A UNIFIED MODEL SYSTEM OF ACTIVITY TYPE CHOICE, ACTIVITY DURATION, ACTIVITY TIMING, MODE CHOICE, AND DESTINATION CHOICE

Naveen Eluru University of Texas at Austin
Abdul R Pinjari University of South Florida
Ram M Pendyala Arizona State University
Chandra R Bhat University of Texas at Austin

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Outline

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- Modeling Methodology
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Introduction

- Recognition and move towards activity-based models
  - Desire to better understand how pricing policies and technological innovations impact travel demand
  - Concerns regarding global climate change
- Activity based models explicitly recognize
  - Travel is undertaken to fulfill activity needs and desires dispersed in space and time
  - Universally strive to mimic and replicate activity-travel choice processes of individuals

Introduction

- These choice processes include:
  - activity type choice
  - time of day choice
  - trip chaining or linking choice
  - joint versus solo activity engagement choice
  - destination choice
  - mode choice
  - activity sequencing decisions
  - activity time allocation (duration) decisions
- Many of these choice processes are discrete in nature, while a few may be continuous in nature

Introduction

- Given the large number of choices that are involved in the behavioral process current models resort to the adoption of deeply nested logit models
  - One choice process is nested within another choice process and so on, forming a long chain of inter-connected nests to complete the representation of the behavioral process
  - As it is virtually impossible to estimate such long chains of nested logit models simultaneously (i.e., in one single step), components of the nested logit model are usually estimated one step (or maybe two steps) at a time and the logsum from one level is carried up to the next higher level, resulting in a sequential estimation and model application approach

Introduction

- The sequential treatment of choice mechanisms is convenient from a practical model estimation
- However, from an application standpoint, it is unclear whether such model systems truly replicate behavioral processes. By imposing sequence on the choice process are we really moving away from conventional four step model
- There is considerable evidence that many choices are made jointly or simultaneously and that there are significant unobserved factors that simultaneously impact multiple choice dimensions
- Further, it is important to incorporate the influence of activity travel environment (including level of service measures) on activity participation

Introduction

- An implicit recognition that individuals and households are making a "package" of activity-travel choices as a "bundle"
- This paper presents a joint model system of five choice dimensions:
  - Activity type choice
  - Activity time of day choice (treated as discrete time intervals)
  - Mode choice
  - Destination choice
  - Activity duration (continuous choice dimension)

Introduction

- This paper aims to specify and estimate a comprehensive econometric model system that jointly models these five choice dimensions
- The model system explicitly includes consideration of built environment attributes including level of service variables and spatial land use characteristics to capture the potential impacts of such variables on the activity generation process
- Such a model specification provides the ability to examine induced and suppressed demand effects in response to changes in system capacity and level of service

Model Structure

- Alternatives include:
  - IH maintenance
  - IH Discretionary
  - five OH discretionary activity purposes (volunteering, socializing, recreation, meals, and shopping)
  - six time periods (3am-7am or early morning, 7am-9am or morning, 9am-12noon or late morning, 12noon-4pm or afternoon, 4pm-7pm or evening, and 7pm-3am or night)
  - two modes of travel (auto, and non-auto)

1 + 1 + (5x6x2) = 62

Model Structure

- Utility Expression

$$U(x)=\{\psi_1 \ln x_1\}+\left\{\gamma_2\psi_2 \ln\left(\frac{x_2}{\gamma_2}+1\right)\right\}+\sum_{pim}\left\{\gamma_{pim}\exp\left(\max_{l\in N_{pim}} W_{lpim}\right)\ln\left(\frac{x_{pim}}{\gamma_{pim}}+1\right)\right\}$$

- Probability is given by

$$P(x_1^*,\ x_2^*,\ x_3^* \text{ at } a,\ x_4^* \text{ at } b,\ ...,\ x_Q^* \text{ at } q,\ 0,0,0,...0)$$
$$= P(x_1^*, x_2^*, ...x_Q^*, 0, 0, ...0)\times P(a\,|\,x_3^*>0)\times P(b\,|\,x_4^*>0)...P(q\,|\,x_Q^*>0)$$

- Where MDCEV probability is

$$P(x_1^*, x_2^*, ..., x_Q^* 0, 0, ..., 0)=\left[\prod_{k=1}^{Q} r_k\right]\left[\sum_{k=1}^{Q}\frac{1}{r_k}\right]\left[\frac{\prod_{k=1}^{Q} e^{V_k}}{\left(\sum_{k=1}^{K} e^{V_k}\right)^Q}\right](Q-1)!,$$

- MNL proabability is

$$P(l\,|\,x_k^*>0;\ l\in N_k)=\frac{\exp\left(\frac{\phi' w_{lk}}{\theta_k}\right)}{\sum_{l\in N_k}\exp\left(\frac{\phi' w_{l'k}}{\theta_k}\right)}$$

Interpretation

- The parameters φ and θ_k appear in both the MDCEV probability expression as well as the standard discrete choice probability expression for the choice of activity location to create jointness between the multiple discrete-continuous and single discrete choices
- Further, the logsum term appearing in the MDCEV probability expression carries the accessibility of destinations (or potential locations) from the single discrete location choice model to the MDCEV model of time investment by activity purpose, timing, and travel mode

Model Structure

- Location choice component
  - Sampling of location alternatives

$$\ln\left(\pi_k \sum_{l \in \text{a random sample of } N_k} \exp\left(\frac{\phi' w_{lk}}{\theta_k}\right)\right) \approx \ln \sum_{l \in N_k} \exp\left(\frac{\phi' w_{lk}}{\theta_k}\right)$$

  - In this study, 30 location choice alternatives are randomly sampled from 1099 potential locations yielding, π_k=36.63

Data

- 2000 San Francisco Bay Area Travel Survey (BATS)
- The analysis in this paper was restricted to the sample of 5,360 non-working individuals aged 16 years or above
- The travel survey records were augmented extensively with several secondary data items
  - Land-use characteristics, transportation network level-of-service data, and Census population and housing data
- In addition, geo-referenced data on businesses, bicycle facilities, highways and local roads were used to derive spatial variables characterizing the activity-travel environment (ATE)

Dependent Variable Distribution

ACTIVITY PURPOSE and TRAVEL MODE	Number (%) of non-workers participating, and mean duration of participation among those participating	ACTIVITY TIMING: Early Morning (3am-7am)	Morning (7am-9am)	Late Morning (9am-12pm)	Afternoon (12pm-4pm)	Evening (4pm-7pm)	Night (7pm-3am)
		63 (2.3%) 140 min	382 (13.9%) 169 min	1131 (41.1%) 121 min	1257 (45.7%) 97 min	720 (26.2%) 103 min	371 (13.5%) 111 min
Maintenance	5360 (100%) 651 min	--	--	--			
IH Discretionary	2133 (39.8%) 341 min	--	--	--			
OH Discretionary	2752 (51.3%) 163 min	--	--	--		--	--
OH Discretionary Auto mode	2473 (89.9%) 158 min						
Volunteering	396 (14.4%) 149 min	4 (1.0%)	81 (20.5%)	137 (34.6%)	89 (22.5%)	72 (18.2%)	63 (15.9%)
Socializing	508 (18.5%) 128 min	6 (1.2%)	20 (3.9%)	125 (24.6%)	159 (31.3%)	97 (19.1%)	77 (15.2%)
Meals	809 (29.4%) 115 min	13 (1.6%)	90 (11.1%)	206 (25.5%)	270 (33.4%)	223 (27.6%)	84 (10.4%)
Non-Maintenance	1092 (39.7%) 60 min	4 (0.4%)	46 (4.2%)	372 (34.1%)	571 (52.3%)	175 (16.0%)	53 (4.9%)
Recreation	738 (26.8%) 145 min	33 (4.5 %)	116 (15.7%)	256 (34.7%)	200 (27.1%)	115 (15.6%)	88 (11.9%)
OH Discretionary Non Auto mode	432 (15.7%) 134 min						
Volunteering	37 (1.3%) 170 min	2 (5.4%)	9 (24.3%)	10 (27.0%)	8 (21.6%)	3 (8.1%)	6 (16.2%)
Socializing	72 (2.6%) 140 min	0 (0.0%)	3 (4.2%)	19 (4.2%)	27 (37.5%)	21 (29.2%)	4 (5.6%)
Meals	135 (4.9%) 119 min	1 (0.7%)	9 (6.7%)	35 (25.9%)	54 (40.0%)	25 (18.5%)	18 (13.3%)
Non-Maintenance	132 (4.8%) 59 min	0 (0.0%)	4 (3.0%)	50 (37.9%)	62 (47.0%)	12 (9.1%)	6 (4.5%)
Recreation	131 (4.8%) 136 min	1 (0.8%)	14 (10.7%)	52 (39.7%)	33 (25.2%)	32 (24.4%)	6 (4.6%)

1096 + 166 = 1262

Empirical Analysis

- Model estimation was performed using Gauss code written specifically to estimate the joint MDCEV-MNL model system
- Although it would have been ideal to estimate a separate destination choice model for each of the 60 OH discretionary activity purpose-timing-mode combination categories, for this initial effort, a single MNL location choice model
- A variety of variables were included in the model specification including
  - household and personal socio-economic and demographic variables
  - contextual variables such as day of week and season of the year
  - spatial variables characterizing the activity-travel environment (ATE) density measures, activity opportunity and accessibility measures, and population and housing data for the neighborhood (traffic analysis zone)

Model Fit

- A comparison was made between the joint MDCEV-MNL model that integrates destination choice with activity choices and an independent MDCEV-MNL model that does not incorporate the log-sum parameters in the MDCEV component using BIC
- The BIC value for the MDCEV-MNL model (with 103 model parameters) is,150514.2 which is substantially lower than that for the independent MDCEV-MNL model (152334.2 with 102 model parameters)

Results -MDCEV

- Larger household sizes are associated with greater levels of participation in maintenance activities (in and out of home)
- Single persons are more prone to out-of-home socializing and recreation in the evening
- The presence of very young kids motivates activity engagement in the prime period of the day as opposed to early mornings and late nights
- The number of working adults contributes negatively to activity engagement in the middle of the day
- Higher levels of car ownership contribute negatively to in-home activity participation and non-auto mode use

Results -MDCEV

- Females are more likely to engage in volunteering and maintenance activities
- Younger individuals are likely to socialize in the evening and night, while older individuals (65+ years) are more likely to volunteer and not undertake night activities
- Fridays are associated with greater out-of-home discretionary activity participation, and night time activities

Results -MNL

Variable	Coefficient	t-stat
LOS Measures		
Auto peak travel time	-0.012	-11.82
Auto peak travel cost	-0.056	-2.59
ATE Attributes		
Density of bicycle lanes	0.129	7.75
Retail employment	-0.005	-5.70
Service employment	-0.005	-4.47
Logarithm of Total employment	0.405	29.06
Fraction of residential land-use	-2.272	-41.69
Logarithm of zonal area	0.056	5.44
Mean zonal household income	0.007	9.19
Accessibility to passive and natural recreation	-0.364	-2.92

Results -MNL

Variable	Coefficient	t-stat
Interaction with socio-demographics		
Density of bicycle lanes * age/100	-0.110	-4.84
Density of bicycle lanes * Continuous income x 10^{-5}	0.042	5.46
Density of bicycle lanes * household vehicles	0.025	4.94
Density of eat-out centers * female	0.003	3.26
Density of eat-out centers * Continuous income x 10^{-5}	0.010	13.31
Density of eat-out centers * age/100	0.027	32.64
Density of eat-out centers * household size	0.014	28.96
Density of eat-out centers * Own household	0.002	2.17
Logarithm of household population * age/100	0.102	6.42
Logarithm of household population * household vehicles	0.011	3.32
Household density * No. of kids < 15yrs	-0.006	-1.32
Household density * household size	-0.001	-0.36
Household density * household vehicles	0.009	3.41
Accessibility to employment * household size	-0.003	-6.25
Accessibility to employment * Own household	0.008	15.38

Results -MNL

- Auto travel times and costs decrease the utility associated with choosing a destination for any activity type
- The presence of bicycle lanes, total employment, the size of the zone, and zonal household income positively impact destination choice for discretionary activities
- Retail and service employment, increasing fraction of land devoted to residential uses in the zone, and accessibility to passive and natural recreation contribute negatively to destination choice for the activity categories
- The long list of interaction terms demonstrates how household and personal socio-economic and demographic characteristics play a key role in influencing destination choice for discretionary activities undertaken outside home

Policy Simulation

- The major objective of this paper was to examine the influence of level of service measures and activity-travel environment (ATE) attributes on activity participation and time-use
- The model was used to examine the impacts of the following scenarios on activity and time use behavior:
  - Doubling travel cost across all time periods
  - Doubling travel cost during peak periods
  - Doubling travel cost for auto mode
  - Doubling travel time across all time periods
  - Doubling travel time during peak periods
  - Doubling travel time by auto mode

Policy Simulation Results

Alternatives	**Activity Purpose**						
Scenario details	Maintenance	IH Discretionary	OH Volunteer	OH Social	OH Meals	OH Shopping	OH Recreation
Travel cost measure increased by 100% for all time periods	0.01	0.02	-0.99	-1.00	-0.84	-0.91	-0.93
Travel cost measure increased by 100% for peak periods	0.00	0.00	-0.58	-0.05	-0.46	0.07	-0.29
Travel cost measure increased by 100% for auto mode	0.01	0.01	-1.16	-1.21	-0.27	-0.31	-0.83
Travel time measure increased by 100% for all time periods	0.04	0.06	-3.36	-3.40	-2.86	-3.09	-3.18
Travel time measure increased by 100% for peak periods	0.01	0.02	-1.88	-0.15	-1.53	0.22	-0.95
Travel time measure increased by 100% for auto mode	0.03	0.04	-3.85	-3.99	-0.95	-1.05	-2.73

Policy Simulation Results

Alternatives	Activity Timing						Travel Mode	
Scenario details	Early Morning	Morning	Late Morning	Afternoon	Evening	Night	Auto	Non-auto
Travel cost measure increased by 100% for all time periods	-0.92	-0.90	-0.92	-0.96	-0.92	-0.87	-1.00	-0.75
Travel cost measure increased by 100% for peak periods	1.34	-3.89	1.30	1.26	-3.93	1.34	-0.30	-0.19
Travel cost measure increased by 100% for auto mode	-0.77	-0.75	-0.69	-0.64	-0.68	-0.76	-2.10	2.48
Travel time measure increased by 100% for all time periods	-3.11	-3.07	-3.13	-3.26	-3.13	-2.95	-3.39	-2.57
Travel time measure increased by 100% for peak periods	4.41	-12.70	4.22	4.12	-12.83	4.37	-0.99	-0.64
Travel time measure increased by 100% for auto mode	-2.54	-2.51	-2.30	-2.12	-2.27	-2.54	-7.03	8.34

Policy Simulation Results

- Increases in travel cost lead to reduced out-of-home activity engagement and slight increases in in-home activity engagement
- Increases in travel cost during the peak period impact volunteer, eat-meal, and recreation activities more than others, and reduce peak period activity engagement while increasing off-peak activity engagement
- Increases in auto travel costs and times reduce the use of auto mode for activity engagement and contribute to enhanced mode shares for non-auto modes

Policy Simulation Results

- In general, travel time increases appear to have larger impacts than travel costs, suggesting that individuals are more time-sensitive when making activity-travel choices
- In terms of the modal impact, it appears that all day travel cost or time increases have a greater impact than a time-specific peak-period travel cost or time increase
- In terms of activity participation, it appears that individuals are more likely to respond to price and time scenarios that cover an entire day as opposed to those that are narrower in the time band of influence

Conclusion

- This study aims to present a comprehensive unified model system of activity-travel choices that is consistent with microeconomic utility maximization theory of behavior
- The activity-travel choice dimensions analyzed in this paper include
  - activity type choice
  - time of day choice
  - mode choice
  - destination choice
  - activity time allocation or duration

Conclusion

- These dimensions are modeled simultaneously using the multiple discrete continuous extreme value (MDCEV) model form while the destination choice is modeled using a classic multinomial logit model (MNL) component
- The model components are tied together within a utility maximization-consistent framework using logsum variables that reflect the accessibility of destinations for each activity type, timing, and mode combination
- Model estimation results and the policy simulation analysis showed that the model offers
  - behaviorally intuitive interpretation
  - goodness of fit statistically superior to that offered by an independent model system that treats various choice dimensions separately and sequentially

Conclusion

- The findings reported here support the notion that individuals make several activity-travel choices jointly as a "bundle", calling for the simultaneous modeling of various choice dimensions in a unifying framework
- Activity-travel model systems that resort to simulating the behavior of agents along the time axis may benefit from the adoption of model forms that are able to simultaneously predict multiple choice dimensions as a "bundle"
- Ignoring to do so may yield erroneous policy scenario predictions

THANK YOU

Any Questions?