ASSESSING TRANSPORTATION POLICY USING AN ACTIVITY-BASED MICROSIMULATION MODEL OF TRAVEL DEMAND

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ABSTRACT: Travel demand models have been providing decision-support for transportation infrastructure planning over the past half-century. However, with limited opportunities for new highway and transit infrastructure in congested areas, “demand-oriented” policy measures (e.g. travel demand management), which allow for more efficient usage of existing road and transit capacity, require improved methods of analysis. This paper presents a new operational prototype microsimulation model of travel and activity scheduling for household agents (TASHA) that provides more precise model outputs than current state-of-practice models, with little increase in the supporting data requirements. It is argued that the model significantly improves our ability to analyze demand oriented policy measures. This paper uses several example transportation policy problems in Toronto to demonstrate the potential benefits of the TASHA modelling approach over current methods.

1. INTRODUCTION

Travel demand models that have been providing decision-support for transportation infrastructure planning over the past half-century. The four-stage model has been the “workhorse” analysis tool for transportation planning since it was originally developed in the 1950’s. This modelling framework, if done well, was able to provide travel demand forecasts with an appropriate level of precision for the context in which it was developed. Decision support for large highway and transit infrastructure projects required relatively crude modelling efforts, particularly when the goals of providing the infrastructure were largely to increase mobility. Since the 1960’s, however, the development of major freeway systems and mass transit infrastructure has slowed dramatically. In the Greater Toronto Area, there are few corridors remaining in which new freeways can be built without severe impacts. There has also been a realization in planning circles that the provision of new roadway capacity quickly leads to new development in newly accessible parts of the city, often causing the new capacity to be filled in a matter of years.

Travel demand management (TDM), Intelligent Transportation Systems (ITS) technology, high occupancy vehicle (HOV) lanes, are some policy instruments that have been used to make better use of existing roadway capacity. Each of these measures, however, requires more precise decision support tools than the traditional four-stage modelling approach. This paper presents a new operational prototype microsimulation model of Travel and Activity Scheduling for Household Agents (TASHA) that provides more precise model outputs than current state-of-practice models, with little increase in the supporting data requirements. The next two sections summarise the functionality of the TASHA model and the data upon which it is based. The following sections use several example transportation policy problems in Toronto to demonstrate the potential benefits of the TASHA modelling approach over currently used methods.
2. TRAVEL/ACTIVITY SCHEDULER FOR HOUSEHOLD AGENTS (TASHA)

The Travel/Activity Scheduler for Household Agents (TASHA) is a new model of activity scheduling and mode choice that is designed to address many of the deficiencies of current state of practice models. TASHA is one example of a growing family of activity-based modelling systems being developed for various cities across North America, including Ohio (MORPC) (Vovsha et. al. 2004), South Florida (FAMOS) (Pendyala et. al. 2005), San Francisco (Jonnalagadda, et al., 2001) and Portland (Bowman, et al., 1998).

Key features of TASHA are as follows:

- It is **disaggregate**. It works at the level of the individual decision-maker so that we can model trip-making within the actual context in which it occurs (travel times, constraints on available choices, etc.) and we can “know” the salient characteristics of the trip-makers that influence their travel decisions (income, age, auto availability, etc.).
- It is **activity-based**. Travel arises out of the need to participate in out-of-home activities. Thus, in order to model trip-making, we need to understand how people organize their lives, since it is the interplay between the desire/need to participate in activities and the mobility/accessibility options provided by the transportation system that ultimately determines travel behaviour.
- It is **household-based**. Although individuals travel, their travel decisions are made to a considerable extent within the context of household-level interactions, constraints and needs. Availability of household vehicles, need to chauffeur children, joint household activities, etc. all have a significant influence on an individual’s daily activity (and, hence, travel) pattern.
- It is a **microsimulation** model, in which each household in the urban area (and each person within these households) is explicitly represented and modelled. This permits the full power of the disaggregate, activity-based approach to be exploited. It also often is the computationally most efficient approach to modelling complex socio-economic systems such as transportation.
- It is developed within the **object-oriented** programming paradigm which facilitates the modular, extensible development of complex simulation systems. It is also **agent-based**, in that persons and households are “intelligent objects” or “agents” who are capable of perceiving their environment, making decisions and acting into their environment.

The full conceptual design, methodology and preliminary results of an operational prototype of the TASHA modelling system are given by Miller and Roorda (2003). TASHA has also been designed to interface with a tour-based model of household mode choice and vehicle allocation (Miller, In press). TASHA was designed to improve upon current four-stage modelling systems used in the Toronto Area in a number of ways, most importantly, the behavioural representation of human decision making, the spatial and temporal precision of outputs, and the sensitivity to demand oriented policies. The conceptual designs of each of the currently used four-stage model and the TASHA model are outlined in Figure 1. A brief comparative summary of the basic features is shown in Table 1. Finally, a descriptive comparison of methods used in of TASHA to those of current state-of-practice four-stage modelling systems used in Toronto is shown in Table 2.
Figure 1. Conceptual designs of the four-stage model and TASHA

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### Table 1: Comparison of features of the four-stage model and TASHA

<table>
<thead>
<tr>
<th>Model Feature</th>
<th>Four stage model</th>
<th>TASHA</th>
</tr>
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<tbody>
<tr>
<td>Level of disaggregation</td>
<td>Household / zone</td>
<td>Person / household</td>
</tr>
<tr>
<td>Unit of analysis</td>
<td>Trip</td>
<td>Activity episode</td>
</tr>
<tr>
<td>Inputs requirements</td>
<td>Conventional trip diary data</td>
<td>Conventional trip diary data</td>
</tr>
<tr>
<td></td>
<td>Population, employment forecasts</td>
<td>Population, employment forecasts</td>
</tr>
<tr>
<td>Outputs</td>
<td>Zonal origin-destination trip tables</td>
<td>Trip chains, activity schedules</td>
</tr>
<tr>
<td></td>
<td>Assigned transit and traffic flows</td>
<td>Assigned transit and traffic flows</td>
</tr>
<tr>
<td>Period of analysis</td>
<td>Peak hour</td>
<td>24 hour period</td>
</tr>
<tr>
<td>Temporal aggregation</td>
<td>1 hour</td>
<td>5 minutes</td>
</tr>
<tr>
<td>Spatial aggregation</td>
<td>Traffic zone level</td>
<td>The prototype version is developed at the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>zonal level of detail. However, this could</td>
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<tr>
<td></td>
<td></td>
<td>be disaggregated to specific locations if</td>
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<tr>
<td></td>
<td></td>
<td>such spatially disaggregate information is</td>
</tr>
<tr>
<td></td>
<td></td>
<td>available.</td>
</tr>
<tr>
<td>Computational requirements</td>
<td>Trip generation, distribution and mode</td>
<td>TASHA runs quickly, but requires</td>
</tr>
<tr>
<td></td>
<td>choice require fairly minimal computational resources. Trip assignments in EMME/2</td>
<td>substantial RAM memory. Parameter</td>
</tr>
<tr>
<td></td>
<td>require moderate computation.</td>
<td>estimation for the tour based model</td>
</tr>
<tr>
<td>Parameter Estimation</td>
<td>Conventional methods and software are</td>
<td>A genetic algorithm is required to</td>
</tr>
<tr>
<td></td>
<td>used.</td>
<td>estimate the parameters of the mode</td>
</tr>
<tr>
<td></td>
<td></td>
<td>choice component</td>
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### Table 2: Comparison of methods of the four-stage model and TASHA

<table>
<thead>
<tr>
<th>Model Component</th>
<th>Four-stage model method</th>
<th>TASHA method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population synthesis</td>
<td>The four-stage model is aggregate in nature. Therefore no</td>
<td>Population synthesis is currently done for future years applying a biproportional</td>
</tr>
<tr>
<td></td>
<td>population synthesis is required.</td>
<td>updating method to base year occupational place-of-residence place-of-work tables to</td>
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<tr>
<td></td>
<td></td>
<td>match future zonal population and employment totals.</td>
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<tr>
<td>Trip / activity generation</td>
<td>Trips are generated using linear regression, cross-</td>
<td>Activities are simulated based on observed distributions available from TTS data. Tours are</td>
</tr>
<tr>
<td></td>
<td>classification, or trip rate models</td>
<td>an outcome of the activity scheduling process.</td>
</tr>
<tr>
<td>Trip / activity distribution</td>
<td>Trip distribution is done either using gravity model, a</td>
<td>Multinomial logit location choice models are used to choose the location of non-work out-</td>
</tr>
<tr>
<td></td>
<td>proportional flow model, or biproportional updating. These</td>
<td>of-home activities. Location choice is a function of the attributes of the person, the</td>
</tr>
<tr>
<td></td>
<td>methods are all at the zonal level of analysis.</td>
<td>household, and zonal attributes such as employment or retail floor space.</td>
</tr>
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</table>
3. DATA

TASHA requires the same data inputs as the four-stage model. Both require data from a conventional trip diary survey, and for forecasting, both require future year zonal population estimates, zonal occupational employment estimates and future year transportation networks. In the Greater Toronto Area, Transportation Tomorrow Survey (TTS) data are used as the base data inputs, and are used for parameter estimation and calibration. The TTS is a telephone home-interview survey conducted on 5% of the GTA population every five years. The survey documents the travel patterns and characteristics of participants throughout the GTA and other parts of south-central Ontario (DMG, 2003). For the implementation of TASHA, trip-based data must be processed to form a “pseudo” activity-based dataset. This process is documented by Eberhard (2002).

4. POLICY APPLICATIONS OF TASHA

The first application of the prototype version of TASHA was in the policy context of travel and emissions estimation for alternative land use scenarios in the Greater Toronto Area (Miller and Roorda, 2002). Clearly, more conventional four-stage models can also be used to evaluate land use scenarios by altering population and employment inputs. The primary advantages associated with TASHA forecasts in this context were the reduction of aggregation biases associated with the use of zone based modelling, the provision of emissions estimates for a 24-hour period (compared to peak period estimates only for the four-stage model), and an improved behavioural realism associated with the method for estimating travel.

However, perhaps the most critical advantage of the TASHA model is its sensitivity to demand oriented policy instruments. The TASHA model was designed to overcome the inability of current state of practice models to adequately assess demand oriented policy solutions to transportation problems. The following sections describe in detail three particular policy questions for which the TASHA model is considered to provide insights that are not provided by the four-stage model.
• Alternative hours (flexible working hours, compressed work weeks, staggered shifts, and telecommunications substitution for travel)
• High occupancy vehicle lanes
• ITS initiatives

5. ALTERNATIVE HOURS

The goal of alternative hours is to allow individuals a greater freedom in their choice of when to travel. Such strategies allow individuals to avoid recurring congestion by either travelling during off-peak times, and in some cases reducing total travel. Forms of alternative work hours include staggered work shifts (employees shifts begin and end at various times selected by the employer), flexible work hours (employees are given some choice over arrival and departure times from work), compressed work weeks (employees work longer hours in fewer days to achieve the same total work hours) and telecommunications substitution for travel (including telework, conference calls, online shopping, schooling and recreation).

Alternative hours strategies are a popular policy tool by government and public institutions since they generally require no investment in transportation infrastructure, but are intended to encourage better use of existing transportation capacity. For example, the Smart Commute Initiative was recently formed in the Greater Toronto Area to develop transportation management associations (TMAs) that will promote TDM measures including alternative hours strategies (Smart Commute Initiative, 2003). However, such strategies can be less successful than anticipated if the constraints and opportunities available to a household are not fully considered. For example:

• A worker on a compressed work week may opportunistically use available time on their additional day off to make additional recreation or shopping trips.
• Worker acceptance of flexible work hours may be constrained by the schedules of other household members such as children that must be dropped off at or picked up from day care, or other household members that would like to use the family vehicle.
• Telecommunications may substitute for some work or leisure trips, but may result in a more dispersed social or business network, resulting in a greater distance trips when they do occur.

Current state-of-practice models used in the Toronto Area are basically insensitive to alternative hours policy scenarios and the resulting secondary effects, because:

• They are trip-based, therefore, substitution of activities for travel cannot be represented
• They do not represent interactions and negotiations within a household, and therefore cannot properly represent the circumstances that constrain the effect of alternative work hours.
• They typically model the peak period only, and cannot easily be used to assess impacts in off peak travel or on the “shoulders” of the peak hour and the associated congestion and pollution effects.

TASHA is a modelling framework in which activity scheduling constraints and negotiations between household members are explicitly modelled. Thus, household circumstances that may reduce the effectiveness of alternative hours policies can be accounted for and better estimates of the transportation impact can be made.


The effective use of scarce roadway capacity through encouraging higher average auto occupancies (including the allocation of dedicated lanes to HOVs) is an issue of concern to urban communities across Canada. In the Toronto Area, there are currently over 60 km of HOV lanes in operation in the Greater Toronto Area (MRC, 2005), and the first HOV lanes on Ontario highways are scheduled to open in the Fall of 2005 (CNW, 2004). HOV lanes provide a travel time incentive to transit users and to individuals that share a ride with another person. Such incentives have the potential to reduce the number of vehicles in HOV corridors, if drivers take advantage of HOV lanes by either carpooling, ridesharing with family
members. However, HOV lanes can result in increased congestion if they take the place of regular lanes of traffic and single occupancy vehicle traffic does not decrease substantially. It is therefore critical to assess the ability and willingness of individual drivers to share rides or take transit and take advantage of HOV lanes.

Four-stage models can be used to evaluate mode choice between automobile, transit and auto passenger modes, thus they can be used to evaluate HOV initiatives in a crude manner. However, the typical mode choice models used are developed, at best, for an individual only. Ridesharing, however, inherently involves communication and negotiation between two or more persons. The process of finding a “match” between individuals travelling approximately from the same origin to the same destination at the same time is critical to the availability of ridesharing as a feasible mode.

As a household-based activity/travel model, TASHA is unique in its ability to model within-household ridesharing. Ridesharing results from the scheduling process in one of three ways in the TASHA model. Activity schedules of all household members are first developed, with joint activities being added simultaneously into the schedules of those people. Hence, ridesharing to joint activities is an inherent part of the scheduling process. Second, ridesharing opportunities are also found for people accessing different activities in compatible locations at compatible times. The underlying principle of the model is that a person will drop off or pick up another household member en route to his/her own destination if the utility gain for the passenger of the trip exceeds the utility loss for the driver. Finally, home-based trips that are made solely for purpose of dropping off or picking up another passenger, are allowed for, if there are no other transportation options for the passenger or the utility gain of the passenger exceeds the utility loss of the driver. The three modes of ridesharing are shown in Figure 2.

Clearly the complete assessment of an HOV initiative would require the capability to model carpooling. The current version of TASHA does not model inter-household carpooling. Modelling carpooling in a credible, “behavioural” fashion is an extremely difficult, unsolved problem that should be the focus of dedicated research efforts. There is no model comparable to TASHA worldwide at this time that adequately handles the inter-household car-pool problem.

![Figure 2. Ridesharing scenarios modelled in TASHA](image-url)
7. INTELLIGENT TRANSPORTATION SYSTEMS (ITS)

ITS involve such technologies as:

a) En-route route guidance: Automated traffic information systems (ATIS), including variable message signs (VMS), and in-vehicle navigation tools.
b) Pre-trip route guidance: Real time internet traffic information, real time transit scheduling
c) Real-time system control (e.g. traffic responsive ramp metering and signal control)
d) Incident detection

Investment in ITS infrastructure can be one of the most cost-effective ways to improve the performance of transportation systems. Generally, ITS improves the capacity of highway and transit infrastructure while avoiding many of the social and environmental impacts associated with new highway lanes, such as traffic delays due to construction and the use of agricultural, environmentally sensitive or residential land. It is critical that both short- and long-term planning models be able to assess the impacts of ITS investment policies.

ITS technologies affect transportation systems in two fundamental ways. First, real-time system control and incident detection affects transportation system performance from the supply side. In general, incidents can be cleared more quickly and freely and arterial queuing can be reduced, making travel times shorter and more reliable. Second, en-route and pre-trip guidance provided to travelers affects their behaviour. Information provided to individuals can influence the routes and modes chosen, and occasionally the location of, or the participation in activities of individuals.

Static macroscopic traffic assignment models currently used in practice, such as EMME/2 and TransCAD, are unable to adequately assess such impacts of ITS. Rather, micro- or meso-scopic simulation models with dynamic traffic assignment are becoming increasing used (e.g. Mahmassani et. al., 2004; Ben-Akiva et. al. 1997; de Palma and Marchal, 2002; TRANSIMS, 2004). These models require time varying inputs. For example, a microscopic traffic simulation loads individual vehicles onto a traffic network at specific points in time at specific locations. Yet typical planning level models only provide total origin destination flows that are aggregated to a one-hour period and to a coarse traffic zone system. To use such matrices as input to a microsimulation model requires assumptions about the temporal profile and the exact location of vehicle entries into the traffic network. These are crude assumptions and can have adverse effects on the accuracy of microscopic simulation models.

Currently, TASHA interfaces with a macroscopic static user equilibrium traffic assignment model, as does the four-stage model. However, the precision of TASHA outputs is appropriate for micro- or meso-scopic simulations. Trips and activities are output at a precision of five minutes and disaggregate work and home location data at the block face or even the individual building level can be used if the data are available.

There exists the possibility of developing a feedback mechanism that allows the experiences of the traveller on the traffic network to impact their activity schedule. For example, if a traveler experiences recurring congestion on the drive to work, they may adjust their departure time appropriately or find alternative strategies to improve their commute. Such learning mechanisms have been studied (e.g. Chang and Mahmassani, 1988, Sun et. al. 2005) but are not a current feature of the prototype version of the TASHA model. The object-oriented nature of TASHA and the fact that it is a microsimulation model with explicit representation of individuals facilitate such extensions.

The ability to assess long- and short-range planning impacts of ITS technologies should be a key feature of a planning model. Currently, neither the traditional 4-stage model nor the TASHA activity-based microsimulation model is sensitive to ITS-related policy. However, TASHA clearly is capable of providing the necessary temporal and spatial precision to make use of the capabilities of dynamic traffic assignment and traffic microsimulation methods, and is ideally set up to incorporate learning mechanisms and other behavioural responses to ITS information.
8. CONCLUSIONS

There is a clearly a need for improved modelling methods to assess demand oriented transportation policies. This paper has argued that the TASHA modelling system, whose first prototype version has been developed for the Greater Toronto Area, is a successful example of such a method. This model is particularly well-suited to assess:

- Alternative hours (flexible working hours, compressed work weeks, staggered shifts, and telecommunications substitution for travel)
- High occupancy vehicle lanes
- ITS initiatives

There is a great deal of research that must be done before the TASHA system is ready for large-scale implementation. Current research efforts are focussed on continued calibration, validation, testing of the system, and application to demonstrate policy scenarios. However, the following enhancements are also on the near-term research agenda:

- Integration of the mode choice and activity scheduling components of TASHA as a joint decision
- Improving the activity location choice model and activity generation models embedded within TASHA,
- Fully exploit the richness of the activity-based modelling approach by integrating TASHA with a micro- or mesoscopic traffic assignment model.

9. REFERENCES


