On Modeling Adults' Weekend Day Time Use by Activity Purpose and Accompaniment Arrangement

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ABSTRACT
This paper examines the weekend time use patterns of individuals aged 15 years or older, with a specific emphasis on their maintenance and discretionary activities. The analysis also considers the social context of activity participation by considering the "with whom" dimension of the participations. The sample for analysis is drawn from the 2004 American Time Use Survey (ATUS). Bhat's multiple discrete continuous extreme value (MDCEV) model is used in the empirical analysis. The results underscore the importance of considering the social context of activity participation within the framework of activity based travel modeling.

Keywords: discretionary activities, adults' time use, weekend activity-travel behavior, activity based travel analysis, multiple discreteness

1. INTRODUCTION

1.1 Overview

The main focus of activity-based travel methods is on modeling the complete activity-travel schedule of individuals over a period of a day or a longer unit of time [see (*1*), (*2*), (*3*), and (*4*)]. One of the fundamental aspects of this activity-based paradigm is that individuals do not make their activity participation decisions in isolation. For instance, within a household, the activity-travel patterns of individuals are likely to be inter-linked because of sharing of household maintenance responsibilities by family members, joint engagement of household members in activities and travel, facilitation of activity participation of household members with restricted mobility, and sharing of common household vehicles. Similarly, beyond the confines of the household, an individual's activity-travel patterns may be linked with those of others because of car-pooling arrangements, social engagements, and joint recreational pursuits. In fact, a recent descriptive study of adult activity-travel patterns in the U.S. by Srinivasan and Bhat (*5*) indicates that about half of all out-of-home episodes on weekdays and about three-fourths of all out-of-home activity episodes on weekend days are pursued jointly with other individuals. Further, Srinivasan and Bhat also find that close to a half of all jointly participated episodes on weekdays and weekend days are pursued with non-household members. Clearly, a very significant fraction of out-of-home episodes are pursued jointly, and thus models recognizing these within-household and beyond-household social network linkages can better reflect the behavioral responses of households to land-use and transportation policy actions [see (*6*), (*7*), and (*5*) for extensive discussions of this issue].

To be sure, the need to recognize inter-individual interactions in activity decision-making is certainly not new [see (*8*), (*9*), (*10*), and (*11*)]. However, it is only in the past 5 years or so that this issue has started receiving the attention it deserves [see (*5-7*), (*12-24*); the reader is also referred to a recent special issue of *Transportation* edited by Bhat and Pendyala (*25*) on this topic]. While these earlier studies have contributed in important ways, they focus almost exclusively on intra-household interactions, and mostly on the interactions between the household heads. On the other hand, as just discussed, there is a significant amount of interactions in the wider social network beyond the household [see (*22*), (*26*), and (*27*)]. Many of the earlier studies also confine their attention to maintenance-oriented activities. But, as indicated by Srinivasan and Bhat (*5*), a high percentage of discretionary episodes are pursued with one or more companions, suggesting the important need to consider inter-individual interactions in discretionary activity (and not just in maintenance-oriented activity). Another limitation of most earlier joint participation studies has been the use of conventional activity-travel survey data that do not identify the activity/travel companions explicitly. The result is that these studies have had to use operational definitions of time-space matches to identify companions, which is not as accurate as collecting direct information on companionship.

1.2 The Current Paper

The broad objective of the current paper, motivated by the discussion above, is to model the social context of adult individuals' activity participation. Specifically, the emphasis is on examining the accompaniment arrangement (*i.e.*, company type) in activity participation, which is classified into four categories: (1) no one else (alone), (2) with only family members (including mother, father, siblings, and grandparents), (3) with only friends (including friends, colleagues, neighbors, co-workers, peers, and other acquaintances), and (4) with both family members and friends/acquaintances. Further, because of the limited attention in the earlier

literature on discretionary activity-related interactions, we focus on company type analysis for discretionary purposes. Within this context, we use a rather disaggregate classification of the discretionary activity category to accommodate differences in company type by discretionary activity purpose. The five discretionary activity purposes used in the paper are: (1) Social (attending/hosting social events and communicating with others, (2) Relaxing (relaxing and thinking, watching television, reading and writing for personal interest, computer use and board games for leisure), (3) Arts and Events (art-related hobbies, attending art events/concerts, and attending sporting events), (4) Sports (playing games and sports), and (5) Other physically active activities (including indoor and outdoor physical activities such as walking, biking, running, weight-training, swimming, and aerobics). [1]

In the current paper, we confine the analysis to weekend days because of the high prevalence of participation in discretionary activities over the weekends [see (*28*)], as well as because there is much more joint activity participation on weekend days relative to weekdays [see (*5*)]. We also focus on company type for out-of-home activity purposes, since almost all in-home episodes are pursued with family members. Besides, the accompanying arrangement for in-home episodes can be expected to be less structured and more spontaneous than for out-of-home episodes.

The data used in the empirical analysis is drawn from the American Time Use Survey (ATUS), which collects activity purpose information for all in-home and out-of-home episodes over the course of a day using a very disaggregate taxonomy. The survey also explicitly obtains information on all individuals accompanying the respondent for each activity episode. The ATUS data is confined to adults (15 years or older) and, thus, the focus in the analysis is on adults' activity patterns. The formulation used in this paper is the multiple discrete-continuous extreme value (MDCEV) model [see (*29*,*30*)], which is able to examine the factors that influence adults' time use in the 22 activity purpose-company type combinations considered in the study. These correspond to the combinations of 5 discretionary activity purposes and 4 company-types for out-of-home activities (=20 alternatives), a combined in-home (IH) discretionary activity (or leisure) category, and another maintenance activity category (in-home and out-of-home chores, grocery shopping, and other household service-related pursuits). All individuals invest some positive amount of time on the survey day in maintenance activities, and so this category serves as the "outside good" in the MDCEV formulation. The model is then able to predict daily participation choice and time use in each of the IH leisure and 20 out-of-home discretionary activity-company type combinations, given individual characteristics. The MDCEV formulation is ideally suited for the current analysis because it recognizes the diminishing marginal utility (or satiation) of an additional unit of time investment in any of the 22 alternatives. It also allows corner solutions (no participation) in one or more of the discretionary activity alternatives and accommodates multiple discreteness in participation (*i.e.*, participation in more than one alternative).

The rest of this paper is structured as follows. The next section provides details of the model used in our analysis. Section 3 describes the data source and sample formation procedures. Section 4 presents the results of the empirical analysis. Finally, Section 5 summarizes the important findings from the research.

[1] There is obviously some subjectivity in the classification adopted here, though the overall consideration was to accommodate differences between the disaggregate activity purposes along such contextual dimensions as location of participation, physical intensity level, duration of participation, amount of structure in activity planning, and company type of participation [see Srinivasan and Bhat (*5*)].

2. THE MODEL

This section of the paper discusses the basic structure of the MDCEV model in Section 2.1, followed by the introduction of a more elaborate error structure in Section 2.2.

2.1 Basic Structure

Consider, without loss of generality, that the first activity purpose corresponds to maintenance activity (grocery shopping, household chores, personal business, medical appointments, *etc*.). As one would expect, all individuals invest some time on maintenance activities over the weekend day. Let there be (*K*-1) additional alternatives, one of which is in home (IH) leisure and the rest of which correspond to the (*K*-2) alternatives corresponding to different out-of-home discretionary activity purpose-company type combinations (as indicated in the earlier section, *K* = 22 in the empirical analysis of the current paper). Let t_k be the time invested in alternative *k* (*k* = 1, 2, …, *K*), and consider the following additive, non-linear, functional form to represent the utility accrued by an individual (the index for the individual is suppressed in the following presentation)[2]:

$$U = \exp(\varepsilon_1)\ln(t_1) + \sum_{k=2}^{K} \gamma_k \exp(\beta' z_k + \varepsilon_k) \ln\left(\frac{t_k}{\gamma_k} + 1\right) \quad (1)$$

In the above expression, z_k is the vector of individual-related exogenous variables specific to alternative *k* (*k* = 2, 3, …, *K*; there is no such vector for the first alternative because of the presence of a time budget constraint, as discussed later). The term $\exp(\beta' z_k + \varepsilon_k)$ represents the random marginal utility of one unit of time investment in alternative *k* at the point of zero time investment for the alternative. This can be observed by computing the partial derivative of the utility function U with respect to t_k and computing this marginal utility at t_k = 0. Thus, $\exp(\beta' z_k + \varepsilon_k)$ controls the discrete participation decision of the individual in alternative *k*. We will refer to this term as the baseline preference for alternative *k*. The γ_k ($\gamma_k > 0$) terms for *k* = 2, 3, …, *K* are translational parameters that allow corner solutions for the individual's time use problem. That is, these terms allow for the possibility that the individual invests no time in certain alternatives *k* (*k* = 2, 3, …, *K*). There is no γ_1 term for the first alternative because all individuals invest some positive amount of time in maintenance activity (*i.e.*, only interior solutions are allowed for maintenance activity). The γ_k terms (*k* = 2, 3, …, *K*), in addition to serving as translation parameters, also serve the role of satiation parameters that reduce the marginal utility from investing increasing amounts of time in any alternative (of course, the log functional form used in the utility expression also contributes to decreasing marginal utility). For the inside "goods" (*k* = 2, 3, …, *K*), values of γ_k closer to zero imply higher satiation effects [*i.e.*, lower durations of time investment, subject to any time investments at all, in activity *k*; see (*30*)]. Note that, to maintain the constraint that $\gamma_k > 0$, we reparameterize γ_k as $\gamma_k = \exp(\lambda_k)$

[2] Several other additive, non-linear, utility forms, as proposed by Bhat (*30*), were also considered. However, the one provided below was the best form in the empirical analysis of the current paper.

and estimate the λ_k values. Of course, once the λ_k values ($k = 2, 3, \ldots, K$) are estimated, one can obtain the γ_k values[3].

From the analyst's perspective, the individual is maximizing random utility (U) subject to the time budget constraint that $\sum_{k=1}^{K} t_k = T$, where T is the time available to participate in maintenance and discretionary activities[4]. The optimal time investments t_k^* ($k = 1, 2, \ldots, K$) can be found by forming the Lagrangian function (corresponding to the problem of maximizing random utility U under the time budget constraint T) and applying the Kuhn-Tucker (KT) conditions. After cumbersome, but straightforward, algebraic manipulations, the KT conditions collapse to [see (*30*)]:

$$
\begin{aligned}
&V_k + \varepsilon_k = V_1 + \varepsilon_1 \text{ , if } t_k^* > 0 \ (k = 2, 3, \ldots, K) \\
&V_k + \varepsilon_k < V_1 + \varepsilon_1 \text{ , if } t_k^* = 0 \ (k = 2, 3, \ldots, K) \text{ , where} \\
&V_1 = -\ln t_1^* \text{ and} \\
&V_k = \beta' z_k - \ln\left(\frac{t_k^*}{\gamma_k} + 1\right) \ (k = 2, 3, \ldots, K)
\end{aligned}
\tag{2}
$$

The reader will note that only the utility differences ($V_k - V_1$) for $k = 2, 3, \ldots, K$ matter in the optimal time investments, as reflected in the KT conditions of Equation (2). This is because of the budget constraint. The time investment in the first alternative is immediately known once the time investments in the other alternatives are available [see (*30*) for a detailed discussion].

Assuming that the error terms ε_k ($k = 2, 3, \ldots, K$) in Equation (2) are independently and identically distributed across alternatives with a type 1 extreme value distribution, the probability that the individual allocates time to the first M of the K alternatives (for duration t_1^* in the first alternative, t_2^* in the second,……, t_M^* in the M^{th} alternative) is [see (*30*)]:

$$
P(t_1^*, t_2^*, \ldots t_M^*, 0, 0, 0, \ldots, 0) = \left[\prod_{i=1}^{M} c_i\right]\left[\sum_{i=1}^{M} \frac{1}{c_i}\right]\left[\frac{\prod_{i=1}^{M} e^{V_i}}{\sum_{k=1}^{K} e^{V_k}}\right](M-1)!, \text{ where} \tag{3}
$$

[3] Technically speaking, the γ_k parameters can be parameterized to be a function of individual characteristics as $\gamma_k = \exp(\lambda_k' w_k)$ where w_k is a vector of individual attributes (including a constant). Such a specification accommodates variations in satiation across individuals. However, in our empirical analysis, we did not find any statistically significant effect of individual characteristics on satiation effects.

[4] The total time available for maintenance and discretionary activities is considered to be exogenous in the current analysis. T is computed as 24 hours minus the time invested in sleep, work, work-related, education, and travel activities.

$c_1 = \left(\frac{1}{t_1^*}\right)$, and $c_i = \left(\frac{1}{t_i^* + \gamma_i}\right)$ for $i = 2, 3, \ldots, M$.

2.2 Mixed MDCEV Structure and Estimation

The structure discussed thus far does not consider correlation among the error terms in the baseline preferences of the alternatives. On the other hand, it is possible that individuals who like to participate in certain kinds of out-of-home discretionary activity, say social activity, due to unobserved individual characteristics will participate more than their observationally equivalent peers in all companion type arrangements involving social activity. Similarly, it may be that certain individuals have an overall unobserved tendency to participate with friends in activities (say, due to their social nature), and these individuals have a higher likelihood (than their observationally equivalent peers) to participate with friends in all activity purposes. Such error components can be accommodated by defining appropriate dummy variables in the z_k vector to capture the desired error components, and considering the corresponding β coefficients in the baseline preference of the MDCEV component as draws from a multivariate normal distribution. In general notation, let the vector β be drawn from $\phi(\beta)$. Then the probability of the observed time investment $(t_1^*, t_2^*, \ldots t_M^*, 0, 0, 0, \ldots, 0)$ for the individual can be written as:

$$P(t_1^*, t_2^*, \ldots t_M^*, 0, 0, 0, \ldots, 0) = \int_{\beta} P(t_1^*, t_2^*, \ldots t_M^*, 0, 0, 0, \ldots, 0 \,|\, \beta)\phi(\beta) d\beta, \quad (4)$$

where $P(t_1^*, t_2^*, \ldots t_M^*, 0, 0, 0, \ldots, 0 \,|\, \beta)$ has the same form as in Equation (3).

The parameters to be estimated in Equation (4) include the β vector, the λ_k scalars that determine γ_k ($k = 2, 3, \ldots, K$), and the σ vector characterizing the covariance matrix of the error components embedded in the β vector. The log-likelihood function involves a multivariate integral whose dimensionality is determined by the number of error components in β. The parameters can be estimated using a maximum simulated likelihood approach. We used Halton draws in the current research for estimation [see (*31*)]. We tested the sensitivity of parameters estimated with different number of Halton draws per observation, and found the results to be very stable with as few as 125 draws. In this analysis, we used 150 draws per individual in the estimation.

3. DATA SOURCE AND SAMPLE FORMATION

3.1 Data Source

The data source used for this analysis is the 2004 American Time Use Survey (ATUS). The survey, sponsored by the Bureau of Labor Statistics and conducted by the U.S. Census Bureau, collected detailed individual-level activity information for one day from a randomly selected adult (15 years or older) in each of a subset of households responding to the Current Population Survey (CPS) interviews [see (*32*) for details on survey, sampling, and administration procedures]. The detailed account of the respondent's activities includes the type of each activity episode (the classification is based on the Australian Bureau of Statistics 1997 time use survey), start and end times of each activity episode, location of activity episode participation, and who accompanied the respondent in the activity episode. For all out-of-home activities, additional

information on the type of the activity participation location (for example, bank, gym, workplace, *etc.*) is also recorded. Furthermore, data on individual and household demographics, employment characteristics, and characteristics of the day on which the activity is undertaken were also obtained.

3.2 Sample Formation

Several steps were involved in the process of generating the sample for analysis. First, all the sleep, work, work-related, education, and travel episodes were removed from the larger set of activity episodes undertaken by individuals during the survey day. The total time in the day (24 hours) less the time allocated to the above mentioned episodes provides the time available to an individual for maintenance and discretionary activities. Second, only individuals who were surveyed during a weekend day were selected. Third, all activity episodes were classified as maintenance activities or discretionary activities based on whether they involved maintenance shopping and household services, or whether they were undertaken for socializing and leisure. Fourth, all discretionary episodes were classified as in-home or out-of-home based on the location of participation, and all the in-home episodes were subsequently aggregated into a single category of in-home discretionary (leisure) activity. Fifth, the out-of-home discretionary (OHD) episodes were classified into one of five major categories: social, relaxing, arts and events, sports, and other physically active activities (referred to as active recreation). Sixth, each activity episode was classified into one of four accompaniment types: no one else (alone), with only family members (family), with only friends (friends), and with both family members and friends (combination). In the rest of this paper, we will use the short form (in parenthesis) to refer to the company types. Seventh, the total time invested during the weekend day in each of the 22 activity purpose-company type categories was computed based on appropriate time aggregation across individual episodes within each category. Eighth, data on individual and household characteristics, and other activity characteristics were appended to the data. Finally, several screening and consistency checks were performed, and records with missing or inconsistent data were eliminated.

3.3 Descriptive Time Use Statistics in Sample

The final sample for analysis includes the weekend time use of 6048 individuals aged 15 years or older. Table 1 presents the descriptive statistics of participation in each of the activity purposes defined in the study. As can be observed from the first row of the table, all individuals participate in maintenance activity on the survey day (see the column labeled “Total number (%) of individuals participating”). Also, the mean duration of time investment in maintenance activity is rather high at about 6 hours (see the second number column of the first row). The next row similarly indicates a high level of participation in IH leisure (93%), and a high level of time investment in IH leisure (a mean of about 4.5 hours). The remaining rows provide the statistics for out-of-home discretionary activity participation levels and time investments by purpose. These statistics indicate the relatively high level of participation in social activities and a low level of participation in sports activities. Also, when participated in, the time investment in arts and events is high, while that in active recreation is low. Overall, the results indicate the high baseline preference and low satiation toward maintenance activity and IH leisure relative to other out-of-home discretionary (OHD) activity purposes. Among the OHD activity purposes, there is a high baseline preference for social activity and a low baseline preference for sports. In

addition, there is a high level of satiation for relaxing and active recreation, and a low level of satiation for arts and events.

The last two columns in Table 1 indicate the split between single activity purpose participation (*i.e.*, individual participation in only one activity purpose category) and multiple activity purpose participation (*i.e.*, participation in multiple activity purpose categories) for each activity purpose. Thus, for instance, 166 of the 6048 individuals (3%) participate only in maintenance activity during the weekend, and 5882 (97%) participate in maintenance activity along with participation in one or more of the other activity purposes. For the IH leisure and out-of-home discretionary activity purposes, the single and multiple participations are computed as discussed in the notes in the table. The results clearly illustrate the high prevalence of participating in multiple activity purposes on the same weekend day, providing strong support for the use of the MDCEV model rather than standard discrete choice models.

Table 2 presents the number (percentage) of individuals participating in each of the out-of-home activity purposes on the basis of accompanying individuals. For instance, the entry for the "social-No one" cell indicates that 49 individuals (3% of the 1830 individuals participating in social activity) participate in social activity alone, while the entry for the "social-family" cell shows that 807 adults (44% of the 1830 individuals participating in social activity) participate with only family members (note that the percentages for each row across company types sum to more than 100% because of multiple discreteness in company types; for instance, an adult may participate in multiple social episodes on the same day, some in which the adult participates with family and others in which the adult participates with friends). The results reveal that individuals are most likely to pursue relaxing and active recreation alone, while they are very unlikely to pursue social activities alone. Among all the out-of-home discretionary activity purposes, arts and events are more likely to be pursued with family than other activity purposes, presumably due to common shared interests in specific hobbies/arts among family members. On the other hand, relative to other activity purposes, sports activities are much more likely to be pursued with friends.

4. EMPIRICAL ANALYSIS

4.1 Variable Specification

Several types of variables were considered as determinants of adults' time investment in each of the activity purpose-company type categories. These variables included (1) individual demographics (gender, ethnicity, education level, marital status, and age), (2) household demographics (household size, number of adults, presence and number of household children, and household income), (3) employment characteristics (employment status, number of working hours per week, full-time or part-time employment, and employment status of spouse), and (4) characteristics of the survey day (day of weekend and whether the weekend day is part of a holiday season such as Thanksgiving and Christmas). Several different functional forms for variables (such as linear and non-linear age/income effects and dummy variable specifications) were attempted. Additionally, different error components specifications to generate covariance patterns in the baseline preferences of the MDCEV alternatives were also considered. The final specification was based on intuitiveness, insights from the previous literature, and statistical fit considerations.

4.2 Empirical Results

The final specification results of the mixed MDCEV model are presented in Table 3. The maintenance activity purpose serves as the base category for most (but not all) variables. The results are presented so that the effect of each variable is first identified separately along the activity purpose and company type dimensions. The final rows of the table identify any interaction effects of the variable over and beyond the unidimensional effects[5].

4.2.1 Household Demographics

The household demographic effects in Table 3 show that adults in households with many other adults are more likely, relative to adults in households with fewer adults, to participate in maintenance and IH leisure pursuits. This is perhaps a reflection of high maintenance-related needs, and more opportunities for joint participation in IH leisure activities, in households with several adults [see (*33*) and (*34*) for a similar result]. Further, there is a higher disposition to participate in out-of-home discretionary (OHD) activities with friends, or friends and family, when there are several adults in the household. There is also a higher likelihood of participating in arts and events with family when there are several adults.

The number of children in the household also has an impact on discretionary activity participation levels of an individual. Specifically, as the number of children in the household increases, individuals show a lower preference for IH leisure activities. This may be associated with a need to have a change from caring for children in-home and/or reflect the higher propensity to participate in outdoor pursuits with young children [see (*35*) for similar results]. The presence of children in the household also makes it less likely for individuals to undertake activities with friends, though this effect is tempered for sports activities.

Finally, among the set of household demographics, the results reveal that individuals in low income households are more likely to participate in basic household maintenance activities, and the relatively inexpensive pursuits of IH leisure, out-of-home social and relaxing activities (rather than the more expensive out-of-home discretionary pursuits of arts and events, sports, and active recreation). This result is clearly a manifestation of financial constraints.

4.2.2 Employment-Related Variables

Employed individuals show a higher propensity than unemployed individuals to participate over the weekend in the relatively less physically strenuous activities of socializing and relaxing. Perhaps employed individuals consciously pursue the maintenance and high physical intensity discretionary activities over the weekdays, with the conscious choice to "take it easy" over the weekends. However, if the individual is employed full-time, s/he has a high likelihood of maintenance activity participation over the weekend, a reflection of time constraints during the work week. Full-time employed individuals also participate more with the family in weekend out-of-home discretionary pursuits, presumably to make up for the time away from the family on workdays.

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[5] Thus, the alternative specific coefficients for the "number of adults in household" variable are: Maintenance activity (0.148), IH leisure (0.204), social-alone (0.000), relaxing-alone (0.000), arts and events-alone (0.000), sports-alone (0.000), active recreation-alone (0.000), social-family (0.000), relaxing-family (0.000), arts and events-family (0.265), sports-family (0.000), active recreation-family (0.000), social-friends (0.204), relaxing-friends (0.204), arts and events-friends (0.204), sports-friends (0.204), active recreation-friends (0.204), social-combination (0.373), relaxing-combination (0.373), arts and events-combination (0.373), sports-combination (0.373), and active recreation-combination (0.373).

The spousal employment effects are also rather intuitive. It appears that individuals coordinate with their employed spouses to carve out time over the weekends to participate alone or jointly with the spouse in out-of-home discretionary activity pursuits. This is reinforced by the finding that individuals with employed spouses are less likely to participate with friends than with family or family and friends.

4.2.3 Individual Demographics

The effects of individual demographics reveal the important role of gender in weekend time use. Women have the primary responsibility for household maintenance activity, as reflected in the highly significant positive coefficient on the female dummy variable for maintenance activity. This result is consistent with the findings of several earlier studies [see (*10*), (*33*), (*36*)]. The higher participation level of women in arts and events reinforces the gender stereotype of women being more involved with arts and crafts, and social events, than men [see (*5*)]. Furthermore, the results show that women are more family-centric than men, and have a higher likelihood of undertaking out-of-home discretionary activities with family, or family and friends. It is also interesting that women are less likely to participate in sports with friends than are men.

Married adults, according to the estimation results in Table 3, invest more time than unmarried adults in household maintenance activities, possibly due to increased household responsibility. Such adults are also more likely than unmarried adults to pursue in-home leisure activities, and the physically active pursuits of sports and active recreation.

The age-related variables are introduced as dummy variables, with the category of greater than 60 being the base. The results show that young adults (15-40 years) are less likely than older adults to participate in social and active recreation, while middle-aged adults (41-60 years) are more predisposed toward arts and events. Young adults are also more likely than other adults to participate in out-of-home discretionary activities with friends and family, perhaps because of the increased opportunity to interact with individuals on both sides of their generational divide (for instance, a 30 year old adult is more likely to have children as well as parents to interact with, relative to a 50 year old whose interaction options may be more limited). Finally, the results indicate the increased likelihood of young and middle aged adults (15-60 years) to participate in sports with friends, while older adults (>60 years) appear to stay away from such high intensity physical pursuits.

The impacts of the education variables are rather interesting. Adults with a bachelor's degree or higher are less likely to pursue IH leisure, and more likely to participate in sports and active recreation. This result suggests an increased awareness among highly educated adults of the benefits of investing time in health and fitness-enhancing pursuits, and underscores the importance of a good education for a healthy society. The finding that highly educated individuals are less likely to participate with friends is not immediately intuitive, and needs further exploration in future studies.

The race-related effects of the Caucasian dummy variable reflect an increased participation propensity in IH leisure and active recreation among Caucasians relative to other races. The latter result may be indicative of cultural issues or racial inequity in the accessibility to adequate recreation facilities.

4.2.4 Survey Day Characteristics

Table 3 indicates that individuals are more likely to participate in maintenance and IH leisure activities on Sundays than on Saturdays. This finding is consistent with those of several earlier

studies [see (*28*) and (*35*)], and reinforces the notion that Sundays serve as "rest" days to transition between the weekend and the upcoming work week. Further, any out-of-home discretionary pursuits on Sundays are more likely to revolve around the family than those on Saturdays.

Finally, the weekend days that are a part of holidays (such as Thanksgiving, Hanukah or Christmas) are more likely spent relaxing outside home. The out-of-home discretionary activities are also more likely to be pursued with family, or family and friends. These results reflect reunions with close family/friends, and attendance at such events as parades and office parties.

4.2.5 Baseline Preference Constants

The baseline preference constants (Table 3) capture generic tendencies to participate in each discretionary activity purpose category (note that there are only dummy independent variables in the specification, and thus the baseline preference constants reflect overall alternative preferences for the base population segment defined by the combination of the base categories across the dummy exogenous variables). All the baseline preference constants for the out-of-home discretionary activities are negative, indicating the overall higher participation levels in IH leisure and maintenance activity.

4.2.6 Satiation Parameters

The satiation parameter γ_k ($k = 2, 3, ..., K$) for the inside goods (*i.e.*, the 21 discretionary activity alternatives) influence the length of participation in any alternative. Specifically, the higher the value of γ_k, the less is the satiation effect in the consumption of the alternative *k* [see (*30*)].

Table 4 provides the estimated values of γ_k and the corresponding t-statistics values. The satiation parameter values are significantly different from 0, thereby indicating that there are clear satiation effects in discretionary activity time investments. The results indicate low durations of participation in social activities, when such activities are participated alone or with family. On the other hand, the satiation levels are low (*i.e.*, high duration) for the following categories: (1) relaxing with family and friends, (2) solo participation in arts and events, (3) sports alone or with family, (4) active recreation with family, and family and friends. Overall, the results reflect different levels of satiation based on activity purpose and accompaniment type.

4.2.7 Error Components

The final specifications included two error components - one specific to the activity dimension, and the other specific to the company type dimension (see Section 2.3). The out-of-home activity dimension error component had a standard deviation of 0.585 (with a t-statistic of 9.52), and the company type error component had a standard deviation of 1.300 (with a t-statistic of 33.34). These error components indicate that there are common unobserved factors that predispose individuals to participate in specific activity purposes and in specific company types arrangements. For instance, an individual predisposed to social activity, because of such unobserved factors as being a social extrovert, has a high baseline preference for all company type arrangements involving social activity. Similarly, an individual who is family-focused participates with the family more in all out-of-home activity purposes compared to her/his observationally equivalent peers. These correlation effects are very highly significant from a statistical standpoint.

4.2.8 Overall Likelihood-Based Measures of Fit

The log likelihood value at convergence of the final joint model is -10554. The corresponding value for the model with only the MDCEV baseline preference constants and the satiation parameters is -11783. The likelihood ratio test for testing the presence of exogenous variable effects and unobserved heterogeneity is 2457, which is substantially larger than the critical chi-squared value with 48 degrees of freedom at any reasonable level of significance. This clearly indicates variations in the time investments among many of the discretionary activity purpose-company type combinations based on household demographics, individual demographics, employment attributes, day of the weekend effects, and unobserved individual characteristics. The model in this paper can be applied to examine the time use impacts of changes in any of these independent variables.

5. CONCLUSION

This paper uses the MDCEV formulation to examine adults' weekend day time investments in maintenance, in-home leisure, and out-of-home discretionary (OHD) activities. The formulation considers the social context of OHD participation by modeling time use by the type of accompanying arrangement. The data used in the analysis is drawn from the American Time Use Survey (ATUS), which collects a very detailed one-day activity dairy from a sample of adults (15 years or older) responding to the Current Population Survey (CPS) interviews. Unlike conventional activity-travel surveys, the ATUS survey explicitly collects information on all accompanying family and non-family members for all activity episode participations. Thus, it is an ideal dataset for exploring the social context of adults' time use and activity participation[6].

The results provide important insights into the determinant of adults' weekend day time use behavior. For instance, the results show that adults in low-income households participate less in expense involving out-of-home discretionary pursuits than do adults in high-income households, reflecting monetary constraints. There are also distinct gender differences, with women pursuing more of the maintenance activities, and being more family-centric in their pursuit of out-of-home discretionary activity, than men. Household composition, marital status, age, education, race and the day of weekend also have important effects on adults' weekend time use, and the social context of the time use.

In summary, the results underscore the substantial linkages in the activity participation of adults with other family and non-family members. The extent of this linkage varies by type of activity, household demographics, individual demographics, and the characteristics of the weekend day. These inter- and intra-family linkages, and their variations across individuals, need to be accommodated within the framework of activity-based travel modeling for accurate travel forecasting and reliable transportation policy analysis.

[6] A limitation of ATUS is that it does not collect locational information on household residences or activity episode participation locations. Hence, our analysis is unable to include built environment and locational effects on time use behavior. If available, this information can be incorporated as additional attributes in the MDCEV model.

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LIST OF TABLES

TABLE 1 Descriptive Statistics of Activity Purpose Participation

Activity purpose	Total number (%) of individuals participating	Mean duration of participation among those participating (min.)	Number of individuals (% of total number participating) who participate….	
			Only in activity purpose	In activity purpose and other activity purposes
Maintenance activity	6048 (100%)	371.29	166 (3%)	5882 (97%)
In-Home (IH) Leisure	5640 (93%)	259.15	2844 (50%)*	2796 (50%)*
Social	1830 (30%)	143.21	1164 (64%)†	666 (36%)†
Relaxing	879 (15%)	123.28	395 (45%)	484 (55%)
Arts and events	562 (9%)	169.18	278 (49%)	284 (51%)
Sports	229 (4%)	158.92	77 (34%)	152 (66%)
Active recreation	568 (9%)	112.84	278 (49%)	290 (51%)

* These numbers imply that 2844 (50%) of the 5640 adults who participate in IH leisure do so alone without participating in any other out-of-home discretionary activity, while 2796 (50%) participate in IH leisure along with one or more out-of-home discretionary activity purpose participations.

† The numbers for the out-of-home discretionary (OHD) activity purposes are computed to characterize multiple activity participations within the group of OH activity purposes. Thus, 1164 individuals (64%) out of the 1830 adults who participate in social activity do not participate in any other OHD activity category, while 666 adults (36%) participate in social activity along with other OHD activities.

TABLE 2 Number (%) of Individuals by Company Type Arrangement for Each Out-of-Home Discretionary Activity Purpose

Out-of-home discretionary activity purpose	**Number (%) of individuals within each purpose participating with…..**			
	No one	Family	Friends	Family and Friends
Social	49 (3%)	807 (44%)	679 (37%)	520 (28%)
Relaxing	263 (30%)	262 (30%)	84 (10%)	360 (41%)
Arts and events	51 (10%)	279 (50%)	162 (29%)	86 (15%)
Sports	15 (7%)	73 (32%)	116 (51%)	32 (14%)
Active recreation	249 (44%)	172 (30%)	144 (25%)	29 (5%)

TABLE 3 Empirical Results

	Household Demographics						Employment related variables					
	Number of adults in household		Number of children in household		Annual Household Income < 25k		Employed		Full time employed?		Spousal employment	
	Est.	t-stat	Est.	t-stat	Est.	t-stat	Est.	t-stat	Est.	t-stat	Est.	t-stat
'Activity' Dimension												
Maintenance activities	0.148	3.15	-	-	0.412	4.52	-	-	0.295	7.13	-0.321	-4.02
In-home(IH) leisure	0.204	4.28	-0.161	-9.06	0.558	6.08	-	-	-		-0.530	-6.58
Social	-	-	-	-	0.368	4.04	0.246	3.79	-	-	-	-
Relaxing	-	-	-	-	0.368	4.04	0.373	4.49	-	-	-	-
Arts and events	-	-	-	-	-	-	-	-	-	-	-	-
Sports	-	-	-	-	-	-	-	-	-	-	-	-
Active recreation	-	-	-	-	-	-	-	-	-	-	-	-
'With Whom' Dimension												
Alone	-	-	-	-	-	-	-	-	-	-	-	-
Family	-	-	-	-	-	-	-	-	0.194	2.48	-	-
Friends	0.204	3.37	-0.317	-7.72	-	-	-	-	-	-	-1.458	-14.46
Family and Friends	0.373	5.44	-	-	-	-	-	-	-	-	-	-
'Activity-With Whom' Dimension												
Arts and events – Family	0.265	3.09	-	-	-	-	-	-	-	-	-	-
Relaxing – Friends	-	-	-	-	-	-	-	-	-	-	-	-
Sports – Friends	-	-	0.174	1.86	-	-	-	-	-	-	-	-
Relaxing – Family and Friends	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 3 Empirical Results (cont.)

	Individual Demographics												**Survey day characteristics**			
	Female		**Marital Status**		**Age related variables (Age>60 is base)**				**Bachelor's or higher degree**		**Caucasian**		**Sunday**		**If the day was a holiday**	
					Between 15-40 years		Between 41-60 years									
	Est.	t-stat	Est.	t-stat	Est.	t-stat	Est.	t-stat	Est.	t-stat	Est.	t-stat	Est.	t-stat	Est.	t-stat
'Activity' Dimension																
Maintenance activities	0.727	10.83	0.521	6.60	-	-	-	-	-	-	-	-	0.217	3.79	-	-
In-home(IH) leisure	0.174	2.58	0.537	6.72	-	-	-	-	-0.250	-5.67	0.096	1.61	0.356	6.17	-	-
Social	-	-	-	-	-0.421	-5.35	-	-	-	-	-	-	-	-	-	-
Relaxing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.421	2.27
Arts and events	0.398	4.07	-	-	-	-	0.406	3.89	-	-	-	-	-	-	-	-
Sports	-	-	0.273	3.07	-	-	-	-	0.385	2.61	-	-	-	-	-	-
Active recreation	-	-	0.273	3.07	-0.300	-3.02	-	-	0.354	3.68	0.329	2.04	-	-	-	-
'With Whom' Dimension																
Alone	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Family	0.406	4.45	-	-	0.726	8.32	-	-	-	-	-	-	0.243	2.89	1.291	6.94
Friends	-	-	-	-	1.335	13.66	-	-	-0.379	-4.20	-	-	-	-	-	-
Family and Friends	0.616	5.55	-	-	0.747	6.88	-	-	-	-	-	-	-	-	0.884	3.61
'Activity-With Whom' Dimension																
Arts and events – Family	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Relaxing – Friends	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sports – Friends	-1.484	-5.80	-	-	1.426	2.67	1.535	2.81	-	-	-	-	-	-	-	-
Relaxing – Family and Friends	-	-	-	-	-	-	-	-	-	-	-	-	-0.491	-2.05	-	-

TABLE 3 Empirical Results (cont.) - Baseline preference constants

Baseline Preference Constants	Maintenance Activity*	In-home Leisure	Out-of-home Discretionary Activities				
			Social	Relaxing	Arts and Events	Sports	Active Recreation
	-	3.031 (29.08)	-	-	-	-	-
Alone	-	-	-3.335 (-17.43)	-1.821 (-12.66)	-3.619 (-18.32)	-4.787 (-16.22)	-2.037 (- 9.57)
Family	-	-	-0.947 (- 6.70)	-2.595 (-16.02)	-3.084 (-13.61)	-3.922 (-19.62)	-3.139 (-13.62)
Friends	-	-	-0.524 (- 3.81)	-1.655 (-10.90)	-2.529 (-15.09)	-3.809 (- 7.22)	-2.661 (-11.74)
Family and Friends	-	-	-2.171 (-12.78)	-4.306 (-19.26)	-4.160 (-20.43)	-5.509 (-21.24)	-5.722 (-18.88)

* Maintenance activity is the base category for the baseline preference constants.

TABLE 4 Satiation Parameters for Discretionary Activity Categories

Activity purpose – Company type combinations	Parameter	t-statistic*
In-home (IH) leisure	0.053	25.64
Social – Alone	0.039	3.80
Social – Family	0.037	9.51
Social – Friends	0.135	3.84
Social – Family and Friends	0.067	2.37
Relaxing – Alone	0.061	9.58
Relaxing – Family	0.087	15.36
Relaxing – Friends	0.105	8.83
Relaxing – Family and Friends	0.170	8.94
Arts and events – Alone	0.149	4.76
Arts and events – Family	0.085	7.84
Arts and events – Friends	0.062	14.12
Arts and events – Family and Friends	0.089	9.99
Sports – Alone	0.197	6.82
Sports – Family	0.193	5.66
Sports – Friends	0.132	6.61
Sports – Family and Friends	0.099	12.30
Active recreation – Alone	0.110	5.15
Active recreation – Family	0.245	4.62
Active recreation – Friends	0.138	3.29
Active recreation – Family and Friends	0.165	2.98

* The t-statistic is computed for the test that the satiation parameter γ is equal to 0.