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Goulias, Konstadinos G.

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Konstadinos G. Goulias

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A Dynamic Microsimulator for Travel Demand Forecasting

Konstadinos G. Goulias

Department of Civil Engineering
The Pennsylvania State University

Working Paper, No. 95

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A Dynamic Microsimulator for Travel Demand Forecasting

Konstadinos G. Goulias
Assistant Professor of Civil Engineering
The Pennsylvania State University
University Park PA, 16802

Research Summary

1. Introduction

The use of cross-sectional models in travel demand forecasting involves some fundamental problems. First, it is based on the untested assumption that cross-sectionally observed variations in travel behavior can be used as valid indicators of behavioral changes over time. Second, future values of socioeconomic and demographic input variables are obtained using inaccurate allocation and post-processing methods to transform aggregate forecasts into "pseudo-dissaggregate" data. And third, it does not properly represent response lags involved in long-term mobility decisions (e.g., residence location and car ownership). The result is a questionable basis on which travel demand forecasts are made.

An alternative travel demand forecasting system, Microanalytic Integrated Demographic Accounting System (MIDAS), is presented in this paper. The system consists of two components: a microsimulator of household socioeconomics and demographics, and a dynamic model system of household car ownership and mobility. Each component is made up by models formulated at the household level. Replicated in the socioeconomic and demographic microsimulator, are interactions and causal paths that underlie lifecycle evolution of individuals and households. Simulation units evolve from year to year, experiencing marriages, divorces, births, deaths, and so forth. Employment, income, driver's license holding, education level, and household size and composition, are among the variables that are internally generated in the simulation. Numerous parameters have been provided for easy modification to represent different future growth paths.

The novelty of the approach here is the combination of dynamic models of travel behavior with sociodemographic and economic microanalytic simulation. The new forecasting tool is based on the following. Since simulation in general implies modelling of a process that evolves over time, dynamic disaggregate models -- models that explicitly include the time dimension at the level of the most elementary unit of analysis --- are the natural ingredient of the simulation. Hence, throughout the design of the tool here, dynamic models at the level of the household and the household member are used to replicate real world changes in sociodemographic characteristics and mobility.

The parameters of the model system have been estimated using observations from 5 contacts of the Dutch National Mobility Panel data, covering a period of four years between April 1984 through April 1988. Other sources of information, external to the Panel, were also used to estimate key parameters.

The model system is a flexible forecasting tool with which a wide range of future scenarios can be examined to answer a variety of "what-if" questions. It can replicate reality with accuracy comparable to other forecasting models and could replace the inaccurate allocation methods, often used to provide inputs for the travel demand models. However, the method is complex, poses high demands in model estimation, and requires a large amount of data.

In the next section, the structure of the microsimulator is presented together with a brief presentation of the system components. Following this, an example of forecasts is outlined. Section 3 contains an example of MIDAS forecasts and in section 4 a brief summary is presented.

2. Structure of MIDAS

MIDAS recreates the progression of a household through life cycle stages, and simulates changes in the household members' socioeconomic attributes and demographic attributes, such as employment status and driver's license holding. Then it uses these endogenously generated socioeconomic attributes to forecast household car ownership and mobility.

The MIDAS mobility component consists of a car ownership model, household motorized-trip generation models, a modal split model, car-trip distance models, and transit-trip distance models. All models are formulated for weekly totals. Note that these mobility measures are obtained from the Dutch Panel Survey, which is the repeated observation of households and household members every year between 1984 and 1989.

In the simulation, a household member will age, form an independent household, gain employment, obtain a driver's license, marry, give birth, and so on. The size and composition of the household will change accordingly. A household member may be added to a household through a marriage, or a household may be split into two through a divorce. A child will leave his parents and form a new household. Such changes are probabilistically generated in the simulation. The model parameters that determine the probability of these events are obtained from the Dutch Panel data set.

The most important probabilistic events represented by models are:

Birth and Death; The probability that a woman in a household will give birth to a child in a given year is expressed as a function of the age and employment status of the woman, and the number of children that already exist in the household. The probability of death is a cohort-based model.

Households Formed by Children; The event of "leaving the nest," i.e., a child moving out and forming an independent household, is modeled as a function of the age, sex, and employment status of the child.

Employment; The employment status of a person is determined using transition matrices developed by sex and age group.

Income Change Models; Given the employment status, the personal income is determined using a set of dynamic models with serial correlation for the four possible combinations of the employment status at time t - 1 and time t: (not employed, not employed), (employed, not employed), (not employed, employed), and (employed, employed).

Driver's License and Education; The driver license holding and education are determined using transition matrices similar to those for employment status.

New Household Members; A set of personal attributes needs to be generated whenever a new household member is introduced in the simulation. When a new person enters a household through a marriage, his/her age and education level is determined based on the existing member's age and sex. The new member's employment and income are then determined given his/her age and sex.

Household Dissolution; A household is split into two, or eliminated from the simulation, after a divorce, death or other events that cause its dissolution. If children are present in the household, they are randomly assigned to the respective parents.

The MIDAS Mobility Component is made of the following models:

Car Ownership Model; An ordered-response probit car ownership model is used to determine household car ownership. The model determines the probability that a given household will have no car, one car, or two or more cars. The model coefficients are estimated using the maximum likelihood method in five stages to account for possible biases due to the dynamic nature of the model.

Dynamic Motorized-Trip Generation Models; A weekly household motorized-trip generation model is developed and used separately for households with cars available and those without a car available. The estimation method used produces coefficients with all the desirable properties-efficiency, consistency, and unbiasedness.

Modal Split Model; A new model was created for this stage. The model is called Binomial Logistic and is presented in Goulias and Kitamura, 1991. The model predicts the relative frequency of household choices between two modes car and public transit(bus, tram, metro). The model is estimated by the maximum likelihood method.

The socio-demographic component is integrated with the mobility component (car ownership, trip generation, modal split) to form a comprehensive simulation system and perform travel demand forecasting for every year between 1986 and 2010.

3. MIDAS Forecasting

Most model parameters are estimated using subsamples from the Dutch Panel data set. Observed Dutch Panel household and person attributes of 1984, 1985 and 1986 are used as initial conditions -- this is a properly weighted subsample to resemble the Dutch population -- in the simulation. Demographic and socioeconomic attributes and mobility levels of these (and internally generated new) households are simulated year by year to 2010 in MIDAS.

In this section, a parameter to control income growth is manipulated in one simulation exercise to represent the Dutch Central Planning Bureau's (CPB) "low", "middle", and "high" economic growth scenarios. There are numerous parameters in MIDAS that can be easily modified to enable a wide range of scenario analysis. The results of a "baseline" MIDAS run are first presented (hereafter called the middle scenario) in Table 1. These baseline results have been compared to observed Dutch National mobility statistics, car ownership forecasts produced using a cohort-based model, and mobility forecasts by a large scale national model and found

Table 1
Comparison of Three Income Growth Scenarios

	Base Year 1986	MIDAS Forecasts for 2010 by Income Growth Rate					
		Low		Middle		High	
Population (x 10^6)+	14.5	15.1		15.1		15.1	
Population, ≥ 12 Years Old (x 10^6)++	12.3	13.0		13.0		13.0	
Household Size	2.64	1.96	-26%	1.94	-27%	1.96	-26%
Labor Force Participation*	42.7%	41.3%		41.2%		41.1%	
Average Income per Employed Person	100	125		157		198	
Number of Licensed Drivers (x 10^6)**	7.19	10.22	42%	10.04	40%	10.06	40%
Percent of Licensed Drivers	49.6%	67.7%		66.5%		66.6%	
Number of Automobiles (x 10^6)**	4.50	6.80	51%	7.10	58%	7.40	64%
Automobiles per Person	0.31	0.45		0.47		0.49	
Automobiles per Household	0.82	0.88		0.90		0.96	
Automobiles per Driver	0.62	0.67		0.70		0.73	
Number of Motorized Trips per Week							
Per Person	9.35	12.51	34%	12.86	38%	13.38	43%
National Total (x 10^6)**	115.0	162.6	41%	167.2	45%	173.9	51%
Number of Car Trips per Week							
Per Person	8.28	11.21	35%	11.47	39%	11.99	45%
National Total (x 10^6)**	101.8	145.7	43%	149.1	46%	155.9	53%
Number of Transit Trips per Week							
Per Person	1.07	1.31	22%	1.39	30%	1.38	29%
National Total (x 10^6)**	13.2	17.0	29%	18.1	37%	18.0	36%

+CPB scenario.

++Van den Broecke Social Research (1987, Deel I, p.3, Deel IV, Table 1).
The 2010 figure adjusted to agree the CPB forecast.

*Among individuals of 15 years old and over (CPB), or 18 years old and over (MIDAS).

**MIDAS forecasts are expanded using the national population (of individulas of 12 years old and over for mobility measures).

to produce similar forecasts (Goulias, 1991).

The MIDAS baseline forecast (Table 1) represents an income growth of 57% by year 2010. The results in Table 1 are for year 1986 (base year), and 2010 only (due to space limitations). Simulation results are given for household size, labor force participation, license holding, automobile ownership, and for five mobility measures: number of motorized trips, number of car trips, and number of transit trips. All mobility measures are weekly totals including trips made on weekend. Nationwide figures are developed by multiplying national population estimates to the per-capita figures generated by MIDAS.

The results show a rapid decrease in household size, gradual increase and then decline in labor force participation, and increases in the driver population and household car ownership. All mobility figures show substantial increases.

Household size declines from the initial 2.64 in 1986 to 2.38 in year 2000, and 1.94 in year 2010. This represents a much more rapid decrease than the CPB scenario (2.3 in 2010). However, Central Bureau of Statistics (CBS) statistics indicate that the average number of persons per household declined from 2.95 in 1975 to 2.54 in 1985 (CBS, 1988). This represents a decline of over 0.4 person per household in a decade, or 0.041 person per year. The above decrease forecast by MIDAS, i.e., 0.44 person in the first 15 years and 0.26 in the following 10 years, may in fact accurately reflect the observed trend. The continuing decline in the twenty-first century depicted by MIDAS may reflect the aging of the population. Should there be reasons to believe that this trend may change in the future, then MIDAS is capable of generating forecasts reflecting such changes.

Household size and driver's license holding are assumed to be independent of income in MIDAS. The slight differences found for these variables across the three scenarios are purely due to random variations in the simulation, and vanish when the number of repetitive simulation runs is increased for each scenario.

More importantly, employment is assumed to be independent of household income or wage rates in the current version of MIDAS. In fact employment decision is likely to depend on both household income, wage rates, and family size. For example, a secondary worker in a household may choose to work or not to work depending on the income provided by the principal worker. The secondary worker may also decide to participate or not to participate in the labor force depending on the wage rates available. The current version of MIDAS uses a simple probabilistic approach to employment, and does not reflect these aspects of labor force participation decision.

The number of cars is forecast to increase by 51% by 2010 under the pessimistisch growth scenario, 58% under the middle scenario, and 64% under the optimistisch scenario. Clearly a higher income growth rate leads to a higher level of car ownership, but these car ownership growths exceed the income growths at the low income levels and are not as fast as the income growths at the higher income levels (25%, 57% and 98%, respectively). At the nationwide level, motorized-trip rates grow virtually at the same pace as car ownership. Car trip rates also show growth rates similar to those of car ownership.

Public transit trip rates, on the other hand, show more complex growth patterns; the trip rate is higher for the high scenario (29%) than for the low scenario (21%), while it is the highest for the middle scenario (30%). Apparently two forces are at work. When income growth is slow, the lower car ownership level leads to more frequent use of public transit and lower use of long distance rail. On the other hand, higher income implies more long distance rail trips, leading to the highest transit trip rate with the middle scenario. When average income reaches extremely high levels then transit use begins to decline again.

4. Conclusions

This study represents an entirely new approach to travel demand forecasting. Unlike the conventional approach of using externally produced aggregate demographic and socio-economic forecasts as input to a cross-sectionally estimated model system, the dynamic system of this study, MIDAS, generates demographic and socio-economic, as well as car ownership and mobility forecasts internally through microsimulation. A system of dynamic models, estimated using the Dutch National Mobility Panel data set is applied in the simulation.

The use of microsimulation is motivated by its flexibility and its ability to forecast direct and indirect effects of the simulated policies on the system analyzed. Microsimulation helped to fill the gap in forecasting the input to travel demand models and provided the framework to design the new dynamic forecasting tool illustrated in this summary.

The dual methodological role of the effort summarized in this study is a) attempt to close the gap existing between travel demand forecasting and demographic forecasting, using concepts of dynamic analysis of travel behavior; and b) provide a didactic instrument that can be used as a test-bed for alternative behavioral theories and models, i.e. a tool that can incorporate assumptions and perform tests of validity intelligibly.found to be a credible and flexible forecasting tool.

The primary objective of the study — to determine whether long-range travel demand forecasting can be practically and meaningfully performed using microsimulation with a system of dynamic models and parameters estimated using a panel data set — has been met along with the secondary objective — to design a flexible tool for building scenarios based on alternative policy strategies. The forecasting exercise reported here offers evidence that a dynamic microsimulator is a feasible, credible, and flexible forecasting model system. One of its strengths lies in the fact that it can internally generate pertinent demographic and socio-economic factors while maintaining coherent relationships among them. However, the model system is complex, requires substantial effort for estimation of the models, and needs a sizeable amount of data.

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