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Integrating an Activity-Based Model with a Dynamic Traffic Assignment Model

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Abstract

The very notion of user-equilibrium, the most commonly used route choice model in transportation literature, implies an integration of traffic supply and demand models. Sadly, research in these models has evolved separately. On the supply side, dynamic traffic assignment has matured to replace static assignment models. Moreover, recent advances in DTA have lead to the development of theoretically sound simulation-based models that are capable of realistically propagating traffic flow while reasonably satisfying UE conditions. On the demand side, research has focused on activity-based approaches to adopt a holistic view of the complex phenomenon of travel by focusing on the overall sequence of activity-travel participation of all household members over a day. Therefore, it is important to integrate recent advances in traffic models in a single platform in order to realize the benefits of both tracks of research. To this end, TRANSIMS is perhaps one of the earliest transportation packages that integrate an activity demand model with a dynamic traffic assignment model in a single platform. This paper describes the general framework of the TRANSIMS model through a planning application in Portland, Oregon.

Background

Activity-based demand models have been motivated by the lack of realism in conventional trip-based demand models, which 1) do not have a behavioral foundation; 2) ignore spatial and temporal constraints; and 3) offer little or minimal sensitivity to changes in land use, demographics, and policies. Activity-based models recognize that travel is derived from the need to partake in activities distributed in space and time and as such, they are concerned with the overall sequence of activities of all household members over a day or longer. Therefore, unlike trip-based models, activity-based models do consider the linkages among the different activity-travel decisions of an individual as well as the linkages among the household members [1]. A number of activity-based models have been developed in recent years, such as CEMDAP [2], Boston Model [3], the Portland Model [4], and many others.

On the supply side, the limitations of the static traffic assignment (STA) procedures have led to the development of dynamic traffic assignment (DTA) models. DTA models overcome the limitations inherent in STA models such as the failure to capture the traffic dynamics, trip chaining and the effect of intersection delay on the calculation of least-cost paths. DTA models have a plethora of applications ranging from real-time management to offline planning and evaluations, and it is by far the tool most suited for operational planning applications. A number of simulation-based DTA modules have been developed in the recent past such as VISTA [5], DynaMIT [6] and DYNASMART-P [7].

Therefore, it is clear that advances in both tracks have taken place. However, to capture the benefits of recent advances in traffic modeling, it is imperative to integrate activity-based demand models and DTA supply models. Unfortunately, this has not been the general case, where trip-based demand models, instead of activity-based demand models, have often been linked with DTA models. This paper illustrates a practical example in integrating an activity-based demand model with a microscopic DTA supply model through a regional application in Portland, Oregon.

Model Framework

The model framework involves five basic steps (Figure 1). In the first step, a synthetic population of households and individuals is distributed demographically and spatially according to census and land use data. Then, using a household travel activity survey, synthetic households are matched with survey households, thus inheriting the latter's activity patterns, time schedules, and travel modes. Location choice models are then applied in the third step to determine the location of each activity stop on the network from a set of candidate locations using an initial set of mode-time factors, zone-to-zone skims (or impedances), and zonal attraction weights. In the fourth step, travel plans are generated by finding the shortest (or min-cost) paths between each pair of activity locations along tours. Finally, the plans are simulated on a second-by-second basis to determine the state of the system (travel times and turning penalties).

Three types of feedback loops are present within the solution framework, all of which assume that the household locations and the activity patterns remain intact. The first feedback loop is between the location choice model and the router, whereby the latter is used to find the time-dependent shortest path between each pair of activity locations (as determined by the location choice model) and consequently the predicted trip distances and times. Average trip distances and times by activity purpose (work, shopping, recreation, other, etc…) and trip types (home-based, non-home-based, etc…) are then checked against observed trip distances and times for calibration and validation purposes. Should the calibration fails, the location choice parameters (mode-time factors) and zonal weights would be updated and the process will iterate until a satisfactory calibration is achieved.

The second feedback loop is between the router and microsimulator, whereby the experienced trip times from the microsimulator are fed back to the router to re-adjust the existing plans (paths) for travelers. The process is repeated until stabilization in trip times is achieved, and this concludes the first iteration of TRANSIMS. The final feedback loop is an outer-loop between the microsimulator and location choice model, whereby experienced zone-to-zone travel-time skims from microsimulator are fed back to the location choice model to determine an updated set of activity locations. The process iterates until the activity locations become stable, or equivalently the zone-to-zone travel-time skims from two consecutive outer-loops iterations are stable.

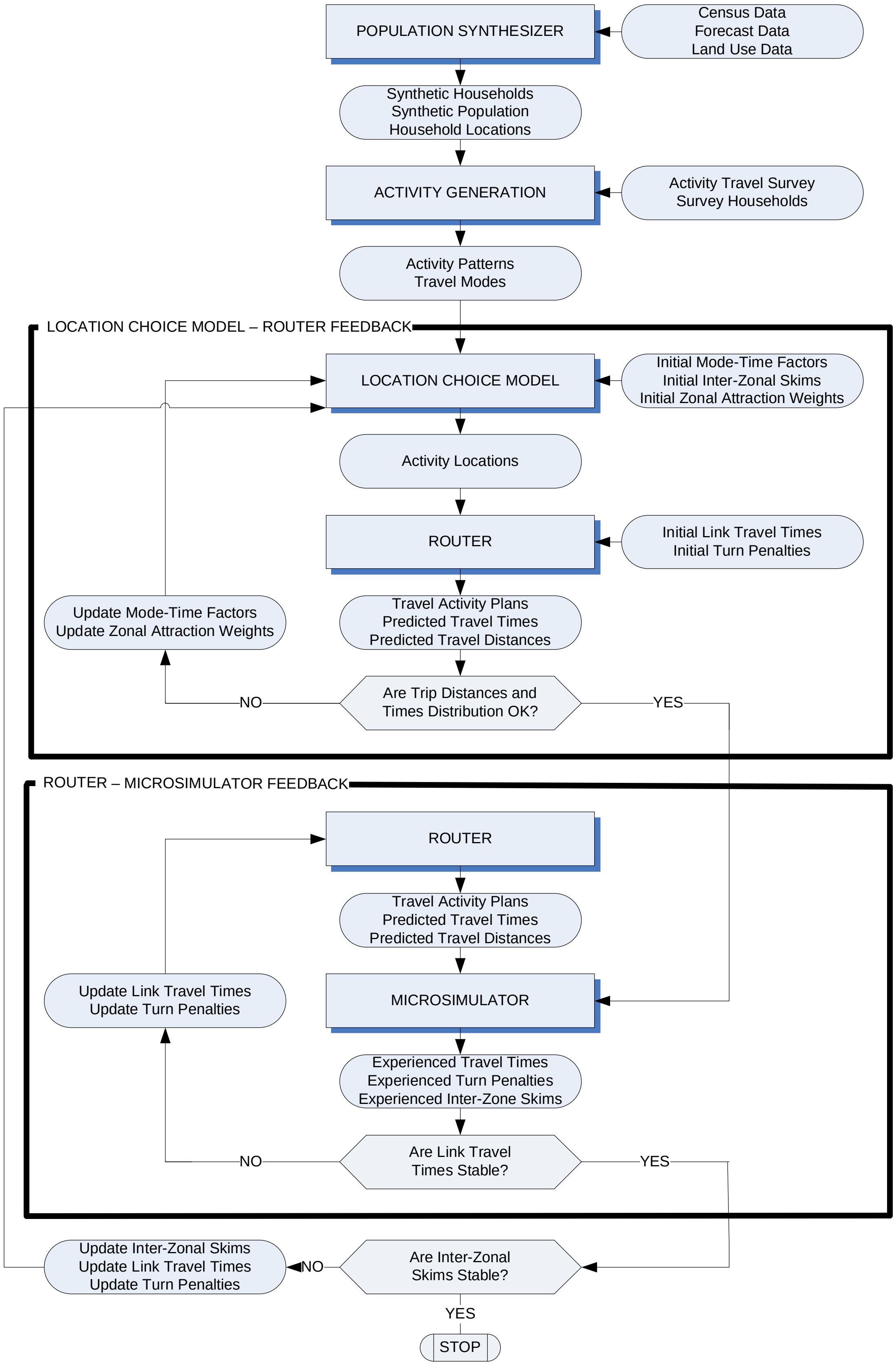

Figure 1 – Model solution framework

Activity Generation Model

The activity generation model matches, based on demographic characteristics, a synthetic household to a survey household and assigns the activity patterns of the latter (available from travel survey) to the former. A classification and regression tree (CART) is used for the matching process. Synthetic and survey households are first classified based on their demographic characteristics, to a single node (type) in matching tree. Then each synthetic household is randomly assigned to a survey household belonging to the same terminal node (type) in the classification tree. Each synthetic individual is then matched to a survey individual according to age, work status, and gender, in that order. Once a best match is found, the synthetic individual inherits the activity pattern of the survey individual, including activity times and duration, and travel modes.

Activity Location Choice Model

A simple logit choice model is used to assign a location for each activity along a tour. A two-stage location-choice process is implemented to speed up the computations. A destination zone is first selected, based on zone-to-zone travel time skims (or logsums) and zone attraction weights, and then an activity location within that destination zone is selected, based on expected trip times and location attraction weights. Two types of tours are modeled, namely anchored and non-anchored tours. Anchored tours are tours where the main activity is work, school, or college, whereas non-anchored tours are tours where the main activity is shopping, recreation, visit, or discretionary. For non-anchored tours, the activity with the longest duration on tour will be selected as the anchor, and the same procedure will be applied to locate the destination zones. Once all the destination zones are located, a location then selected, from a set of candidate locations within each destination zone.

Scheduling of Activities

This process identifies each tour and the anchor activity within that tour. It then uses the travel times to and from the anchor activity to estimate the departure time from the previous activity and the arrival time at the next activity. The types of adjustments that are permitted are controlled by the type of constraint associated with each activity. If the activity has no time constrains, the end time of the activity will be rescheduled to the estimated departure time and the activity duration will be used to set the activity start time. If the activity has a fixed time constraint, the program will work within this constraint to adjust the activity, nearby activities, and the travel time estimate to maintain as much consistency as possible. If a simple solution is not possible, the program will proportionally distribute the error to the affected travel times and activity durations. This process continues until all activities are adjusted before and after the anchor activity location.

Simulation and Validation Results

The generated activities are then fed into the router to generate the plans for all individual travelers. The plans are then simulated, on a second-by-second basis, to determine the state of the system (link travel times, speeds, and turn penalties). The resulting link travel times are then fed back to the router to determine an updated set of plans for all travelers. An MSA-based heuristic is used to determine the top-most set of travelers that need to update their plans. The process is repeated until user equilibrium (UE) is achieved (less than 5% discrepancy in travel times) for maximum of 20 feedback loops. In the current application, due to the scale of the problem and the presence of signalized intersections, UE has not been totally achieved; however, a stable solution (path assignment) has been attained. The zone-to-zone travel time skims from the last microsimulator-router run are then fed back to the activity generation to start another full run. A total of five full TRANSIMS runs (outer-loop iterations) have been conducted for this study.

A total of 410 directional link-counts covering major freeways, expressways and arterials have been used to check the validity of assignment results. Overall, the estimated daily link counts are within 5% of observed values, with estimated counts on most facilities being within 15% of observed values with the exception of expressways at 28%. However, such a facility has proved to be hard to validate in the past with the calibrated trip-based model also resulting in 23% more counts. The tour-based model is doing a reasonable job generating travel demand needed for a planning-level simulation of the Portland region.

Conclusions and Future Research

This paper illustrates a method of integrating advanced supply and demand models to generate validated traffic forecasts for Portland, Oregon. In this regard, a synthetic population is created and located from available census data, activity patterns are generated for the population and later transformed into individual tour plans, which are then simulated on a second-by-second basis to determine the state of the network. An iterative solution framework is then applied to achieve consistency between observed and simulated trip distances as well as consistency in travel times and hence activity plans. The calibration process of the location choice model has been satisfactory, with trip distance distributions by activity purpose reasonably tracking observed distributions. Finally, the link validation results from the microsimulator are deemed adequate to replicate the trip-based model results for Portland.

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