A Joint Tour-Based Model of Vehicle Type Choice, Tour Length, Passenger Accompaniment, and Tour Type

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ABSTRACT

This paper presents a joint model of tour type (purpose), tour length, passenger accompaniment, and vehicle body type choice to simultaneously model several choice dimensions critical to tour-level activity-based travel demand model development. Over the past several years, travel demand modeling has moved into the era of activity-based models in which tours are the unit of analysis. When individuals undertake tours, there are a range of choice decisions that are made. This paper explores the simultaneity in the decision process associated with four choice dimensions, all of which are of much interest to travel modelers. The simultaneous choice model is capable of accounting for correlations among unobserved attributes that may be shared across choice dimensions thus accommodating error correlation structures. The model is an advanced econometric model that is estimated using new techniques that have only recently been introduced in the travel modeling literature.

INTRODUCTION

The promotion of environmentally sustainable travel choices and mobility patterns has taken center-stage in the transportation planning arena around the world. In view of heightened concerns about climate change impacts associated with personal vehicle travel, there is much interest in understanding the vehicle type choices of households and individuals (Spissu et al, 2009). Not only is it important to understand and model the mix of vehicle types present in a household, but it is also necessary to understand the usage patterns for different vehicle types to fully appreciate the environmental consequences of household and person vehicle usage patterns. Many households have different types of vehicles, including large utility vehicles or minivans, and smaller fuel-efficient compact cars or hybrid-fuel vehicles. There has been previous work examining the mix of vehicle types present in a household and the total mileage that different vehicles are driven (used) over the course of a year (Eluru et al, 2010). While that work offers a valuable basis to represent overall household vehicle fleet ownership choices and vehicle utilization patterns, it does not provide the level of disaggregate detail that planners may desire to analyze vehicle type choice and usage patterns.

Emerging travel demand models are activity-based models that focus on "tours" as the unit of analysis (as opposed to individual "trips") and are microsimulation models that explicitly model choices at the level of the disaggregate unit of interest. However, at this time, there is no tour-based or activity-based model that explicitly models the multitude of choice dimensions that characterize tour formation. This paper focuses on four choice dimensions that are critically important and of much interest to transportation modelers. These choice dimensions are the type or purpose of the tour, the size of travel party, the type of vehicle used to undertake the tour, and the total distance traveled.

This paper presents a joint model of vehicle type choice, tour length, tour type, and passenger accompaniment for automobile-tours undertaken by individuals in households that have a mix of vehicle body types. The unit of analysis is the tour to explicitly recognize the inter-dependency of trips among a tour, and to be consistent with the emerging focus of activity-based travel demand models on tours. Such a joint model can offer valuable insights. For example, there are interesting questions regarding the relationship between vehicle type choice and tour length that arise. Is the more fuel-efficient small vehicle used for longer tours? Is the larger vehicle used on tours where there are multiple individuals present, regardless of length of the tour? The joint consideration of vehicle type choice and tour length explicitly accounts for the endogeneity of tour length in the vehicle type choice process. An interesting policy outcome to test from such a model is whether policies that promote land use density may actually have a counter-intuitive effect of not providing the intended benefits from an environmental benefit perspective. If enhanced land use density serves to shift individuals to using non-motorized transport modes, then one can easily see that environmental benefits will result. On the other hand, if enhanced land use density results in shorter vehicular tours that households can monetarily afford to undertake with large utility vehicles, then the enhanced land use density may not yield the intended environmental benefits. Not only would the joint model system offer insightful policy implications, but it would also offer a mechanism for incorporating vehicle type choice and utilization explicitly in emerging tour-based models – a dimension that is often lacking in current models.

The paper utilizes the National Household Travel Survey (NHTS) data set of 2008 from the United States. This data set is a comprehensive data set of travel and provides detailed information about household and person characteristics, vehicle characteristics, and travel characteristics for a large sample of households in the United States. Each trip is associated with a unique vehicle identifier making it possible to identify the specific vehicle used for a trip and the tour of which the trip is a part. The subsample of households that have a mix of multiple vehicle types was extracted for the model estimation effort of this paper. A joint model of vehicle type choice, tour length, tour type, and passenger accompaniment is being estimated. In specifying the model system, a flexible Generalized Extreme Value (GEV) model structure is being employed to account for possible error correlations across vehicle type choice alternatives in households. A flexible Copula-based approach is being used to account for possible error correlations across the choice dimensions considered in this study. Thus, the model system estimated in this study is a rigorous econometric modeling methodology for simultaneously modeling multiple choice dimensions associated with tours. The authors have successfully used this approach in previous work to shed light on multiple choice dimensions underlying activity-travel demand (Eluru et al, 2009; Pinjari et al, 2008). The paper includes a detailed presentation of the methodology, estimation results, and policy simulation results demonstrating how tour-level choices considered in this paper are impacted by changes in explanatory variables.

DATA

In this paper, the 2008 National Household Travel Survey (NHTS) data set from the United States is used. The subsample employed for analysis in this paper includes only those households who have a mix of automobile body types (multiple vehicle households), have reported at least one automobile tour, and responded to the travel survey on a regular weekday (Monday through Thursday). Only automobile tours reported by respondents 15 years of age or over were considered in the analysis. This resulted in a total of 103512 tours performed by 65296 respondents residing in 38374 households. The average number of tours per person was 1.59 and the average number of tours per household was nearly 2.70. Table 1 provides a summary of some key descriptive variables.

Table 1. Sample Description

Characteristic	***Mean***	***Std. Deviation***
Number of vehicles in the household	2.8	1.1
Age of the respondent	50.9	15.9
% of respondents possessing driver's license	98%	0.13
% full time employed	48%	0.50
% male	48%	0.50
% employed	63%	0.48
Number of respondents in the household	3.0	1.3
Number of adults in the household	2.3	0.68
% households with income ≤ $79,999	47%	0.50
% households owning residence	95%	0.21
% households do not reside in Metropolitan Statistical Area (MSA)	21%	0.41
% households residing in MSA of population 1 million or more	47%	0.50
% households residing in urban area	59%	0.50
% households residing in urban cluster	9.6%	0.29
Number of children in the household (age less than 18 years)	0.76	1.1
% households where race of the householder: White	89%	0.31
% households where race of the householder: Hispanic	6.2%	0.24
Sample Size, N	103512 Tours	

TRIP CHAIN ANALYSIS

This paper considered tours of various types. Table 2 provides a univariate examination of the four choice dimensions of interest in this paper.

Table 2. Descriptive Characteristics of Trip Chains (N=103512)

Choice Dimension	***Frequency***	***Percent***
Vehicle Type Distribution		
Automobile/car/station wagon	42159	40.7
Van (mini, cargo, passenger)	12875	12.4
Sports utility vehicle	24719	23.9
Pickup truck	20164	19.5
Hybrid vehicle	3595	3.5

Tour Distance/Length Distribution		
< 5 miles	22360	21.6
≥ 5 and < 10 miles	18597	18.0
≥ 10 and < 15 miles	17385	16.8
≥ 15 and < 25 miles	19325	18.7
≥ 25 and < 40 miles	14224	13.7
≥ 40 miles	11621	11.2
Tour Passenger Accompaniment		
Solo Tour	28402	27.4
Joint Tour	60484	58.4
Partly Joint and Partly Solo Tour	14626	14.1
Tour Type		
Home-based Simple Work Tour	19125	18.5
Home-based Complex Work Tour	11234	10.9
Home-based Simple Non Work Tour	42651	41.2
Home-based Complex Non Work Tour	24141	23.3
Work-based Tour	6361	6.1
Total	103512	100.0

Home-based tours are those that begin and end at the home location. A work-based tour is one that begins and ends at work. Only home and work-based tours are considered as these two locations are often considered anchors or foci of trip making. A simple tour is one that includes only a single stop, while a complex tour includes more than one stop. Thus a home-based simple work tour is of the form H-W-H while a home-based complex work tour will include at least one non-work stop in addition to the work sojourn within the chain. A non-work tour is one that includes no work stop. A simple tour has only one non-work stop (of the form H-S-H) while a complex tour will have more than one stop within the chain.

From a sustainability perspective, it is of much interest to explore the various tour characteristics by auto vehicle body type. Table 3 shows the average characteristics of tours undertaken using different vehicle body types. Larger vehicles show lower tour travel times and shorter distances, but larger accompaniment values.

Table 3. Average Characteristics of Tours Undertaken by Different Vehicle Types

	Average				
Vehicle Type	Tour Travel Time (mins)	Tour Distance (miles)	Time spent at Stops (mins)	Number of Psgrs on Tour	Number of Stops
Automobile/car/station wagon	40.4	18.0	256.2	1.4	1.6
Van (mini, cargo, passenger)	37.3	15.8	215.9	1.9	1.7
Sports utility vehicle	39.2	17.3	246.3	1.6	1.7
Pickup truck	39.5	18.0	263.7	1.3	1.5
Hybrid vehicle	40.5	18.1	228.5	1.6	1.7

Table 4 shows how the various tour types are distributed across vehicle body type, considering traveling party situation. It is surprising to note that vans show the lowest percentage for joint tours. On the other hand, they have a much higher rate of utilization for solo tours and partially joint tours, perhaps reflecting the many trips undertaken by women – either solo to take care of household obligations or partially jointly as they chaufer children to and from activities.

Table 4. Tour Vehicle Body Type by Accompaniment Type

	Accompaniment Type			
Vehicle Type	Solo Tour	Joint Tour	Partly Joint and Partly Solo Tour	Total
Automobile/car/station wagon	38.4%	42.3%	38.6%	40.7%
Van (mini, cargo, passenger)	17.6%	8.6%	18.2%	12.4%
Sports utility vehicle	25.7%	22.3%	26.7%	23.9%
Pickup truck	14.3%	23.5%	13.0%	19.5%
Hybrid vehicle	4.0%	3.2%	3.5%	3.5%

With respect to distance, some trends are discernible. It does appear as though the car is used to a larger degree for the long tours while the van is used less for longer tours. This may again reflect the types of tours and the individuals undertaking the tours by van, as opposed to a conscious decision on the parts of travelers to use the more efficient vehicle (as opposed to the less efficient van) for longer tours. Indeed, pickup trucks are used to a greater degree for longer tours, presumably because of the versatility and space/size/capacity provided by pick-up trucks. Hybrid vehicles show a larger degree of utilization for the highest travel distance category.

Table 5. Tour Vehicle Body Type by Tour Distance

	Tour Distance					
Vehicle Type	< 5 miles	>= 5 and < 10 miles	>= 10 and < 15 miles	>= 15 and < 25 miles	>= 25 and < 40 miles	>= 40 miles
Automobile/car/station wagon	39.5%	40.5%	39.9%	41.2%	41.4%	43.1%
Van (mini, cargo, passenger)	14.2%	13.2%	12.6%	12.1%	11.4%	9.5%
Sports utility vehicle	23.6%	24.3%	24.9%	23.9%	23.4%	22.9%
Pickup truck	19.3%	18.4%	19.2%	19.6%	20.4%	20.5%
Hybrid vehicle	3.4%	3.6%	3.3%	3.3%	3.4%	4.0%

ANALYSIS BY TOUR TYPE

The type of tour (tour purpose) is another major dimension of interest in activity-based modeling, and it is often the case that tour-based model systems consider different tour types separately in the specification of models of mode and destination choice. Therefore, in this paper, a series of tabulations are presented to show how various tour dimensions of interest vary by tour type.

Table 6 presents average values of various dimensions for the different tour types. As expected complex tours have longer travel times and distances. Work tours tend to be longer, presumably because the commute trip tends to be longer than other types of trips. The time spent at stops is also higher for tours involving the work stop, primarily because the activity time includes time spent at the work location. Non-work tours have higher average number of passengers; these are likely to be joint tours with family members or chauffeuring tours. The average number of stops indicates that complex tours, on average have nearly three intermediate stops. The work-based tours average just a little over one stop, consistent with the notion that travel from work is usually for lunch, or work-based business, or a quick errand that can be undertaken within the constraints of a work schedule.

Table 6. Average Values of Tour Attributes by Tour Type

Tour Type	Average				
	Tour Travel Time (mins)	Tour Distance (miles)	Time spent at Stops (mins)	Number of Psgrs on Tour	Number of Stops
Home-based Simple Work Tour	41.8	21.0	447.1	1.1	1.0
Home-based Complex Work Tour	58.9	27.5	457.0	1.3	2.7
Home-based Simple Non Work Tour	28.0	12.0	138.5	1.7	1.0
Home-based Complex Non Work Tour	52.8	21.7	188.9	1.7	2.9
Work-based Tour	25.8	10.6	258.4	1.3	1.2

The next table, Table 7, shows the distribution of passenger accompaniment arrangement for each tour type. As expected home-based simple work tours tend to be solo tours, while home-based non-work tours tend to be joint or partially joint tours involving one or more passengers accompanying the driver. The home-based complex work tour shows a high percent of partly joint tours (one in three); this is likely due to stops on the way to and/or from work to serve passenger or carpool for some length of the trip.

Table 7. Distribution of Passenger Accompaniment by Tour Type

Accompaniment Type	Tour Type				
	Home-based Simple Work Tour	Home-based Complex Work Tour	Home-based Simple Non Work Tour	Home-based Complex Non Work Tour	Work-based Tour
Solo Tour	92.3%	61.6%	48.8%	41.6%	79.4%
Joint Tour	5.7%	5.3%	38.2%	38.8%	16.3%
Partly Joint and Partly Solo Tour	2.0%	33.0%	12.9%	19.6%	4.3%

Considerable focus in this paper is placed on the automobile type choice for tour-making. Table 8 presents the distribution of automobile body types by tour type. It appears that the complex tours and simple home-based non-work tours exhibit higher percentages for van and sports utility vehicle. These types of tours are likely to involve an accompanying individual, and may therefore involve the use of the family-oriented vehicle (which may be a van or sports utility vehicle).

Table 8. Automobile Body Type Choice Distribution by Tour Type

	Tour Type				
Vehicle Type	Home-based Simple Work Tour	Home-based Complex Work Tour	Home-based Simple Non Work Tour	Home-based Complex Non Work Tour	Work-based Tour
Automobile/car/station wagon	42.4%	41.7%	40.0%	40.2%	40.9%
Van (mini, cargo, passenger)	7.9%	10.7%	13.9%	15.5%	8.2%
Sports utility vehicle	22.6%	26.0%	23.8%	24.3%	22.9%
Pickup truck	24.5%	17.9%	18.7%	16.4%	24.0%
Hybrid vehicle	2.7%	3.7%	3.6%	3.6%	4.0%

Table 9 presents trip length distributions for the different tour types. The trip length distributions show some clear differences across tour types. Home-based complex work tours tend to be longer in length, primarily due to two factors – first, they are complex involving multiple stops and second, they involve travel to and from work, which tends to be longer than non-work travel. Home-based simple non-work tours tend to be smaller in length, with one-third being less than five miles in length. Work-based tours also tend to be rather short, with 42 percent less than five miles in length, and another 22.5 percent between five and 10 miles. Clearly, tours undertaken while at work are short in distance presumably due to the need to adhere to work schedule constraints.

Table 9. Trip Length Distribution by Tour Type

	Tour Type				
Tour Distance	Home-based Simple Work Tour	Home-based Complex Work Tour	Home-based Simple Non Work Tour	Home-based Complex Non Work Tour	Work-based Tour
< 5 miles	14.7%	4.1%	34.0%	8.1%	41.6%
>= 5 and < 10 miles	13.9%	10.1%	21.8%	17.0%	22.5%
>= 10 and < 15 miles	17.9%	14.0%	17.4%	16.8%	14.6%
>= 15 and < 25 miles	20.5%	22.8%	14.5%	24.9%	10.4%
>= 25 and < 40 miles	17.0%	24.7%	7.5%	19.0%	6.2%
>= 40 miles	16.0%	24.2%	4.9%	14.2%	4.8%

The analysis in this section clearly shows that there is considerable inter-dependence across tour attributes including tour type, vehicle body type choice, tour length, and passenger accompaniment (tour party size). It is therefore prudent to consider modeling these dimensions in a simultaneous equations framework that provides a rigorous analytical framework for estimating these activity-travel choices.

MULTINOMIAL LOGIT MODEL OF VEHICLE TYPE CHOICE

Due to the focus of this paper on sustainability considerations, a pure uni-dimensional choice model of vehicle type choice was estimated prior to the estimation of the more complex simultaneous equations model system. The vehicle type choice model considers four vehicle types – car, van, sports utility vehicle, and pickup truck. The hybrid vehicle alternative had to be eliminated from the choice estimation effort due to the small sample size and infrequent occurrence. Table 10 presents the multinomial logit model estimation results.

Table 10 presents estimation results. The pickup truck vehicle body type is considered the base or reference alternative. The constants indicate that the car and SUV vehicle types tend to be used more than the van and pickup truck, presumably because these vehicles are more prevalent in the fleets of household vehicles. Although it may be prudent eventually to estimate separate models for work tours and non-work tours, this preliminary model estimation effort considers tour type as an independent explanatory variable.

Table 10. Multinomial Logit Model of Vehicle Body Type Choice for Tours

	Car		Van		SUV	
Variable	coefficient	t-stat	coefficient	t-stat	coefficient	t-stat
Constant	0.3438	20.7	0.1081	3.6	0.3090	14.5
Tour distance in miles	0.0013	2.0	-0.0076	-7.6	-0.0037	-5.0
>2 vehicle occupants on tour	0.3975	17.3	1.1022	31.2	0.7849	27.7
Mixed joint and solo tour			0.5994	16.2	0.3474	12.3
Simple home-based work tour	-0.1414	-5.6	-0.3694	-8.7	-0.1914	-6.4
Complex home-based work tour	0.1567	5.2			0.1292	3.6
Complex home-based other tour	0.0693	3.4	0.3171	9.1		
Number of children			0.0997	9.3	0.0441	4.7
Household resides in non-urban region X Complex tour			0.1253	2.7	0.1238	3.8
Hhld income less than $40,000			-0.1008	-3.1	-0.1187	-4.6
Age ≤40 years			-0.2614	-8.5	-0.1871	-8.6
Log-likelihood Value: -7569.1	Number of observations: 102352					
ρ^2 adjusted: 0.46639						

Note: Pickup Truck alternative is the base/reference alternative.

It is found that tour distance has a significant negative impact on the use of Van and SUV vehicle types, and positive impact on the use of the car. This suggests that distance does play a role in influencing vehicle choice for tours. This is of critical significance from a sustainability policy perspective. The erstwhile exclusive focus on vehicle miles of travel is not sufficient to fully understand the extent to which land use patterns and household travel choices impact the environment. One must consider the vehicle type that is used for different types of trips. One can have short trips and tours, but if these trips and tours are being undertaken using large gas guzzling and highly polluting vehicles, then the lower vehicle miles of travel is not necessarily offering any environmental benefits over situations where cars are being driven for greater miles.

Presence of other passengers on a tour positively impacts choice of larger vehicles – the van and sports utility vehicle. All three vehicle types shown in the table are less likely to be used for a simple home-based work tour relative to the pickup truck. However, for complex home-based work tours (where individuals are presumably running errands and chauffeuring individuals on the way to/from work), the sports utility vehicle and the car exhibit positive coefficients. For complex tours not involving a work stop, the van and the car are more likely to be chosen reflecting the potential that these tours are undertaken by the adult in the household with primary household and child care responsibilities. Households in non-urban regions are more likely to go with larger vehicle types such as vans and sports utility vehicles. Lower income households are less likely, on the other hand, to choose the van and sports utility vehicle (presumably because these vehicles are more expensive to own and operate). Younger individuals appear less likely to use larger vehicles, presumably because they have not entered the lifecycle stage associated with larger household sizes and presence of children.

CONCLUSIONS

Overall, it is clear from the analysis in this paper that there are several attributes of tours that influence one another with important implications for achieving sustainable development patterns and for modeling activity-travel demand in a tour-based paradigm. Many tour based models currently ignore vehicle type choice in the context of modeling travel demand. When a policy appears to reduce VMT, the presumption is that environmental benefits will be realized. Likewise, when a policy appears to increase VMT, the presumption is that environmental impacts will be adverse. However, in the absence of adequate consideration of the vehicle type choice dimension, erroneous conclusions may be drawn. If reduced VMT is associated with the use of larger more polluting vehicles, and increased VMT (longer tours) is associated with the use of smaller more fuel efficient vehicles, then the expected impacts may not materialize as originally anticipated. Environmental benefits may not be realized from measures that reduce VMT and tour lengths, and adverse environmental impacts may not result due to increases in VMT and tour lengths. The final presentation at the conference will offer a comprehensive rigorous econometric model system of tour type, vehicle type, tour length, and number of vehicle occupants that can be used to estimate these choice dimensions simultaneously while accounting for unobserved attributes that impact multiple dimensions of interest.

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