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Taking models out of the box: Prospects for expanding the scope of travel demand microsimulation

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Introduction

Several papers have been written describing the transition toward activity-based models of travel demand, including those already implemented for MPO's in San Francisco, New York, Portland, Columbus, Dallas and Sacramento (see Bradley and Bowman 2006 for a recent summary). A common feature of these models is that they use microsimulation to apply models to each separate individual in a synthetic, representative population. While the focus of attention has been primarily on the shift to tour-based and activity-based model structures, it is this concurrent shift to a microsimulation framework that can truly revolutionize the way we go about travel demand forecasting.

Over the years, the travel demand forecasting process has been constrained by the aggregate, zone-based approach that has been standard practice. Now, using microsimulation, we can transcend many of the limits of the 4-step approach—using parcels or grid cells instead of TAZ's as the basic spatial unit, using time slices of a half-hour or less rather than a few periods across the day, and using a wide variety of attributes of each person and household instead of just a few demographic segmentation variables. In addition, we are no longer constrained to a pre-determined hierarchy of choices, such as the four steps of generation, distribution, mode choice, route choice. We now have flexibility in terms of which choices are modeled and the sequence in which they are modeled. In fact, we can even specify different types of decision models and hierarchies for different types of individuals (e.g. workers vs. non-workers, children vs. adults, etc).

This paper describes a few of the prospects for expanding the scope of travel demand forecasting models in the quickly evolving environment of microsimulation models. The paper covers three main areas: (1) additional types of behavior and choices that can be modeled, (2) alternative approaches to specifying the input assumptions and designing policy and sensitivity analyses, and (3) new ways of examining model outputs. Two areas that I do not focus on are the integration of travel demand microsimulation models with land use microsimulation and with network meso- or microsimulation models. Those areas are already the topic of much research in academia and consulting, and the discussion below assumes that a full microsimulation framework will evolve in the coming years; one that includes land development, residential and employment location decisions, activity scheduling, tour- and trip-making, and realistic simulation of highway and transit vehicles. My focus is on new ways of using such a model system.

Capturing heterogeneity: The most recent activity-based simulation models have already gone a long way towards reducing aggregation error by allowing the use of a much broader spectrum of person and household characteristics. In the meantime, many recent analyses using mixed logit and other advanced estimation approaches have indicated that observed characteristics can only explain a fraction of the "taste variation" that is identified in Stated Preference and Revealed Preference choice data. In other words, our current advanced microsimulation models still tend to underestimate the amount of variation in Value of Time (VOT) and other important tradeoff ratios, compared to the variation that actually exists across the population. This discrepancy can lead to inaccurate forecasts for congestion pricing, introduction of new transit services, and other types of policies.

In the microsimulation framework, rather than using the same set of average coefficients for each individual of a certain type, we can draw coefficients randomly from a pre-specified distribution, so that each person may have "their own" set of tastes and preferences (utility coefficients) for each type of travel. This approach fits well with advanced econometric methods that estimate distributions of parameters rather than single mean values. Because we are simulating each individual separately in any case, this strategy will not require any further complication to the microsimulation approach, and can thus provide substantial improvements in behavioral realism for very little additional effort.

Over the next few years, efforts should be focused on identifying suitable distributions to apply in models, without having to estimate such distributions from scratch for each new study. For example, we currently use rules of thumb regarding VOT ratios and ratios of out-of-vehicle and in-vehicle time coefficients when specifying mode choice models. Those rules of thumb need to be extended to include appropriate shapes for the distributions around those values. For example, a typical distribution for VOT seems to be a log-normal shape with a coefficient of variation (standard deviation divided by the mean) somewhere between 0.5 and 1.0.

Modeling parking choice: While we tend to model transit access and egress in as much detail as possible, we tend to ignore parking choices for auto trips, treating each car trip as if it begins and ends at a building rather than a parking space. In urban districts where parking is priced and supply is limited compared to demand, this approximation is not likely to be appropriate. Furthermore, parking policy is a key Travel Demand Management (TDM) option in such locations; an option about which most current forecasting models can provide no guidance.

Some new microsimulation models, such as in Sacramento, Denver and Oregon, are designed to forecast the location of trip ends to the level of an individual parcel or building. They also predict the timing of departure and arrival for those trips to within time slices of one-half hour or less. With that level of spatial and temporal resolution, it becomes possible to simulate the parking choices of auto trips to downtown areas. The simulation model can keep track of the number of spaces occupied and available in each parking garage and lot, as well as on-street spaces. Over a number of iterations, an approach such as "shadow pricing" could be used to constrain the demand to the capacity of each parking facility, analogous to what we currently do in traffic assignment for road capacity, and sometimes for park-and-ride lots as well. Alternatively, a detailed traffic simulation model could replicate the parking search process, giving a more realistic representation of parking supply constraints and their effects on street traffic levels. Again, this is analogous to the improvements that detailed traffic simulation could provide for mode choice and departure time choice models as well.

Clearly, parking choice models will require collecting data on the price and capacity of parking at a detailed level, and will require forecasting those same values for future years. However, parking supply constraints and pricing are probably only relevant for fairly constrained geographic areas within most urban regions, and the simulation of parking behavior would only need to be done within those districts.

Modeling physical activity and health outcomes: A key area of policy research at present concerns the effects of urban design, job and school location, and transportation infrastructure on the amount of physical exercise that people undertake in form of walking and cycling, and the resulting effects on obesity and health. Related research is focused on the accessibility to various types of restaurants and grocery stores, and how those also influence obesity and health. As the many studies in those areas begin to produce a body of consistent evidence, it will be attractive to have an appropriate simulation framework to give an idea of which future transportation and land use policies are likely to have the most benign/beneficial effects on public health. Advanced microsimulation models are appropriate because they can incorporate (a) a detailed, parcel-level land use resolution for accurate representation of accessibility by walk, bicycle and transit, and (b) a large amount of detail on personal and household characteristics to identify the people most likely to take advantage of such accessibility. Models that also include microsimulation of residential choice and in- and out-migration can also capture the phenomena whereby those people who move into neighborhoods where "walkability" and transit access are improved are also those most likely to use those alternative modes (a "self selection" effect).

At first glance, such an extension of our models may seem as if we are reaching too far. Consider, however, how much money and effort has been invested in predicting vehicle emissions and ambient air quality (an area, by the way, which can also be greatly improved using microsimulation models). Given the growing concern about obesity and diabetes as the coming generations' most serious health problems, it will become more and more important to consider those impacts within urban planning. This is another area where microsimulation models will provide a suitable tool for applying a growing body of research.

Behavioral dynamics and state-dependence: For many years, it has been recognized that cross-sectional data from household surveys are not the best source of evidence to create models to predict policy changes over time. There are likely to be constraints, habits, and information delays that determine which people will react most strongly to policy changes. For example, those who have recently moved their residence and/or undergone a major change in employment or household composition are most likely to seek out or be aware of different transportation choices, whereas others will tend to be more habit-driven. Despite this recognition, the cost and difficulty of collecting and analyzing longitudinal panel data, along with the infeasibility of applying dynamic models in a 4-step framework, has prevented any widespread application of dynamic models. However, there are at least three developments that may counteract this tendency.

First, with passive GPS data collection and various types of remote sensing, it is becoming possible to collect data on the same individuals and/or facilities over time without depending on survey respondents to fill in many questionnaires over time. We can expect that much more electronic data on "before and after" changes over time will become available, and that such data can be used to at least calibrate microsimulation models to produce realistic differences between short-term and longer-term elasticites to system changes, even if the models do not explicitly represent every dynamic aspect of behavior.

Second, the same advanced econometric methods that allow us to estimate models of taste variation and heterogeneity can also be used to estimate dynamic models including state-dependence and lagged effects. In essence, dynamic state-dependence can be thought of as a particular type of heterogeneity that depends on past choices and behavior, as well as a past history of exogenous influences.

Third, the microsimulation framework can be flexible enough to apply dynamic models, if applied with transition-based models of demographic evolution and residential and employment location changes. In that case, the person and household variables used in the models can include not only current year characteristics, but past year characteristics and recent transitions as well.

Scenario-based analysis: Travel demand forecasting as a field may be unique in its insistence on using single point forecasts for complex phenomena extending 20 or 30 years into the future. This practice may have been more appropriate when it was clear that travel demand per capita would continue to grow, and the main policy consideration was simply to provide adequate roads and transit service. Now, when growth in travel has started to flatten out, but concerns are growing related to congestion levels, land availability, health impacts, climate change and oil scarcity, it is no longer a given that extrapolating past trends is the best basis for studying the future. It is standard practice in many other fields to include at least three scenarios—low, middle and high growth—and possibly several more as well.

Use of different scenarios not only provides a range for forecasts and a way of testing the sensitivity of models, but it can also add an important additional criterion for policy evaluation—which alternatives are the most “future-proof”. If one policy is slightly inferior to another under central and high growth futures, but is highly superior in a low growth future, it may be prudent to adopt that policy in the interest of risk reduction. As the travel forecasting profession becomes more involved with investment grade forecasts in the context of private and public/private infrastructure funding, the importance of risk analysis—forecasting under a carefully designed range of exogenous assumptions—may come to be accepted. If that is the case, microsimulation models can help to make the extra effort involved in running additional forecasts worthwhile.

Perhaps one reason why scenario analysis with 4-step models has not been widely undertaken is that the outcome would appear to be predictable without going through the effort. Most aggregate models can only reflect road and transit capacity-related policies with any accuracy, and do not include a very wide range of behavioral responses to those policies. In that case, policies with high capital expenditure in long-life facilities, such as highways, will tend to be inferior in future scenarios with low income and/or population growth, and actually running the forecasts may not provide much more insight than that simple statement. With microsimulation models, however, it is possible to test a wider range of policies, including a variety of capacity addition policies, demand management policies and urban design policies. It is also possible to get a wider variety of outputs, such as which aspects of choice behavior are being affected most under various policy/scenario combinations, as well as who are the biggest winners and losers in terms of both geography and socio-economics. As the behavioral detail and spatial and temporal detail in the models increase, scenario analysis can become an important learning process for policy analysts.

Investigating the results: Currently, we tend to look at mode splits, trip lengths, highway link volumes and speeds and transit passenger loads forecast by our models, but look at very little else in any detail. Because microsimulation models produce travel and activity lists in an output format similar to household travel/activity diary surveys, we can perform virtually any type of analysis with the forecast output that we can with survey data. This has often been touted as an advantage of the microsimulation approach, but it is one that has not been greatly exploited as of yet. It will require some imagination, as well as good GIS and database software, to depict the model forecasts in ways that are both intuitive and informative.

How could such detail prove beneficial to decision makers besides providing pretty maps and graphics? One use may be to identify population segments and geographic areas that are most apt to change behavior in response to specific policies, and then make sure that those people are aware of the policies and encouraged to respond in appropriate ways. Such “social marketing” strategies can be expected to become more and more a part of the planners’ arsenal for keeping the transportation system functioning as other strategies become infeasible or inadequate. To use a model in this way, however, may also require a fundamental shift in the way that many planners approach models—moving from an attitude of “show me what I already know” to “show me something I didn’t already know”. That in turn, would require a level of trust in the behavioral “guts” of the models that existing 4-step models generally have not earned.

Conclusions

As compared to research carried out in academia, applied activity-based models travel demand models in the US have adhered fairly closely to their aggregate forerunners in terms of the general decision hierarchies and the reliance on large scale cross-sectional household surveys for estimation data. A very important concurrent shift, however, has been the transition to a microsimulation-based model application framework. The preceding sections have discussed some ways in which the level of disaggregation and flexibility inherent in the microsimulation approach could allow us to apply a wide range of behavioral research findings, much of it from other data sets and research contexts. Examples include representation of taste variation, state-dependence and other types of heterogeneity, representation of impacts on physical activity and health, studies of parking behavior, and use of models in social risk analysis and social marketing. It is likely that several other new possibilities will arise as well as we gain more expertise in creating and using the models, and as we integrate models to simulate land use, travel demand, and network performance in a consistent manner.

References

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