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Space, money, life-stage, and the allocation of time

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Abstract. Demographic, socioeconomic, seasonal, and scheduling factors affect the allocation of time to various activities. This paper examines those variables through exploration of the 1990 Nationwide Personal Transportation Survey, which has been inverted to track activity duration. Two key issues are considered. First, how much can activity duration and frequency explain travel duration? The analysis shows activity duration has positive and significant effects on travel duration, supporting recent arguments in favor of activity based models. Second, which recent trend is the main culprit in the rise in travel: suburbanization, rising personal incomes, or female labor force participation? This paper examines the share of time within a 24-hour budget allocated to several primary activities: home, work, shop, and other. The data suggest that income and location have modest effects on time allocation compared with the loss of discretionary time due to working.

Introduction

An interest in when and where trips are made leads remorselessly to the realization that travel cannot be understood in isolation from the activities that induce it. Travel and activity are two sides of the same coin, activities must be pursued in space and over time, and space must be traversed in time to engage in activities. Furthermore, how time is spent depends on how money is earned – the decision to work profoundly alters daily schedules for two main reasons: less available time and more available money. To account for the interaction between travel and activity, transportation analysts have begun studying activity duration, frequency, sequencing, chaining, and scheduling (Clarke et al. 1981; Allaman et al. 1682; Damm 1983; Ettema et al. 1993, 1995, 1996; Ettema & Timmermans 1997; Golob & Golob 1983; Kitamura & Kermanshah 1983; Pas 1984; Kitamura 1985; Pas & Koppelman 1986; Recker, McNally & Root 1989; Hamed & Mannering 1992; Hatcher & Mahmassani 1992; Kalfs 1995; Levinson & Kumar 1995a, b; Ma & Goulias 1996a, b; Golob & McNally 1997; Pas & Harvey 1997; van Beek, Kalfs & Blom 1997; Kalfs & Saris 1997; Niemeier & Morita 1996; Hsu & Hsieh 1997). This contrasts with early research that analyzed trips independent of their underlying activities, an approach now embedded in current practice.

The study of human activity patterns has attracted researchers across disciplines. Sorokin and Berger (1939), Szalai (1972), Robinson (1977), Michelson (1985), and Robinson and Godbey (1997) have pioneered the analysis of the use of time. Sociologists have examined the impact of rising female participation in the labor force on the quality of life and changing roles of time at work and leisure (de Grazia 1962; Schor 1991; Cross 1993). Planners and geographers have studied the allocation of time by activity and by location, for demographic and socioeconomic classes (Meier 1959; Chapin & Hightower 1965; Chapin 1968, 1974; Hanson & Hanson 1981; Garling 1992) and developed space-time metrics (Hagerstrand 1970). Economists have developed a theory on the use of time proposing that households or individuals combine time and market goods to produce "commodities" (Becker 1965). Despite these recent research efforts, little transition has been made from theory to practice, and these ideas are only slowly entering the domain of transportation planning.

This paper has two main purposes. First, it demonstrates the significance of activity duration on travel duration after controlling for activity frequency. Second, it isolates the simultaneously occurring factors from the past few decades that have been suggested as the culprits in the rise in travel.

How much can activity duration and frequency explain travel duration? This paper does not concern itself with the chicken-and-egg argument of causality. It suffices that an activity and its associated travel are economic complements; one cannot be undertaken without the other. However, since all activities (including travel) are undertaken within the confines of a 24-hour day, to some extent they also substitute for each other. This research seeks to identify complementary and substitutable activity (and travel) pairs. While the focus remains on predicting travel duration as a function of activity patterns (since the author's primary interest is in transportation), one could just as easily consider the effect of travel or location on activity duration.

The simple constraining fact of the daily *activity* budget should not be confused with the *travel* budget, still subject to significant debates (Zahavi 1974; Zahavi & Ryan 1980; Zahavi & Talvittie 1980; Chumak & Braaksma 1981; Prendergast & Williams 1981; Tanner 1981; Purvis 1995). Daily travel duration for an activity depends in part on that activity's duration and frequency. Simply put, the more times an individual undertakes an activity in a day, the more travel there will be. However, after controlling for activity frequency, does activity duration still affect time in travel? The paper posits that individuals will travel farther for non-home activities at which they spend more time. Two reasons suggest themselves. Individuals may wish to minimize total costs by spending more time at an activity in a single visit rather than requiring multiple visits. Alternatively, not all activities of the same kind are equal, the expenditure of additional time in travel implies greater benefits accrue at the farther activity. It seems reasonable that the activity at a farther destination has a higher quality or value.

Which of the recent trends of suburbanization, rising personal incomes, and female labor force participation engendered the rise in travel? This paper dissects these longitudinal trends by examining cross-sectional variations. To the extent that a long-term change in any particular explanatory variable occasioned the resultant shift in travel and activity patterns, differences within the observed range of that variable at a single point in time ought to manifest themselves. For instance, the last three decades have seen rising personal income. If income trends affect travel patterns, than in a cross-section, individuals with higher income should also have different activity patterns than those with a lower income. Of course, not every longitudinal factor can be captured in a single cross-section. There remain implicit assumptions that the effect of the various independent variables on the dependent variable (e.g. minutes per activity) have remained largely stable over time, and that the other important factors missing from the analysis don't change much either. While this analysis cannot validate the temporal stability of these effects, future research should be aimed in that direction. Hypotheses about the effects of the explanatory factors of household income, spatial location (local and national), and demographics on time use are approached through an exploratory data analysis, with an analysis of variance approach, and employing a multivariate choice model.

The past decades have seen a marked increase in the suburbanization of houses and jobs. The suburbanization of housing in the absence of the concomitant suburbanization of jobs would surely have led to an increase in work travel duration. Fortunately for commuters, jobs did follow housing away from the central city, so little change in overall commuting times among workers has been seen (Gordon, Richardson & Jun 1991; Levinson & Kumar 1994). Still non-work travel has risen (Gordon, Kumar & Richardson 1988; Levinson & Kumar 1995a). Furthermore, suburbanization has been accompanied by differential growth rates between the so-called rust and sun belts. This paper argues that spatial location is a weak explanatory variable for time allocation.

Per capita income has risen sharply over the past decades, though per family and per worker income has grown less, due mainly to the rise in the number of workers and declining household size. Income creates the opportunity to purchase services such as food preparation, childcare, and entertainment previously produced at home. However, this research contends that income is also a weak variable. Though time in travel rises slightly with income above a certain threshold income (where mode usage shifts from transit to auto dominance), this fails to explain the shifts in activity patterns.

The change in work status (entry into the labor force) may be the driving factor. The reduction in time at home associated with working outside the house creates constraints that outweigh the opportunities associated with income and changes in accessibility associated with location.

This paper begins with a description of the data used in the analysis. Then time spent in travel is regressed against activity duration and frequency. Next is an examination of inter-activity complementarity. The subsequent section explores the data and examines the variables hypothesized to influence the amount of time spent at each activity. A presentation of a choice model relating the explanatory variables and the amount of time spent at each activity follows. A summary of study results and suggestions for future research concludes the paper.

Data

This analysis uses the 1990/91 Nationwide Personal Transportation Survey (NPTS). The Research Triangle Institute, sponsored by the United States Department of Transportation (USDOT 1991), conducted the NPTS as a telephone interview survey between March 1990 and March 1991. The NPTS collected data on household demographics, income, vehicle availability, location and all trips made on the survey day for almost 22,000 household interviews and over 47,000 persons making almost 150,000 trips. Strictly speaking, the NPTS was not a simple random sample, there were known biases in favor of the number of telephone lines per household. However, for the level of analysis conducted here, those biases are not expected to alter the results in an important way, so for the statistical tests, random sampling is assumed.

This study employs a one-day cross-sectional survey, though different individuals were interviewed on different days over the course of the survey. Other activity studies have used multi-day surveys, which is certainly to be preferred, all else being equal. Multi-day surveys allow inter-day scheduling tradeoffs for single individuals to be captured directly rather than being inferred from overall averages. For instance while shopping may or may not be undertaken on a given day, it is much more likely to be undertaken for a given week, month, etc. Unfortunately, all-else is not equal, there are not (yet?) any large, multi-day samples which can provide the same information as the NPTS for the United States. For the same survey budget, there is always a tradeoff between depth and breadth, and while this study (and the survey) leans towards breadth, both are important to fully understand the nature of travel and activity behavior. Research into both the behavior, and the best ways to measure that behavior (that is, the appropriate tools) are still important in this relatively new area of inquiry.

First, it may be useful to define travel, activities, and their inter-relationship. Activities are of two classes: location-specific activities and travel. Location-specific activities are defined based on the reported destination activity (purpose) from the travel survey. Travel is the activity which links other spatially separated location-specific activities. The 1990 NPTS provided respondents with a choice of answering where they went next (trip purpose), how they got there (mode), and how long it took (trip duration). In some places in this paper, activity and travel categories are consolidated for analysis.

Only two pieces of time information were provided: the time of departure for a trip, and the travel time for that trip. To create activity data, this study takes the NPTS "Travel Day" database, and by looking ahead to the departure time of the next trip, determines the duration of the stop at the destination. A number of individuals did not report the time of arrival or departure for one trip during the day. These individuals were excluded, as their daily time did not add to 1440 minutes. Only individuals who began and ended the day at home were considered in this study, and time at home was computed based on final arrival time at home and initial departure at the beginning of the day. This is added to any stops at home in the middle of the day. For the graphs and tables presented in this paper, only adults aged 18 to 65 were considered. The elderly and children clearly have different travel and activity patterns, and these may be evaluated in further research.

Travel duration

Why should a practitioner of travel analysis care about understanding activity duration? While the analyst may recognize that the total travel time depends on the number of trips (or activities), that analyst may point out that activity frequency is well ensconced in the standard urban transportation modeling procedures as trip generation. Table 1 demonstrates the dependence of travel time on both activity frequency and activity duration using a simple linear model, as described below.

$$T_i = \beta_0 + \beta_1 F_i + \beta_2 D_i$$

where: T_i = daily travel duration for activity i (in minutes)
F_i = daily activity frequency for activity i (Times activity i appears as destination)
D_i = daily activity duration for activity i (in minutes)
$\beta_0, \beta_1, \beta_2$ = coefficients

The underlying assumption of this functional form is that travel time will be composed of fixed and variable components. One component is indepen-

Table 1. Descriptive statistics and models to predict travel duration by activity duration and number.

	Home	Work and related	Shopping	Personal business	School church	Doctor dentist	Friends relatives	Social recreational	Total other
Descriptive statistics									
Travel duration (T_i)									
Mean	28.8	24.1	14.7	24.1	17.8	19.1	23.2	23.6	30.2
Std. dev.	40.1	24.5	17	30.1	14.3	11.9	24.5	28.3	32.7
Number of stops (F_i)									
Mean	1.41	1.13	1.27	1.65	1.16	1.07	1.25	1.29	1.84
Std. dev.	0.69	0.47	0.64	1.08	0.46	0.26	0.6	0.63	1.29
Activity duration (D_i)									
Mean	984	492	65.6	89.5	204	85.1	178	150	193
Std. dev.	257	158	82.7	118.1	161	75.3	147.9	137	168
Model (Dep = Travel duration)									
Coefficients									
Constant (β_0)	41.22	5.18	–0.84	3.22	3.72	–3.51	0.52	–3.78	3.65
(t-stat)	20.36	3.61	–1.28	3.07	2.83	–1.00	0.33	–2.76	4.18
Number of stops (β_1)	7.89	16.90	10.82	11.24	8.63	20.77	14.46	16.4	12.23
(t-stat)	12.40	22.93	22.91	20.61	8.57	6.23	13.41	16.36	32.41
Activity duration (β_2)	–0.024	0.000	0.031	0.028	0.020	0.005	0.027	0.043	0.028
(t-stat)	–13.623	–0.098	8.334	5.660	7.057	0.415	6.095	9.172	9.668
N	8038	4287	2589	2260	850	165	1201	1750	4768
Adj. R-Square	0.04	0.11	0.22	0.20	0.14	0.20	0.17	0.23	0.24
Std. Error	39.42	23.17	15.05	26.89	13.25	10.62	22.41	24.91	31.87
F-Stat	181.20	262.91	376.70	291.09	72.56	22.24	123.41	262.42	740.80
Sig. F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: Mean daily activity duration, daily travel duration, and number of stops are only for those making trips (number of stops > 0), as are associated regressions. Durations are daily totals in minutes. Number of Stops represents activity frequency.

$T_i = \beta_0 + \beta_i F_i + \beta_2 D_i$

dent of the number of trips, assuming the trip is made. A second element is linearly proportional to the number times that activity is undertaken per day. The third part reflects the importance of that activity, measured by the minutes spent at the activity. The more time spent at an activity, the more willing will the traveler be to travel farther to get there. This hypothesis of a positive correlation between travel and activity duration finds corroboration in Kitamura et al. (1997) and Goulias and Ma (1997) among others. There are two reasons why travel may depend both on the number of activities and on the duration of activities.

Since given two locations to perform an activity, the individual will choose the closer one, *cetris paribus*, then the choice of the farther one implies a benefit sufficiently greater to outweigh the travel cost. An activity will be undertaken when the net benefit (benefit – cost) exceeds the net benefit for any other alternative activity. If both benefit and cost are positively associated with time, an individual should be willing to expend more time in travel to get more benefit by spending time at an activity.

Alternatively, increased time spent at a far away activity for one point in time may be a means to conserve travel in toto, by consolidating time at an activity and eliminating additional trips. To spread the cost of travel over the largest time possible, the longer an individual has to travel, the more time that individual well spend at the activity.

To provide some interpretation for Table 1, using the Travel duration to Home column as an example, the number of stops is positive (7.89) while the activity duration is negative (–0.024), the constant is 41.22 minutes. This means that each stop at home adds 7.89 minutes to travel to home to the otherwise expected 41.22 minutes of travel, each minute at home reduces travel to home by 0.024 minutes.

Of nine activities for which this exercise was conducted, activity frequency was significant (and positive) in all nine, reflecting its primacy in existing travel forecasting procedures. Activity duration was significant in seven of the nine categories, positively so in six, while negatively so for time at home. The negative relationship for time at home makes sense when it is recalled that trips to home are coupled with trips to non-home activities, and home and non-home activities are generally substitutes (as described in the next section).

This model formulation can be extended with consideration of more complex functional forms and additional variables. However, it should be noted that prediction of time in travel for any given individual is notoriously hard, and a function of many factors which cannot be readily captured. This explains why so many trip duration models are analyzed at the aggregate level, as with most conventional trip distribution procedures, including gravity and logit models.

Correlations

This section examines the issue of inter-activity complementarity and substitutability. In economics, two activities are considered substitutes if they have a positive cross-price elasticity, that is: if the price of A increases, then the demand for B rises. However, they are complements when they have negative cross-price elasticity: if the price of A goes up then demand for B declines. The Pearson correlation matrix provides similar information. Here, two activities are defined as complements if the correlation between their durations is positive, that is the time spent at each is positively associated. Similarly, if the correlation is negative, the activities will be considered substitutes. The correlation matrix of course tells nothing about causation – which in activity patterns runs both ways as individuals adjust preferences to the confines of an activity budget. One difficulty in causality here in contrast to economics is that quantity and price are the same in this analysis – both are measured in units of time.

Because all activities (including travel) are undertaken within the confines of a 24-hour day, to some extent they necessarily substitute for each other. But are any non-travel activity pairs (where a non-travel activity pair is for instance time at home and time at work, or time at shop and time at other) complementary? At first glance, work, which earns money, and activities such as shopping and eating out, which spend money, may be thought to be complementary, since money can be substituted for time spent performing chores at home. Activities (such as personal services) which in the absence of a job might be performed at home would instead be purchased from the outside when the job consumes time and produces income. However, depending on how activities are classified this may or may not be the case. Broad activity categories, such as shopping, eating out, and personal business can be undertaken at almost any income level. So while the income from work may affect the quality of the activity, there is no guarantee that the quantity will change. The economic concept of normal goods (whose consumption rises with income) cannot be directly applied in the case of time, which like money is subject to a budget.

For each distinct pair of 24 activity types (12 non-travel activities and 12 travel activities) the correlation was computed (the matrix is available from the author on request). The results are grouped into the three summary rows in Chart 1. Total Cells is the number of cells in the sub-matrix, and the significance is determined by whether the column and row are positively (or negatively) correlated using the Pearson correlation test.

First, the “Activity-Activity” sub-matrix results indicate that activities are most likely to be substitutes for each other. Of the significant correlations, only time at home and time at shop were positively associated, indicating that

Chart 1. Summary of duration correlation matrix.

Sub-matrix	Total cells	Positive and significant	Negative and significant	Not significant
Activity-activity	60	1	29	30
Activity-travel	144	15	39	90
Travel-travel	60	11	10	39

Note: Significance is computed using the Pearson correlation test, Activity refers to non-travel activities (home, work, shop, etc.), Travel refers to travel activities (travel to home, to work, to shop, etc.).

shopping for goods which are consumed at home substitutes for consuming time and effort out of the home, perhaps at “other” activities. The suggestion that work and activities such as shopping and other might be associated was clearly refuted by the data, indicating that the time loss from having to work outweighs the advantages of additional money to spend on out-of-home activities. This neither demonstrates nor refutes though, for instance, that among workers, those with more money spend more time outside the home, which is examined in the next section.

Second, the results from the “Activity-Travel” sub-matrix are somewhat more complicated. In almost all cases, an activity was positively (and significantly) associated with travel to that activity, indicating as expected that a trip and its activity are complements. What’s more, travel was positively (and significantly) associated with different activities in four cases, perhaps representing trip chaining. Time at home was negatively associated with most types of travel, except travel to shop. Similarly, time at work was also negatively associated with travel to all activities except work.

Third, the “Travel-Travel” sub-matrix indicates that travel to an activity is positively associated with the return trip, often to home, as shown by the positive association between travel to home and travel to other activities. In theory, travel to work could either increase or decrease travel to other activities. If one engages a long trip to work, there is less time for other activities and thus travel. However, if the other trip is to be made anyway, it might be recorded as a long trip, if it is a stop on the chain between home and work for instance. In fact, travel to work is negatively and significantly associated with travel to seven other activities. In general, travel between other activities (neither home nor work) are uncorrelated.

Activity duration

Having shown travel duration depends on activity duration, the next logical question is "Upon what does activity duration depend?" This section examines how activity duration varies with explanatory factors. This analysis considers spatial, socioeconomic, and demographic factors. The spatial variables include land use density, metropolitan population, and region of the nation. The socio-economic analysis examines household income for workers and non-workers, stratified by gender. Demographic variables considered are gender, age, and life-stage. Because of change over time, the differentiation in the use of time across each of these variables indicates the extent to which they explain the long-term rise in travel and shift in activity patterns. These variables are addressed in turn.

Density

While research into the relationship between density and travel behavior is vast, little empirical work has examined local density or residential location within the metropolitan region and activity duration. Local residential density is the best available measure in the 1990 NPTS database of relative household location within the metropolitan region. Building off previous research (Levinson & Kumar 1997), this paper adopts the position that local residential density measures most importantly congestion and distance from the metropolitan center(s), rather than density itself.

Accessibility to activities, and thus time use, may vary with density. For instance, out-of-home activities may be more easily accessed in the city than the low-density suburbs. Historically, the center city was the location of the accessibility peak. Over time this changed, as the suburbs became increasingly accessible for more activities, particularly shopping. If the monocentric dominance remains, a higher out-of-home activity behavior in the high-density areas would be expected. This may be further compounded by differences in socio-economic variables. Urban areas have a different, and self-selected, population mix than suburban and rural areas. Thus, those who enjoy the benefits of urban activity will take advantage of it, while those who prefer space and quiet sort themselves into the lower density suburbs.

Examining the effect of density on activity duration gives mixed results (Figure 1). While the very highest density classes, those over 10,000 persons per square miles (ppsm) show significant differences in most of the activity categories, there remains a high degree of variance. In the suburban densities for instance, one density will be associated with a significantly higher than average activity duration, while an adjacent class will be associated with a significantly lower than average duration. In fact, time at home, shopping, and in other activities declines at the highest densities, while time at work

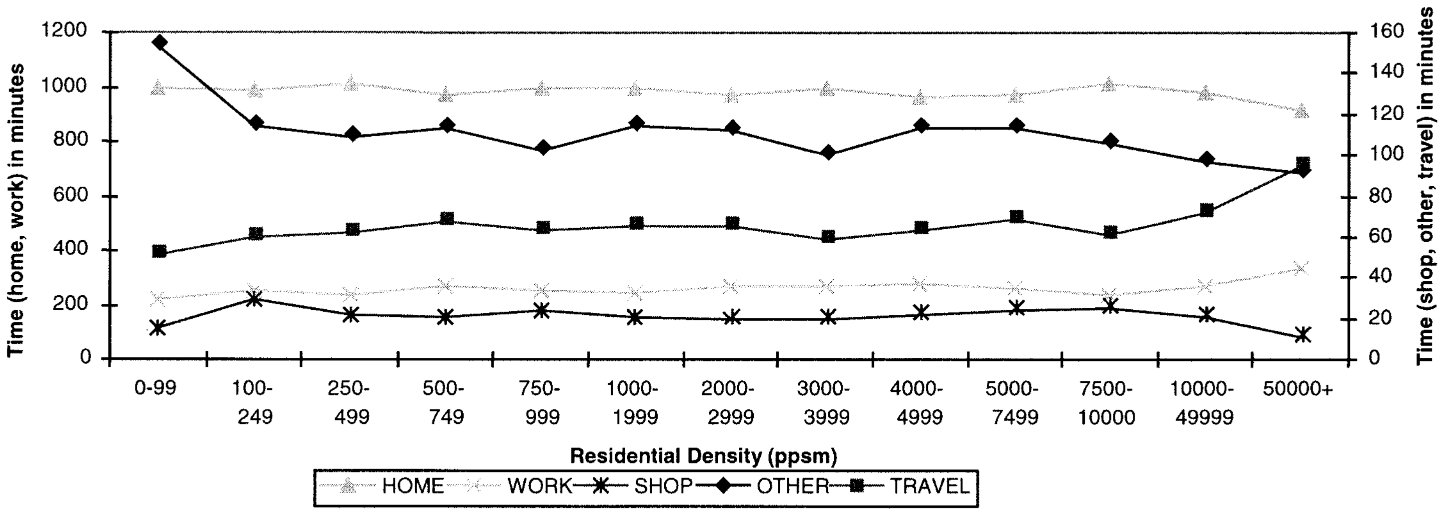

Figure 1. Time at activities by residential density.

and in travel rises. Broadly speaking, the suburbs (densities of 100–10000 ppsm) are relatively homogenous, while the highest and lowest densities have noticeably different patterns. This suggests that shifts in metropolitan location to lower density suburbs cannot be the dominant cause of the rise in total travel. An analysis of variance (ANOVA) test shows that residential population density is a statistically significant factor in measuring the time spent at home and work and in travel. However, density is not a particularly important factor, variation in density explains less than 1% of the variation in activity patterns for those three categories. (Detailed ANOVA results are available from the author). To compare, Robinson and Godbey (1997, p. 195) briefly considered rural vs. urban differences and found that rural residents spent less time working and commuting to work and more time at home. They did not examine density explicitly.

Metropolitan area and population

Because national data to examine activity duration are scarce, little research has been undertaken comparing metropolitan areas in a consistent fashion. Robinson and Godbey (1997) and Kitamura et al. (1997) both have national (US) databases, but they did not consider metropolitan size explicitly. As with density, hypotheses surrounding activity duration and metropolitan area population rest principally with an accessibility argument. In brief, the larger the metropolitan area, the more choice for out-of-home activities that a resident has. The additional choices may provide the incentive for the marginal consumer of non-home activities to pursue a few more minutes per day outside the home.

An examination of the census defined CMSAs finds little metropolitan differentiation in the use of time (detailed results available from the author). As cities increase in size, there is a slight but statistically insignificant trend toward more time at work and less at home. A comparison of the mean duration for each activity by city and nationally shows few cities deviate significantly from the average. Only 8 of 95 cells in the table (city by activity) differ from the mean with more than 95% confidence on a two tail *t*-test. About 5 cells can be expected to differ at that confidence level without ascribing any meaning to the results. The lack of inter-metropolitan differentiation refutes suggestions that changes in travel patterns can be explained by the rise of certain fast-growing sunbelt cities at the expense of the rustbelt.

An analysis of variance test shows that population is statistically significant factor for explaining variations in the duration of the home, work, and travel categories, though not an important factor as it explains less than 1% of the variation. Interactions between population and region of the country were generally not significant except for the travel duration category.

Region of country

Variations in time use by region of the country can be due to several factors. The most obvious is climate associated with the seasons. Other explanations may relate to demographic differences that are associated with region. Florida and Arizona have a high proportion of retires (though this study examines principally working age adults). Similarly family sizes are not uniform either. Ethnic groups are not evenly spread across the United States. For example, Hispanics comprise a relatively large share of the population in New York, Florida and states bordering Mexico, as do Asian-Americans in the West, Native Americans in the Rocky Mountain states, and African-Americans in the East, particularly the southeast. If behavior is associated with ethnicity (and it is a plausible assumption), then it may be reflected spatially.

An investigation of the data, illustrated in Figure 2, suggests that there are significant differences between some of the regions for some activities. People in the South Atlantic spend less time at home and more time at work than the national average (at the 95% confidence level), while those in the two South Central divisions spend less time at work. All divisions were near the national average on time spent shopping. Activities in the other category were found briefer than average in the Middle Atlantic, and longer in the West North Central states. Those in the Middle Atlantic are traveling more though, while the Mountain States residents travel significantly less than the national average. Future research should more carefully examine the causes and consequences of regional variation.

An analysis of variance on the effect of region shows that the census region is a statistically significant factor (at the 10% level) for explaining variations in time spent at home, work, and other categories. Again, however, it is not a particularly important factor, explaining less than 1% of the variation. Robinson and Godbey (1997), comparing regions of the country found few differences in the larger categories, though some differences in the way the macroscopic “other” and “home” activities were allocated, for instance, southerners spend more time in church.

Income and work status

Individuals use time to earn money, and money to buy services in place of spending their own time producing them. Since there are diminishing marginal returns to most goods at some satiation point, there are diminishing marginal returns to earning money. Thus, when the income per hour rises above a certain level, an individual may choose to work fewer hours and consume more time in leisure. However, whether this point is represented in the data is unclear, as all income categories above $75,000 per year were consolidated. It is quite

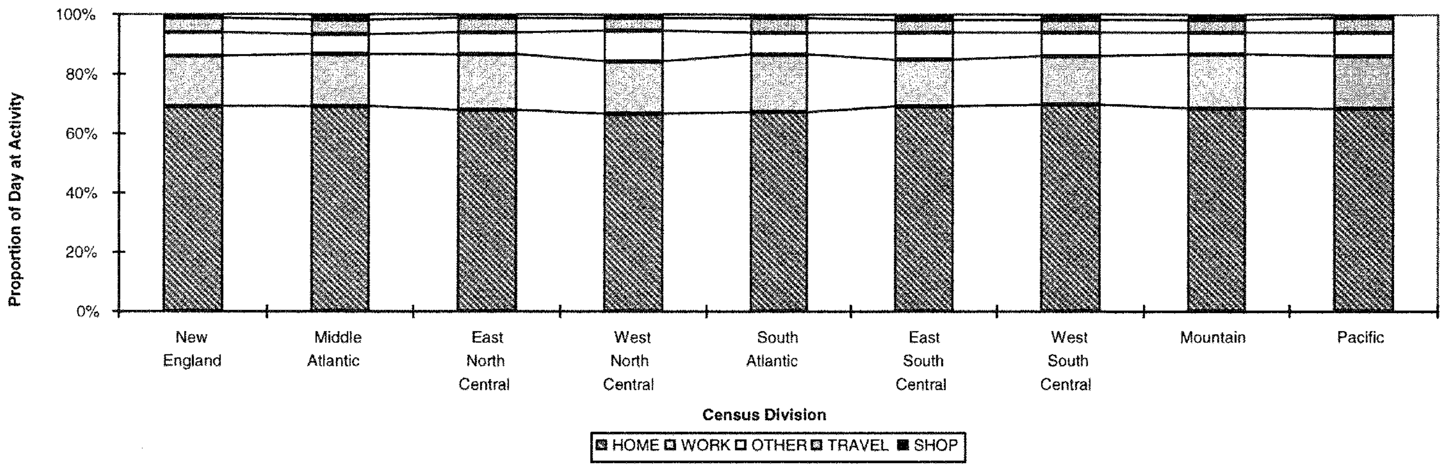

Figure 2. Proportion of day at an activity by census division.

possible that the point at which most individuals choose leisure over income is significantly higher than that threshold.

One may plausibly posit that low income is positively associated with time shopping. Suppose a given quantity of goods needs to be purchased, but that prices vary by store. Individuals with a relatively low value of time relative to money need to make each dollar go further, and may spend more time shopping for discounts rather than accepting the first satisfactory good. Low-income individuals may accept higher search costs to attain lower prices, which may require more time spent traveling and/or shopping.

Table 2 summarizes activity duration for adults 18 to 65 stratified by gender into workers and non-workers. A thorough examination of income variation within each gender/work-status/activity category found little significant differentiation (so the tables are not shown), the differences between category are stark. Women generally spend more time at home than men, and non-workers spend more time at home than workers. This is broadly consistent with other activity duration studies (Kitamura et al. 1997; Robinson & Godbey 1997). The difference between genders is much smaller than that between individuals with different work/non-work status. The variance within each income category is highest in the category with the fewest observations (male non-workers), though this is not so averaging across all income categories. In some income categories, women actually spend less time at home than their male counterparts. Nevertheless, this is only true in 8 of the 34 income/work status categories for which the comparison is made, and the differences are not statistically strong.

At all but one income level, men work more minutes per day than women, again consistent with previous studies. This may be explained by part-time jobs, but those could not be distinguished from the data. Generally, time at work rises with income level, but it might be stated the other way: income level rises with time at work. Causality runs both ways here – high-income workers are expected to put in more time, while those who put in more time can be expected to earn more money. Because the data represent household income, the result is not as stark as it might be if there were data on personal income. It should be noted that time at work is averaged over all seven days of the week, and so includes individuals in the workforce surveyed about weekend travel patterns. Therefore, time at work would be lower than if the survey were confined to weekdays only.

As expected females shop more than men, but female workers even shop more than male non-workers in all but three income categories. Generally, shopping takes the most time among those in the middle income brackets. This pattern appears weakly in all four categories. While the differences between travel times for the work/gender category and the average travel time are significant in only a few cases, the differences between categories are

Table 2. Duration by activity, work-status and gender.

		Home		Work		Shop		Other		Travel		
		Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Cases
Female	Non-Worker	1187	201	–	–	35	65	158	177	60	67	1049
	Worker	964	240	290	256	26	64	98	147	62	56	3021
Male	Non-Worker	1182	226	–	–	19	42	183	206	56	65	433
	Worker	923	253	336	276	14	46	97	151	69	65	3656

Note: All times in minutes per day.

significant more often. For instance, the difference between working women and non-working women on shop time is nine minutes, but this is out of an additional 300 or so minutes per day available because of the absence of work.

Among workers, time at other activities for men and women holds steady across all income categories, averaging 98 minutes for all men and 97 minutes for all women. Non-workers spend more time than workers at other activities (due to that extra 300 minutes). However, after controlling for income, men and women again spend similar amounts of time (non-working males, a small sample, again show very high variance within each income group). The average time for men is still larger: 183 minutes compared with 158 minutes for women.

Travel shows the sharpest income trends. For workers the higher the income, the more time spent traveling, which is consistent with other studies of the issue (Robinson & Godbey 1997). It should be noted that in the very lowest income category (less than $5000 household income) women display a surprisingly high average time in travel, which might be due to transit/carpool dependence in one or zero car households. Non-workers show a high variability in the time spent traveling, and no clear trend can be inferred from the data.

Table 3 compares the amount of explained variance due to income, gender, and work status. Three variables are significant in many cases, but their importance varies greatly. The amount of variance explained by work status of time spent at home is more than 20 times the amount explained by gender and income. It is an even starker result for time at work, where income is not even a significant factor. However, for time spent shopping, gender explains

Table 3. Variance explained by gender, work-status and income.

	Home	Work	Shop	Other	Travel
Main effects	13.17%	19.58%	2.15%	2.97%	1.12%
Gender	0.44%	0.50%	1.18%	0.01%	0.15%
Work-status	10.24%	16.09%	0.38%	2.43%	0.08%
Income	0.38%	0.14%	0.36%	0.27%	0.74%
2-way Interactions	0.59%	0.22%	0.34%	0.79%	0.53%
Gender, work-status	0.02%	0.05%	0.02%	0.08%	0.06%
Gender, income	0.32%	0.13%	0.21%	0.30%	0.30%
Work-status, income	0.27%	0.03%	0.11%	0.48%	0.14%
3-way interactions	0.11%	0.05%	0.08%	0.47%	0.23%
Gender, work-status, income	0.11%	0.05%	0.08%	0.47%	0.23%
Explained	13.88%	19.85%	2.57%	4.24%	1.89%
Residual	86.12%	80.15%	97.43%	95.76%	98.11%
Total	100%	100%	100%	100%	100%

three times as much as work status and income. For time at other activities, both gender and income are not significant, and work status is the most important factor. Finally, for travel, income explains the most variance, followed by gender and work status. In general, the interaction (multiple variable) effects are not particularly important compared with the variables alone.

Life-Stage

Previous research has found relationships between demographic factors and the use of time. First, as noted above, because men are more likely to be in the workforce than women, there is an obvious disparity between men and women on the amount of time spent at home, work, shopping, and other activities. However, corroborating the above evidence, even after controlling for the decision to work, it has been found that working women spend more time shopping and at home, and less time at work than working men (Levinson and Kumar 1995a). This indicates that traditional gender roles remain, which comports with most studies of the subject (Kitamura et al. 1997; Robinson & Godbey 1997).

Figures 3 to 7 show how the use of time varies with age for male and female workers and non-workers. Categories with fewer than 30 observations are suppressed, which explains the gap in the curves for non-working males between ages 31 and 55. Time spent at home (Figure 3) rises sharply with age for non-workers. For workers, it is saucer-shaped, declining from the teen years to the early twenties, flat through the middle years, but rising as men enter their fifties and women their late forties. The rise in time at home in the later years is statistically significant for all groups.

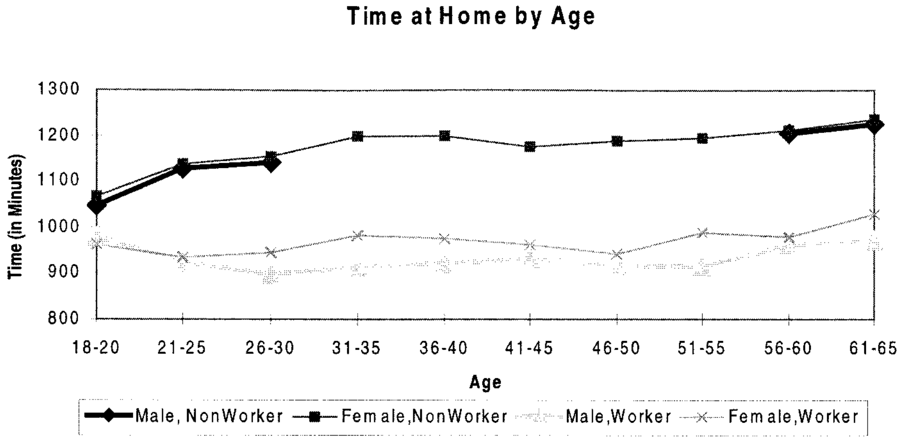

Figure 3. Time at home by age.

In contrast with time at home, time at work (Figure 4) is hump shaped. Work duration peaks in the middle years for men and women. In the early years school substitutes for work, while in the later years home and other activities associated with semi-retirement may be the culprit. Another factor is the greater proportion of women in the older (50+) cohort who never joined the full-time workforce, and so hold part-time workforce, and so hold part-time jobs. Women show a dip from the late twenties to their thirties, which can possibly be ascribed to leaving the full-time workforce for childcare (and more part-time work). This supports part of the "Mommy Track" argument (Schwartz 1989), that women with children work less than those without, what effect that has on their careers is beyond the scope of this research. However, female workers at the highest household income levels (> $65,000) do work somewhat more than those with incomes between $30,000 and $65,000, perhaps because those at the highest incomes can afford more or better day care. The time spent at work in the early thirties for women is statistically different from the average for women at the 95% confidence level (2-tailed), suggesting that it is more than simply noise in the data.

Figure 5, showing time spent shopping, reflects high variability among non-workers. Among workers, time spent shopping rises with age. For women shopping peaks in the middle years, when family size is the largest, for men shopping increases into the fifties and sixties, perhaps explainable by the same reasons that they spend less time at work. Generally non-workers spend more time shopping than workers across age levels.

Figure 6 illustrates time at other activities. This value drops almost monotonically with age. The first explanation is the transition from school to work, shown in workers as they move from part-time to full-time work as they

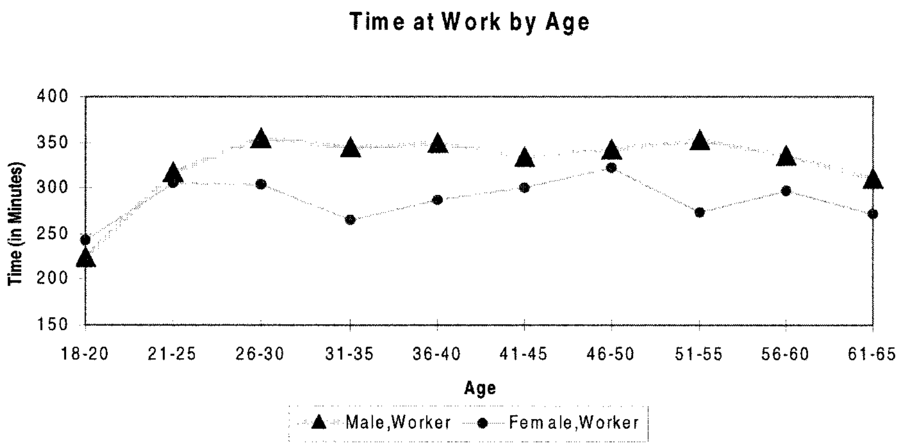

Figure 4. Time at work by age.

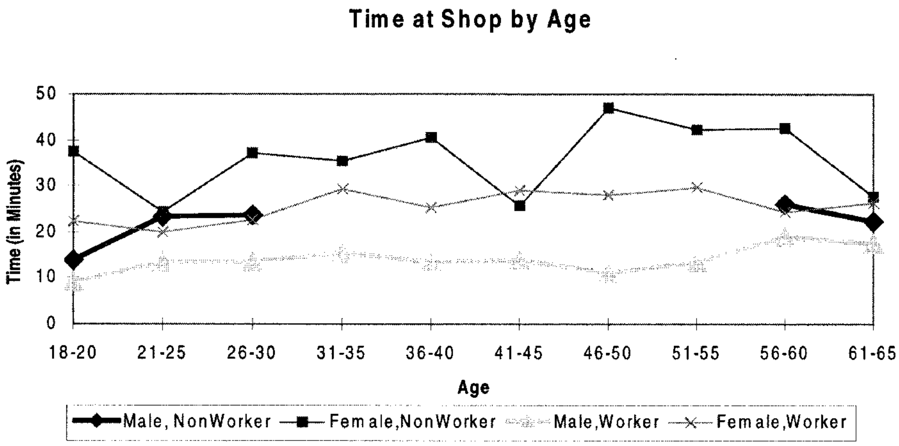

Figure 5. Time at shop by age.

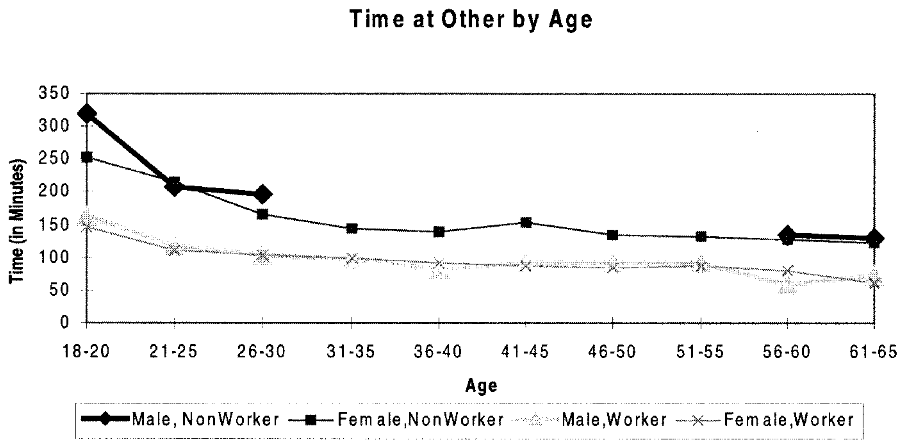

Figure 6. Time at other by age.

finish school in their twenties. The non-workers trend may also be explained by a shift from school to home activities.

Daily travel duration (Figure 7) is interesting. Teenage girls travel more than their male counterparts, but roles reverse by the late twenties. There is a slight peak in driving towards middle age for male workers and female non-workers between 46 and 50, though female workers peak in their twenties and female non-workers actually drive more in their teens.

Age and life-stage are interrelated variables. The NPTS database characterized respondents by whether they were single or lived in a two+ adult household, whether they had children, and if so, whether the children were between 0 and 5 years, between 6 and 15 years, or between 16 and 21 years.

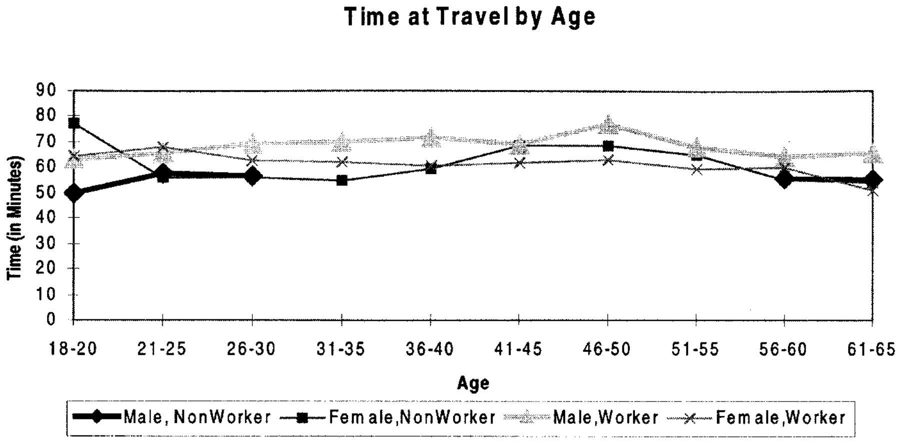

Figure 7. Time at travel by age.

It is expected that adults with young children will spend time at home to be with that child, but that as the child ages, staying home will become less important. Singles and couples also have different life styles, it is posited that singles without children spend more time out of the home than individuals belonging to couples.

Table 4 charts time use by life-stage category and gender. Women without children spend less time at home and shopping, and more time at work and traveling than women with young children. Compared to men in couples without children, those with children actually spend less time at home and more at work. This suggests a household division of labor, while women stay at home to rear children, men work outside the home more to compensate. However, the relatively few single men with children work less and are home more than single men without kids, suggesting that childcare responsibilities eat into other options.

It might be though that women with children shop more than women without, which is true for women in couples, but not single women. Uniformly, singles spend more time at other activities than couples. Except for childless households, singles also spend more time at home. Singles spend more time shopping in 4 of 5 child categories. Members of couples (2+ adult households) consistently spend more time at work and spend more time in travel for 4 of 5 child categories.

The age of the oldest child significantly affects time use. Members of households with young children (0–5) spend more time at home than those with children 6–15, and more still than those with children 16–21, and still more than childless households. The time at home comes principally from time at work (and travel to work). Presumably, this is because parents (usually women

Table 4. Duration by activity, life-stage and gender.

Adults	Young child	Sex	Home				Work				Shop			
					Difference				Difference				Difference	
			Mean	Std. dev.	Of total	Means M-F	Mean	Std. dev.	Of total	Means M-F	Mean	Std. dev.	Of Total	Means M-F
1	None	M	933	270	–3.40	–1.88	292	270	2.12	1.88	16	46	–2.02	–2.95
1	None	F	971	250	–0.93		253	263	–0.47		30	69	2.13	
2+	None	M	943	261	–5.64	–4.09	305	283	5.73	4.97	16	49	–3.95	–4.52
2+	None	F	982	249	–0.33		255	261	–0.68		25	59	2.12	
1	0–5	M	1154	305	1.36	0.89	133	217	–1.43	–0.51	16	20	–0.70	–1.03
1	0–5	F	1040	247	1.98		180	249	–2.81		26	47	0.81	
2+	0–5	M	932	249	–5.49	–12.88	341	280	8.28	14.81	13	44	–5.09	–6.33
2+	0–5	F	1084	242	11.24		158	234	–11.78		31	70	3.93	
1	6–15	M	1045	298	1.07	1.25	193	247	–1.41	–1.39	5	12	–6.56	–3.91
1	6–15	F	968	248	–0.69		267	261	0.28		23	43	0.45	
2+	6–15	M	937	260	–4.71	–6.76	315	280	5.16	7.34	12	37	–5.87	–6.39
2+	6–15	F	1026	240	4.43		213	250	–4.77		29	59	3.38	
1	16–21	M	910	282	–1.05	–1.11	256	268	–0.06	0.64	6	11	–5.08	–2.96
1	16–21	F	997	225	0.38		207	243	–1.42		40	73	1.71	
2+	16–21	M	956	258	–2.11	–1.99	289	276	2.00	2.34	15	56	–2.08	–2.58
2+	16–21	F	993	248	0.65		243	256	–1.22		29	86	1.69	
1	Retired	M	1196	214	3.55	0.36	0	0	–86.53	NA	31	38	0.93	0.39
1	Retired	F	1162	241	2.45		0	0	–86.53		25	40	0.31	
2+	Retired	M	1105	246	6.81	–0.43	135	230	–7.47	–0.16	16	33	–2.01	–3.26
2+	Retired	F	1115	232	8.40		139	229	–7.85		31	57	2.50	
	ALL		984	257			260	271			21	56		

Adults	Young child	Sex	Home				Work				N
					Difference				Difference		
			Mean	Std. dev.	Of total	Means M-F	Mean	Std. dev.	Of total	Means M-F	
1	None	M	128	178	1.79	0.52	72	74	1.65	1.11	333
1	None	F	121	156	1.23		66	56	0.33		324
2+	None	M	109	164	–0.09	–0.70	67	61	1.15	0.82	1489
2+	None	F	114	161	0.82		65	60	0.07		1371
1	0–5	M	111	172	0.01	–0.32	27	31	–2.92	–2.34	6
1	0–5	F	134	159	1.33		60	52	–0.75		78
2+	0–5	M	86	139	–4.78	–3.52	68	63	1.39	3.97	899
2+	0–5	F	110	145	0.08		57	52	–4.10		827
1	6–15	M	131	168	0.66	0.35	65	62	0.03	0.18	27
1	6–15	F	119	152	0.66		63	56	–0.38		119
2+	6–15	M	106	166	–0.58	–0.36	69	65	1.69	1.83	731
2+	6–15	F	109	161	–0.09		63	68	–0.83		718
1	16–21	M	189	168	1.88	1.00	79	99	0.56	0.83	16
1	16–21	F	138	185	1.00		57	44	–1.09		43
2+	16–21	M	110	159	0.02	–0.39	70	74	1.46	1.98	378
2+	16–21	F	115	162	0.55		60	62	–1.28		348
1	Retired	M	146	168	0.77	–0.43	67	78	0.12	–0.25	13
1	Retired	F	179	199	1.15		74	60	0.53		11
2+	Retired	M	122	157	1.04	1.28	61	70	–0.67	1.45	196
2+	Retired	F	102	153	–0.74		53	48	–3.68		229
	All		110	158			65	62			8159

Note: All times in minutes. Difference of Means "Total" is difference of means *t*-test between the cell and overall average for that activity. Difference of Means "M-F" is difference of means between male and females in the same life-stage (number of children, number of adults per household). An absolute value of greater than 1.96 indicates the two values are statistically different at the 95% confidence level.

as noted in the age graphs) drop out of the workforce or spend less time at work to care for children. The variation in time use by age, number of children, and number of adults in the household is larger than the differences over the range of both spatial variation and income.

The ANOVA of the life-stage and the five activities shows a significant relationship between the life-stage and the duration of home, work, and other activities at the 10% level. For time at home and work, the life-stage explains about 2% of the variation.

Choice model

To test the hypotheses and observations outlined above in a multi-variate context, a logit model is formulated and estimated from the 1990 NPTS data. The logit functional form was chosen for its ease of estimation and clarity of results rather than because of theoretical precepts relating to the expectations of the distribution of error terms. The theory of logit analysis used below follows Train (1986). The use of logit, or any discrete choice structure, is perhaps unusual in activity duration analysis (as opposed to activity pattern analysis where it is often used). Other model forms: simultaneous equations, duration models, or micro-economic models (Becker 1965), have been used more often. The appropriate method depends on how the problem is defined, and here it is defined in somewhat more macroscopic terms (share of the day for each activity) than it would be in a more detailed scheduling or time-of-day model.

We may posit that individuals choose (or refine) an activity plan at the beginning of the day. This plan devotes a certain percentage of the day to specific activities: home, work, shop, travel, other. While other decisions (such as the sequence and location of activities) are also made, they are not treated here, as they can be thought to be second order decision. In the ideal model there is a feedback between decisions: whether an individual actually undertakes activity X may depend on its location relative to others, its time sensitivity, etc. This analysis does not incorporate feedback, which awaits further research.

The share of the day spent at any activity depends on a number of factors, but in the use of time, only one activity can be undertaken at a time. In other words for each time slice, for instance each minute, a decision-maker chooses between one of the specified activities. But one minute is very much like the next; the choices are highly connected – switching between activities such as home, work, or shop implies changing locations, which requires transportation, so a simple choice model is not appropriate at that scale. In the aggregate (for example one day), the individual decision-maker chooses the amount of time to spend at each activity. That aggregated quantity is estimated here.

The objective is to explain the shares (minutes per day divided by 1440 total minutes in a day) associated with each activity. For this estimation, a weighted logit model is employed, where each individual chooses the proportion of the day spent at each activity. The utilities of the activities are thus estimated as the dependent variables. The applied model gives the share of the day associated with each activity. The weights for the choices are the observed number of minutes per day spent at that activity, which sums 1440 minutes for all of the activities. This is mathematically analogous to estimation and application of a multinomial logit model with the decision unit being the choice of activity of each individual for each minute (thus there would be 1440 observations per individual). While as a realistic choice structure, each minute is not a useful partition of time – it is far too disaggregated and interdependent, in aggregation it does provide meaningful results.

Four alternatives are defined: time spent at (and in travel to) home, work, shop, and other, which by definition add to 1440 minutes for all of the individuals in the sample. The independent explanatory variables are specific to the decision-maker, and include Activity Frequency, Season, Gender, Age, Household Income, Life-stage, Residential Density, Region, and Metropolitan Population.

The parameter vector (β) is estimated for each choice and each variable, but is assumed constant over all individuals (n), and the activity specific alternative (a_i) is estimated for three of the choices. The variables are estimated for three of the four available choices. One choice (work) is considered the base to normalize the values. Furthermore, a number of variables are dummy variables describing a range of values, one class of the dummy for each variable (for instance one of the four seasons) is suppressed for a similar reason. The model is estimated using the Alogit package (Daly 1993).

Table 5 presents the results of this weighted logit analysis. The largest part of the explanatory value of the model falls on the activity specific constants. Because of the large sample, most of the variables introduced into the model were statistically significant, though their actual impact on time is in many cases small. Some of the insignificant variables for one choice were significant for others, and are left in for explanatory purposes. This model is for understanding rather than prediction, and findings of insignificance of hypothesized variables are as important as findings of significance.

The next most significant variable (for shop and other activities) was activity frequency. It is expected that the more times someone pursues an out-of-home activity, the longer she will spend at that activity. Similarly, the more times someone has to return home, the less time he is actually spending at home, since the trip to return home implies the trip to leave home. The research could be extended through estimation of a multi-stage model considering both activity frequency and duration.

Table 5. Weekday activity duration choice.

Variable	Home		Shop		Other	
	Estimate	"T" ratio	Estimate	"T" ratio	Estimate	"T" ratio
Constant (1)	0.8508	28.4	–2.258	–29.3	–1.488	–27.9
Male (1, 0)	–0.2735	–30.5	–0.2578	–11.5	0.0683	4.4
Age (years)	0.000374	0.9	–0.00148	–1.4	–0.00228	–3.1
Res. density class (1, 13)			–0.0143	–3.3	0.0196	6.4
Northeast (1, 0)	–0.0122	–0.9	0.2035	6.2	–0.5096	–22.1
Southcent (1, 0)	–0.2066	–12.3	–0.4371	–9.6	–0.3103	–11.4
West (1, 0)	–0.1556	–10.8	–0.2397	–6.7	–0.2654	–11.5
1990 Metro Pop (millions)	0.000700	0.9	–0.00546	–3	0.0155	11.1
Household Income ($)	0.000280	0.2	–0.0108	–3.8	–0.00312	–1.6
Winter (1, 0)	0.0276	2	–0.00319	–0.1	–0.184	–8.1
Spring (1, 0)	0.0271	2.1	–0.0727	–2.4	–0.2194	–10.2
Summer (1, 0)	0.0418	3.1	–0.0561	–1.7	–0.1006	–4.5
Single (1, 0)	–0.0905	–14.7	–0.0203	–1.4	–0.0851	–7.7
Childless (1, 0)	–0.1074	–7.1	–0.0573	–1.6	–0.1464	–5.8
Young. child 0–5 (1, 0)	–0.0464	–2.7	–0.2239	–5.6	–0.2994	–10.3
Young. child 6–15 (1, 0)	–0.0918	–5.5	–0.3084	–7.8	–0.2801	–10
Activity Frequency (trips)	–0.00735	–1.7	0.6695	30.5	0.3626	76.2

Summary statistics	Value	Summary statistics	Value
Sample Size	752	Final value of likelihood	–276186
Likelihood with zero coefficients	–375297	Rho-Squared w.r.t. Zero	0.2641
Likelihood with constants only	–281194	Rho-Squared w.r.t. Constants	0.0178

Note: All parameter should be compared with that for work, for which all coefficients were forced to zero. Sample of adults age 18 to 65.

The single variable analysis noted that even after controlling for work status and income, gender roles in activity patterns remain. The results for gender largely corroborate what was found earlier. Men spend less time at home and shop but spend more time at other activities than women. Age patterns are less sharp, while in the single variate analysis, there was no assumption of linearity in the effect of age on duration at various activities, the logit model is estimated with age as a linear variable. The results for age only indicate that time at other declines with age, the home and shop activities show no significant relationship, reflecting in part the non-linearity in the relationship between age and those activities.

Singles spend more time at work and less time at home, shop, and other activities than persons living in households with two or more adults do. Dummy variables for children need to be compared to the suppressed classes (youngest child 16–21 and retired) that spend more time at home than do presumably younger households with younger children. The correlation between number of children, number of household adults, and age should be noted, making direct interpretation less immediately obvious than comparing what happens when these related variables change together.

Spatial variables including density, metropolitan city size and region of the country were tested. Recall the hypotheses about density and city size relate to accessibility, which should be associated with more out-of-home activities, particularly other activities. High-density urban living is positively associated with time at other activities, and negatively associated with time shopping. City size, reflecting access to out-of-home activities, was positively associated with time at other and negatively associated with time spent shopping, sharpening the results of the earlier analysis. Regionally, those in the south central and western areas of the country spend less time at home, shopping, and other activities, and thus spend more time at work than those from other areas. Individuals in the northeast spend more time shopping than elsewhere.

Seasonal factors suggest time at home is higher in winter, spring, and summer, and time at shop lower in those seasons than the base autumn season. (Here, autumn is defined to be coincident with the months of October, November, and December and includes the important Christmas holiday). This corroborates earlier examination of temporal variations by the author (Levinson and Kumar 1995b).

Conclusions

The consideration of activity duration in travel demand forecasting is essential to improve results. Travel duration depends on activity duration as well as the more traditional measure of activity frequency. Activities are rarely complementary, rather, they are mostly strict substitutes, only time at home and time at shop were positively associated in a test of the correlation between the durations for various activities. However, as expected travel and activity are mostly complements, the amount of time spent at an activity is positively associated with travel to that activity. Aside from the complementary return trip home, travel durations between other activities (neither home nor work) are generally not correlated.

The time per activity shows only relatively small variations explainable by economic, demographic, spatial, or temporal factors. Travel and work were positively associated with income. However, individuals with more money don't spend particularly more time out of the home purchasing services that with less money they would perform at home. This suggests that the primary trade-off between money and time is located in the decision to work. Men and women, and workers and non-workers had markedly different behaviors, as has been found in earlier research.

An attempt was made to disentangle the longitudinal trend effects using the NPTS cross-sectional survey. By explicitly considering the rarely addressed spatial factors, this research quantified their statistical significance and measured their importance for long-term time allocation shifts. The rise in travel over the past few decades can largely be attributed to the discretionary time loss due to changes in female labor force participation rather than the concomitant rise in low-density living, sunbelt migration, or per capita income.

Future research should be directed at developing better explanatory measures for the use of time. These may include additional variables, mathematical transformation of the data, different functional forms of the independent equations, or alternative model formulations. In addition, data need to be analyzed explaining the use of time by children and the elderly. Policy implications need to be considered after a thorough understanding of the mechanics of activity choice.

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About the author

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