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Title:

ITERATED TRANSPORTATION SIMULATIONS FOR DALLAS AND PORTLAND (very extended abstract)

Author(s):

Kai "NMI" Nagel, TSASA
Patrice M. Simon, TSASA
Marcus "NMI" Rickert, TSASA
Jörg "NMI" Esser, TSASA

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Kai Nagel, Patrice Simon, Marcus Rickert, Jörg Esser

Los Alamos National Laboratory, Mail Stop M997,
Los Alamos NM 87501, U.S.A., kai@lanl.gov

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1 Introduction

Transportation is an important part both of our economy and of individual freedom. Yet, we all know that we are facing considerable challenges in managing the downsides of transportation, such as congestion, pollution, accidents, etc. Good computational models for transportation analysis and transportation forecasting would certainly be useful, and many research groups are working on this.

One of the difficult problems of transportation simulation is that there is an intricate interplay between effects on short time scales and effects on large time scales. For example, congestion happens on the short time scale of second-by-second driving behavior, yet it can cause changes on long time scales such as people changing their activities or even moving to a different home location. This means that people need to be aware of some aspects of the short time scale dynamics when they are making their decisions for the long time scales. In order for the long time scale decisions to be meaningful, these *perceptions* (or expectations) of the short time scale dynamics needs to have something to do with reality. It is this consistency problem, i.e. to achieve consistency between the assumptions about small scale dynamics when people make their plans on the one hand, and the actually encountered small scale dynamics when the plans are executed on the other hand, which makes the transportation forecasting problem conceptually and computationally hard.

The traditional approach to this is the "four step process", i.e. trip generation, trip distribution, modal split, and trip assignment. The tensions between these different levels are most visible in the trip assignment, where route selection depends on the traffic, and the traffic depends on the route selection. In traditional assignment, this conflict is resolved by some mathematical shortcuts (such as assuming that link delay is a function of demand only), which have the consequence that there is only one solution to this problem, *and* the solution can be found by an iterative relaxation algorithm [1].

With the enourmous increase in computational power on the one hand, and the necessity for more precise forecasts on the other hand, it is possible to get rid of some of these shortcuts and replace them by a better representation of the dynamics. For example, instead of a link delay function, micro-simulation models can be used for network loading and the corresponding computation of time-dependent link delays. Also, it is now possible to model the decision-making process of all several million inhabitants of a region; on computational grounds it is no longer necessary to resort to "packets" of drivers or "streams" of traffic.

Thus, instead of iterating between route assignemnt and link delay function computation, one iterates now between route assignment and traffic micro-simulation. This leads, though, to the necessity to rethink a large part of the methodology:

- The convergence criteria of traditional assignment are no longer valid, and for example for iterated micro-simulations based on pre-computed plans [2, 3], one can no longer assume that they have only one fixpoint, or that a specific algorithm indeed converges and does not get stuck in a local minimum.
- Using *stochastic* simulations is more realistic and also gets rid of some of the problems of getting stuck in local minima, but it raises other issues. One of them is that simulations based on exactly the same input data can vary wildly just depending on the change of a random seed [4]. This is not necessarily unrealistic, but it poses several problems, including the need for new methods to judge convergence, and the need to deal with possibly non-Gaussian outcomes with regard to MOEs (Measures of Effectiveness).

  Also, the method of iterating pre-computed route plans with the network loading loses parts of its theoretical foundation once the network loading is no longer deterministic. For a deterministic simulation, there is a cleanly defined user equilibrium fixpoint: It is reached when in the previous iteration nobody could have been faster by using a different route. However, a stochastic simulation can run through many different traffic scenarios just by changing the random seed, and the best route may depend on the specific situation "today". For example, many people do something like "look down from the freeway bridge, and if the freeway looks congested, stay on the arterial". These kind of conditional strategies are in principle possible in iterated micro-simulations, but the foundations are far from clear.
- Another problem concerns the question if we are really interested in convergence. Do we really believe that in reality each driver tries around until she finds the absolutely best route, or do people settle for "reasonable" solutions? This problem may sound trivial ("just stop the iterations early"), but it is not. The reason is that, as long as we are only interested in the

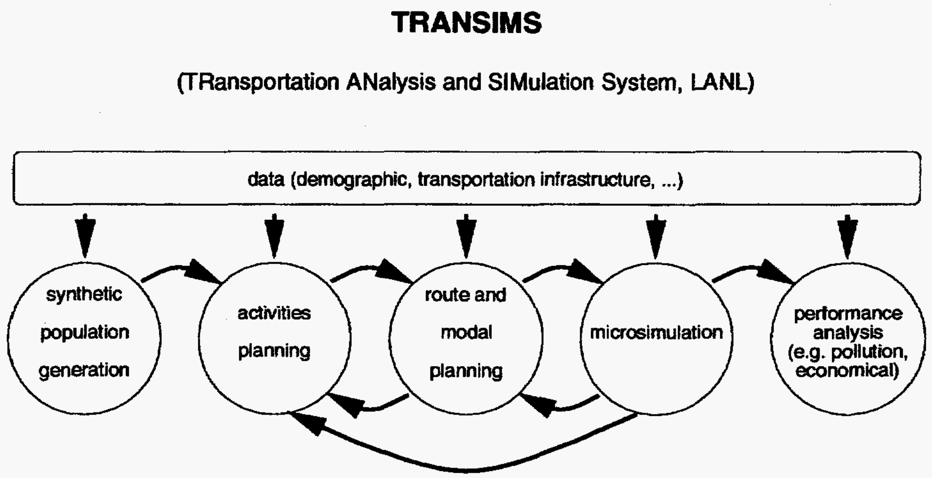

Figure 1: TRANSIMS design. The circles show TRANSIMS modules; arrows show the direction of interaction.

converged state, it really does not matter how we get there, and thus how to reach convergence becomes a purely computational problem. However, if we want to stop before convergence, then the day-to-day decision making of the drivers needs to reflect actual behavior.

2 TRANSIMS

One of the projects looking at these questions is the TRansportation ANAlysis and SIMulation System (TRANSIMS) project [5]. The goal of TRANSIMS is to combine the most important aspects of human decision-making related to transportation, from activities planning (sleep, work, eat, shop, ...) via modal and route planning to driving, into a single, consistent methodological and software framework (see Fig. 1). This is meant to combine the functionalities of (i) activities-based travel demand generation, (ii) modal choice and route assignment, and (iii) micro-simulation. TRANSIMS attempts to employ advanced methodologies in all these modules. Yet, it is probably the overall framework that is the most important part of this attempt. It is, for example, possible to replace the TRANSIMS microsimulation by another micro-simulation that uses the same input and generates the same output [6, 7, 8, 9].

TRANSIMS uses specific regions as examples in order to ensure that the technology is rooted in the real world. Until about the middle of 1997, an approximately five miles by five miles area in Dallas/Texas was used. Since then, TRANSIMS has moved to using data from Portland/Oregon; a case study for this region is planned to be completed by the end of the year 2000. In the following, we want to give short descriptions of these projects and give references to related publications.

3 The Dallas case study

For the Dallas case study [10], only a car-only micro-simulation and a very preliminary version of the router were in place. In consequence, we used as data input regular trip matrices instead of synthetic activities. As a result, the Dallas case study resembles very much a traditional traffic assignment study, with trip matrices as input and link delays as output. The most significant difference to traditional assignment is that the whole study was run *microscopically*, i.e. we generated individual trip from the trip tables, computed individual link-by-link route plans for each vehicle, and these route plans were executed in the micro-simulation.

The Dallas trip tables contained about 10 million trips for a 24-hour period. We only looked at the time from 5am to 10am, which left about 3 million trips. All these 3 million trips were routed (fastest path using free speeds), and only the trips that went through a five miles by five miles "study area" were retained. These approximately 300 000 trips/routes formed the base set for all further treatments. The microsimulation then executed these route plans for the study area. Link travel times were remembered for 15-minute periods. A certain percentage (say, 10%) of all trips was then re-routed, using time-dependent fastest path based on the link travel times from the last micro-simulation [11]. The micro-simulation was then run again, trips were re-routed, etc., until some kind of convergence was reached. The convergence criterion depended on the particular study; many such iteration series were run in order to better understand the relaxation dynamics [12, 6, 13].

The network was a so-called focussed network, which contained *all* streets in the study area, but got considerably thinned out with distance. The router ran on this full network; the micro-simulation ran on the streets in the study area. The full focussed network contained 14751 mostly bi-directional links, of which were 6124 in the study area. Maximum traffic consisted of approximately 100 000 vehicles simultaneously in the simulation. The computing speed of the micro-simulation was between real time and twenty times faster than real time, depending on the particular simulation and the particular (parallel) hardware that was used [14].

The purposes of the Dallas case study were: to demonstrate the capability of the technology to provide input for typical major investment studies; to obtain experience of how to use feedback between router and a stochastic micro-simulation for route assignment; and to obtain preliminary results concerning the sensitivity of the technology with respect to the stochastic aspects. With respect to the last point, we also investigated the effect of using different micro-simulations [8], and we made attempts to validate the model against reality [7] (see Fig. 2).

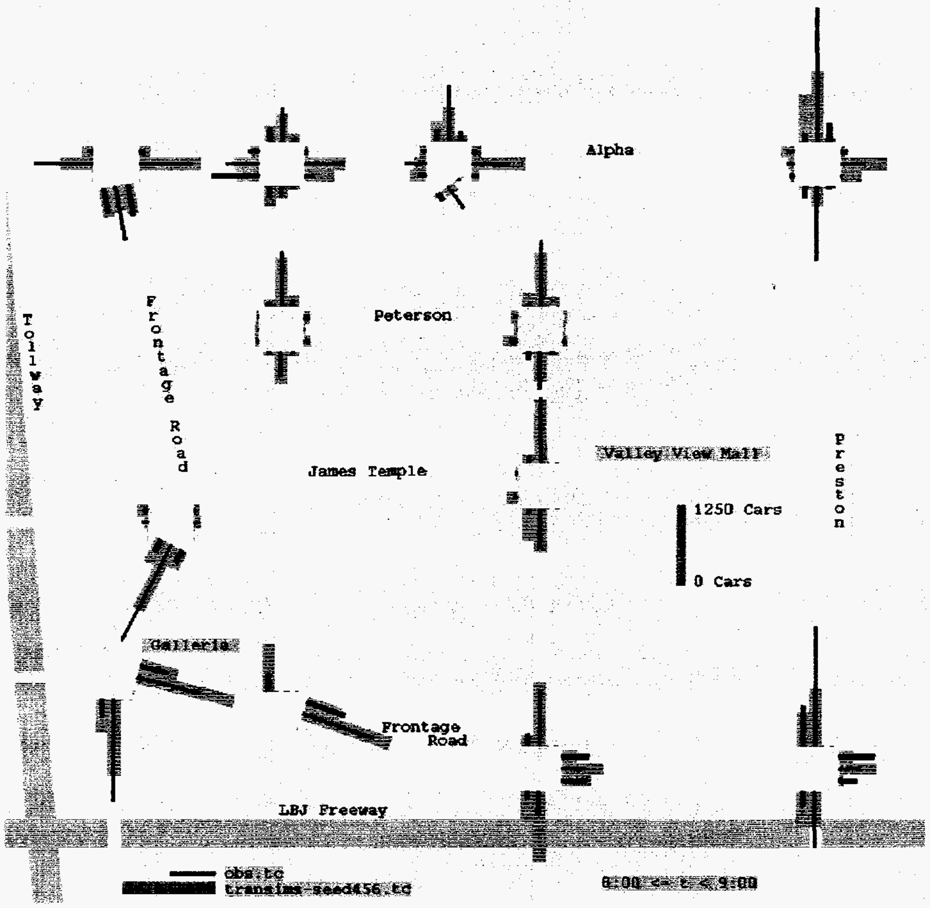

Figure 2: Turn counts comparison in Dallas. The narrower, black-and-white bars show field measurements; the wider, gray bars show simulation results. Each intersection shows counts for left turns, the through direction, and for right turns. The comparison is for hourly counts between 8am and 9am on a typical weekday. For more information, see Ref. [7].

4 The Portland case study

For the Portland case study, it is planned to use all modules of the TRANSIMS design (Fig. 1), from synthetic population generation, via activities generation and modal choice/routing, to micro-simulation and emissions. In this case, iterations are not only necessary between micro-simulation and router, but also between micro-simulation and the activities (re-)planner. The intuitive reason is that people will adjust their activities if they encounter traffic patterns that they did not expect during their activities planning. For example, people will

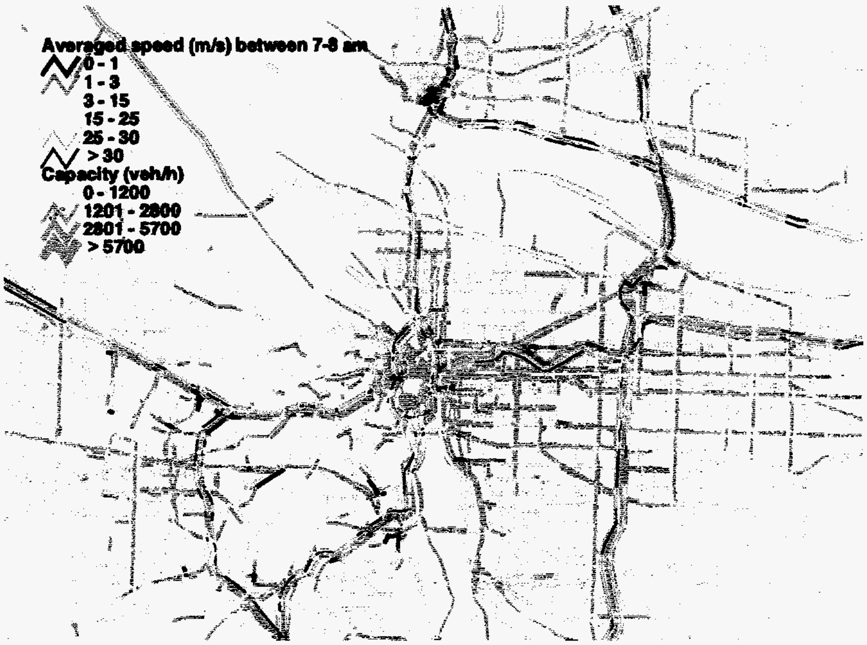

Figure 3: Results of simple home-to-work activities when assigned through a "queue" simulation model. The plot shows link speeds for simulated traffic between 7am and 8am for Portland/Oregon. The model has a tendency to overestimate congestion.

drop intermediate stops at home when transportation uses up too much time.

It is planned to run the simulation on a network that contains all streets in Portland, which amounts to approximately 120 000 mostly bi-directional links. We expect more than 200 000 travellers simultaneously in these simulations. Our current estimates are that the micro-simulation will run three times slower than real time on a 14-CPU SUN server, and about 3 times faster than real time on a 128-CPU parallel supercomputer [14]. Since we plan to run 24-hour simulations, and we expect about 50 iterations between route replanner, activities replanner, and micro-simulation, this translates to about half a year of continuous computing on the 14-CPU machine and to about 1 month of continuous computing on the supercomputer. Although this is feasible, this is clearly still a computational challenge.

In the meantime, we use a simplified micro-simulation to gain intuition about the dynamics of the activities feedback process (see Fig. 3). This micro-simulation is based on a simple queue model for links [15, 9]. Links have hard limits on flow capacity and storage capacity. A vehicle that enters a link gets moved to the end of the link. If there are vehicles ahead on the same link, the new vehicle gets added to the queue. The vehicle can leave the link when (i) it could have traversed the link according to free speed, when (ii) all vehicles ahead have left the link, when (iii) not too many vehicles have left the link already in the same time step according to the capacity constraint, and when (iv) the destination link still has space, i.e. the destination link is not yet filled up to its storage capacity. This model generates a reasonable fundamental diagram [9], it represents "hard" capacity constraints, and it models queue spillback. It is unrealistic when it comes to effects such as different link travel times for different turning directions, or when prioritizing traffic from different links under congested conditions.

We currently use this queue model together with our router in order to test simple activity generation methods. The probably most simple example are home-to-work trips, which means to assign work places to home locations of workers [16, 17]. When using a simplified network of 20 025 (uni-directional) links and running the simulation from 4am to noon, this needs less than an hour of computer time on a single CPU for one execution of the route plans. 50 iterations between simulation, route re-planner, and activities re-planner can thus be run in about three days, clearly a more useful time frame for systematic exploration than the computing times mentioned in the last paragraph.

5 Summary

The use of large scale microscopic simulations represents a considerable jump in technological possiblities in the area of transportation forecasting. Albeit still computationally challenging, it is now possible to track a statistical version of the transportation behavior of each individual for regions with 1.5 million or more inhabitants in faster than real time. This opens entirely new ways for activities-based demand modelling, since it is now possible to obtain realistic estimates of congestion from these micro-simulations.

In this paper, we have first discussed the theoretical challenges that we are facing as a result of this technological development. In particular, all the convergence properties that are known for traditional assigment need to be rethought for the new, more powerful, more realistic, but also more demanding technology.

We then moved on to give a short overview of how the TRANSIMS project attempts to approach some of these questions. We attempted to summarize the current status, and to give references to more complete publications.

Acknowledgments

This paper provides on overview of work done at the TRANSIMS project in Los Alamos. Many researchers and research groups work in areas related to the topics described in the paper. Some of their work is referenced in the papers mentioned below.

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