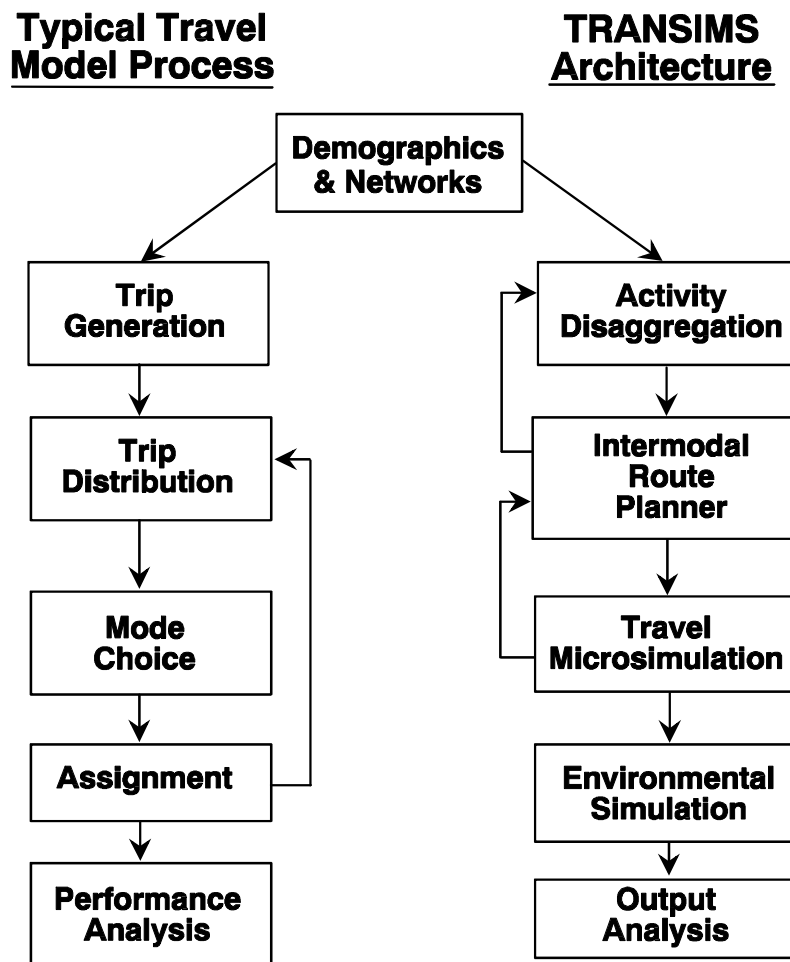
## What Is TRANSIMS?

TRANSIMS is a set of integrated tools for simulating individual-level travel on a regional scale.

Although functionally similar to the four-step travel model process of trip generation, trip distribution, mode choice, and assignment (see Figure 1), TRANSIMS is fundamentally different in that it deals with individual travelers rather than zonal and link volume aggregations. This is referred to as a “bottom-up” computational approach because the second-by-second interactions of individual behaviors (e.g., drivers) are used to observe aggregate dynamic (emergent) behaviors.

TRANSIMS is one part of the multi-track, multi-year, federally funded Travel Model Improvement Program (TMIP). Los Alamos National Laboratory is leading the “Track C” research and development effort to develop new approaches that are intended to advance the state-of-the-art of travel modeling. LANL is a federally sponsored scientific institution near Santa Fe, New Mexico that is best known as the developer of the world’s first atomic bomb. Their world-class expertise in large-scale computer simulations was a major selling point in their selection as the prime TRANSIMS contractor.

**FIGURE 1**  
**COMPARISON OF**  
**APPROACHES**



## **Traffic Microsimulation Process**

The Traffic Microsimulation is based on a cellular automata approach in which each lane of each roadway link is sectioned into an array of cells of uniform length (approximately 7.5 meters). Second-by-second movements of vehicles from one cell to another are based on simple probabilistic rules that account for interactions with other vehicles:

- Speed up when you can;
- Slow down when you must;
- Sometimes slow down for no reason at all;
- Change lanes in order to pass slower vehicles;
- Change lanes in order to follow a scheduled trip plan; and
- Change the “minimum acceptable time gap distance” during congested conditions (e.g., to make a left turn in front of opposing traffic).

Although additional (i.e., more complicated) movement rules could be developed, cell sizes decreased, and re-calculations performed more frequently than once a second, this increased level of computation was unnecessary for achieving the objectives of the interim Traffic Microsimulation program.

## **Case Study Overview**

The Dallas-Fort Worth area was selected by LANL in 1995 to be the site for a demonstration of the functionality of the Traffic Microsimulation program. With planning funds provided by the Federal Highway Administration and the Texas Department of Transportation, NCTCOG assisted in the project by:

- Interacting with Los Alamos National Laboratory, the U.S. Department of Transportation, U.S. Environmental Protection Agency, and others to be sure the interests of the potential end users of TRANSIMS are being considered;
- Preparing network, trip table, and traffic data for the case study; and
- Reviewing the output of the case study model runs.

The case study illustrated TRANSIMS’ ability to partition the benefits and costs of a transportation infrastructure change among subpopulations of travelers. The primary region of interest for the equity analysis was a 25-square-mile area in north Dallas County, with a focus on a major shopping/business center (the Galleria area).

## **Network Coding Procedures**

The network coding structure consists of a series of files maintained in an Oracle database. Separate tables are used for nodes, links, pocket lanes (e.g., left- or right-turn bays), traffic loading points (the location where a vehicle appears on the network), lane connectivity (e.g., all allowed lane movements at an intersection), traffic signal phasings, and traffic signal timings. Although ArcView was used for network viewing, the initial coding for the case study was based on non-GIS procedures.

The link and node files were derived from a previously developed travel model network (a 1990 “focused” network from the I.H. 635 (LBJ) Major Investment Study) that contains most collector streets and all higher functional classification streets. Since local streets were needed within the 25-square-mile study area, Arc/Info was used to incorporate Census TIGER streets onto the base network. Detailed intersection data was obtained through field checks, information supplied by local traffic engineers, and professional judgment.

### **Database Management Issues**

From the user’s perspective, there are legitimate concerns about the extensive network data requirements of TRANSIMS (or any microsimulation approach). Some of the issues for consideration include:

- How much network detail is really needed? If local streets are required, what about non-TIGER driveways and circulator streets?
- How good does the input data need to be? Does it really make a difference whether the lane geometries of every low-volume unsignalized intersection are accurately coded?
- Even if we develop detailed current-year networks, how do we code future-year intersection geometries and signal phasings, timings, and offsets?
- Who has the responsibility for developing and maintaining the databases?

Although use of GIS-based procedures should lead to increased quality/integrity of data, they will not be sufficient to resolve these issues. One strategy for dealing with extensive network detail may be to develop a process in which an initial TRANSIMS-format network can be quickly coded from whatever information is readily available, and then improved over time:

- For initial microsimulation runs on a regional scale, it may not be necessary to conduct extensive field surveys of all signalized and unsignalized intersections. If the number of “mid-block” directional lanes on all roadway links is known (or can be forecasted), intersection data could be synthesized by using profile or default configurations obtained from a sample of intersection observations.
- On an as-needed basis (e.g., for detailed model validation or initiation of local traffic operations studies), the synthesized intersection data can be replaced with observed information.

In other words, the person-hours to be allocated towards intersection coding and other “network cleaning” activities can be tailored to the specific needs of a transportation study. Most intersections in a region could perhaps be initially coded with default or profile configurations, then edited, over time, in a graphical environment. The work related to development of a “network synthetic substitution” procedure has not been completed or sensitivity tested, but is expected to include a series of intersection geometry, signal phasing, and signal timing profiles that vary according to:

- Characteristics of the intersecting streets--functional class (e.g., major arterial versus collector or local), number of “mid-block” lanes in each direction, and traffic volumes in each direction; and
- Local policies, location (land-use, activity density, pedestrian movements), right-of-way con-

straints, and funding.

### **TRANSIMS Output Analysis**

Of equal importance to the issue of the quality of the input network data is the interpretation of the model output. In other words, how do we make sense out of massive amounts of output data?

TRANSIMS is capable of generating at least three types of output data:

- Trajectory/evolution data of individual vehicles, by time step (animations, snapshots, etc.);
- Special event data (signal phase failures, long queues, etc.); and
- Summary data (link travel times, variance of travel time, animation of vehicle densities, etc.).

The interpretation of output data is a work-in-progress for the TRANSIMS project. Strategies for organizing and analyzing output data are expected to include the following:

- Since it is practically impossible to collect/analyze all available information, it is important to adopt a goal-oriented information sampling technique. For example, we may be interested in summarizing traditional weekday measures of effectiveness such as vehicle miles and vehicle hours of travel by subarea or subpopulation. We may also be interested in examining new performance measures such as system reliability (e.g., variability of speeds) along specific routes.
- An adaptive data collection technique may also be implemented, in which certain events (such as excessive queues or delays at an intersection) act as automatic triggers for how additional information is stored and presented. Selected data could also be made available to an individual while the simulation is running, so that the user can make on-line adjustments to the information that is being stored.
- A review of three-dimensional traffic flow animations is another way to spot unusual activities that are worthy of more detailed analysis.

### **What We Have Learned So Far**

The “lessons learned” from NCTCOG’s participation with LANL on the case study, so far, include:

- The TRANSIMS’ interim Traffic Microsimulation program works, including its ability to analyze sub-populations and network reliability. LANL’s initial objectives have been achieved.
- The examination of interim programs in a “real world” case study setting has emphasized the importance of feeding microsimulation data back into the trip planner-and ultimately the activity generator.
- The network coding procedures used for the case study were both cumbersome and error prone, and point out the importance of semi-automated (i.e., “expert”) GIS-based procedures.
- Perfect network representations of the real world are practically impossible to achieve, but maybe this doesn’t really matter-we still need to figure out the level of detail and accuracy that’s needed for specific types of transportation studies.

- A traffic microsimulation makes the limitations of other procedures (e.g., network representations, demographic estimates/forecasts, and time-of-day trip distribution) much more apparent.
- Making sense out of massive amounts of output data is not a trivial task.

### **Next Steps**

The next phase of LANL's TRANSIMS development will focus on case study applications in Portland, Oregon. NCTCOG's activities in 1997 and 1998 will continue to center on an examination of the interim Traffic Microsimulation program and its input and output data:

- We will assist LANL with documentation and dissemination of all TRANSIMS-related work that was performed.
- We will continue to work with the available TRANSIMS output data to see how new types of performance measures (measures of effectiveness) can enter into the "mainstream" planning process of future TRANSIMS end-users. Potential new measures for consideration include:
- Traffic flow animations of congested conditions (for visual examination of problems by both planners and decision makers);
  - Vehicle miles and hours of travel on link segments, by speed range;
  - Reliability and variability in link segment speeds and individual trip speeds;
  - Individual vehicle speed profiles from origin to destination;
  - Individual travel identification (for more comprehensive equity analysis);
  - Variations in the actual "passenger car equivalency" of trucks and other low-performance vehicles, under different conditions;
  - The marginal costs (additional vehicle miles and hours of travel) for "just one more vehicle" along a specific origin-destination path;
  - "Snapshot" traffic density;
  - Size and integrity of vehicle platoons;
  - Intersection delay per vehicle (stop delay + approach delay = travel delay);
  - Number and duration of stops (for intersections, link segments, or travelers);
  - Frequency distribution of queue lengths at intersection approach lanes; and
  - Frequency of signal cycle failures (i.e., a stopped vehicle cannot make it through the intersection on the next green phase).
- We will get involved with additional parametric and sensitivity tests of the Traffic Microsimulation:
  - Identify the ability of the interim programs to address Congestion Management and Intelligent Transportation System strategies;
  - Document the current functionality of the interim programs for representing all network input data;
  - Identify the impacts of the provision/removal of local street detail and traffic loading points;
  - Identify the impacts of changes to link segments (speed limit, grades, precision of length, temporary lane closure), intersection geometry (pocket lane lengths, lane-movement configurations, setback distances, addition/deletion of approach lanes), and traffic signals

- (offsets, signal phasings, signal plans, and right-turn-on-red restrictions); and
- Identify the impacts of variations in travel demand and driver/vehicle characteristics.
- We are also very interested in figuring out how to make TRANSIMS easier to use and understand:
  - Additional research and testing is needed to make the “network synthetic substitution” approach more meaningful;
  - We will provide recommendations on database management, as well as goal-oriented information sampling techniques;
  - We will assess the relevance of both interim and “final” programs to specific real world needs; and
  - We will identify potential enhancements to the interim programs.

### **Closing Thoughts On Microsimulation**

Microsimulation of individual-level travel on a regional scale is a field that holds considerable promise for significantly improving existing travel forecasting procedures used by MPOs and other agencies. At this stage of microsimulation research and development, there are still many unanswered questions about whether the increased level of sophistication in procedures will be, ultimately, “worth the effort.” Here are some closing thoughts about microsimulation and TRANSIMS:

- A case study approach seems to be a workable idea for research-oriented projects that must also demonstrate real-world results.
- One of the difficulties of something like TRANSIMS is that a lot of the procedures fall outside the normal “comfort zone” of the potential end-users. For example, most transportation planners are unfamiliar with day-to-day traffic operations issues, and most traffic engineers are unfamiliar with travel forecasting procedures. Both groups, however, are aware of the difficulties of gathering detailed and accurate data.
- In order to determine if large-scale microsimulation will ultimately lead to improved decision making, the transportation community (researchers, planners, and traffic engineers) needs to get more involved with an identification and assessment of new analysis tools.
- It’s still not clear how much work will be needed to get useful results for a specific transportation study. Will it be ultimately proven that fundamental behaviors are largely transferable between regions, and that all programs can therefore be easily calibrated and validated? The issue for most future users will not be whether decision making is improved, but at what cost.
- Even a “perfect” TRANSIMS process will be limited by the quality of external information. If the results of a year 2020 microsimulation show an extremely clogged network, what does this really mean? Did we mis-specify the intersection coding or traffic loading points, or do we have a problem with our basic demographic assumptions?