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by

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Abstract

This paper focuses on the tradeoff in time allocation between maintenance activities/travel and discretionary activities/travel. With the recognition that people are not completely free to allocate their time between activities and travel, we propose a linear constraint in time allocation between activities and travel, which indicates a minimum amount of travel one must do in order to allocate one unit of time to the activity. This minimum amount of travel is represented by the travel time price, a ratio obtained by dividing the total amount of time traveling to maintenance or discretionary activities by the total amount of time spent on activities of the same type. This travel time price is the time equivalent of the monetary price for performing an activity (whether in-home or out-of-home). We ask two questions in the paper: "If the travel time price of performing maintenance or discretionary activities increases, how will that affect one's time allocation to maintenance and discretionary activities? And if one had one more unit of available time, how would this affect one's time allocation to maintenance and discretionary activities?" We use the San Francisco Bay Area 1996 Household Travel Survey data and apply the Almost Ideal Demand System (AIDS) of demand functions. The empirical results provide the following answers to our research questions. With respect to the time equivalent of income elasticities of maintenance and discretionary activities, we found the former to be less than unity and the latter to be greater than unity. In other words, maintenance activities are a necessity and discretionary activities are a luxury. With respect to the own travel time price elasticities, if the travel time price of performing a certain type of activity increases (for reasons such as traffic congestion), one would reduce the time allocated to that type of activity. As expected, time spent on maintenance activities is less elastic than the time spent on discretionary activities. As for the cross travel time price elasticities (changes in time allocated to activity type i itself in responses to changes in the time price for activity type j), we found that $\varepsilon_{dm} > 0$ and $\varepsilon_{md} > 0$, suggesting a substitution effect between maintenance and discretionary activities.

1. Introduction

Although psychologists have yet to agree on what motivates human behavior, we can at least conclude two universally accepted desires of human behavior: the desire to live and the desire for social belongingness (Tonn 1984; Baumeister and Leary 2000). The desire to live (as a normal human being) motivates us to eat, drink, sleep, clean, rest, and exercise on a regular basis; the desire for social belongingness motivates us to engage in activities that involve others in society. As most of us are constrained by monetary limits, we must engage in activities that earn us money, which will be work. The performance of all these activities requires time. Although we do not gain satisfaction directly from spending our time (we gain satisfaction by performing those activities), time allocation to various activities can be used as a natural surrogate for our satisfaction level.

As activities are distributed in space, we must travel from one activity location to another. Because of the different degrees of fixities associated with different types of activities, traveling within one's daily time-space prism[1] (Hagerstrand 1970) is subject to temporal and spatial constraints. In other words, the amount of time available for the performance of an activity with relatively flexible location and duration (e.g., discretionary activities) is limited[2] and depends on the amount of travel time needed to reach the destination. Lower travel time (resulting from shorter distances and/or higher speeds) means that more time is allocated to activities; higher travel time (resulting from longer distances and/or lower speeds) means that less time is allocated to activities. If the assumption that travel is a derived demand is true[3], lower travel time implies higher utility gained and higher travel time implies lower utility gained. Put another way, as we gain utility from spending our time on activities, travel is the cost that we must endure in order to go to these activity locations.

Even though travel is a disutility to us, we generally cannot reduce our travel time to zero. Our ability to adjust our travel time is constrained by the physical settings of the activities and how fast we can travel (Hagerstrand 1970). Changes in travel time often result from involuntary changes. For example, it might result from either relocation (or addition, withdrawal) of activity opportunities (e.g., relocation of a store) or changes in traffic conditions. Given a change in travel time, individuals must adjust their time allocation to activities, which might take place with or without changes in activity locations. The consequences of a change in travel time can be either short-term or long-term. In the short run, a change in the travel time could cause changes in time allocation to activities; in the long run, a change in the travel time could trigger changes in residential and/or job locations.

In this paper, we focus on the short-term effect of a change in travel time on the time allocation to activities. As we note in the concluding discussion, our use of cross-sectional data to some extent confounds the effects of short-term and long-term changes. However, such data can be viewed as representing a typical mixture of short-term and long-term effects occurring at

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[1] If space is represented by a 2-dimensional plane and time is the 3rd axis, the time-space prism defines the limits in a 3-D space of what is accessible to a given individual, in view of his or her particular spatial and temporal constraints.

[2] If one stays at one location for the entire day, then the upper limit for the time spent on one single activity is 24 hours per day. On the other hand, if one arrives at location A at 2 pm and must be at location B by 5 pm and the travel time between location A and location B is 0.5 hour, then the upper limit of the time spent at location A is 2.5 hours.

[3] Recently, Mokhtarian (2005) and others have begun to question this tenet, although it presumably remains a useful first-order approximation for local daily travel.

any given time, and since (almost by definition) only a relatively small proportion of people are undergoing relevant long-term changes in any random cross-sectional sample, it is fair to view the results as reasonably approximating short-term effects.

A change in travel time is captured through a change in the travel time price, which is the ratio obtained by dividing the total amount of travel time to a particular type of activity by the actual time expenditure on the activity of the same type. Compared to the direct travel time measure, this travel time price has the advantage of acknowledging the effect of the spatial distribution of activity locations on time allocation (i.e., individuals are not equipped with complete allocation power because of the physical locations of various activities) by establishing a link between time spent on activities and on travel[4]. An increase in the travel time price suggests an increase in the time equivalent cost of performing an activity (either from an increase in travel time or from a decrease in activity duration); a decrease in the travel time price suggests a decrease in the time equivalent cost of performing an activity (either from a decrease in travel time or an increase in activity duration). In economic terms, this travel time price can be viewed as the time equivalent of the travel-based monetary price of performing an activity. In this study, we focus on two types of activities: maintenance and discretionary[5]. Given one's current residential and job locations, we ask: how will a change in the travel time price of performing a maintenance or a discretionary activity affect the actual time expenditure on the activity (maintenance or discretionary)? And how will an increase in the total amount of time available[6] affect the time allocation to activities? In economic terms, if we view the travel time ratio as a price separating various activities, calculation of tradeoffs in time allocation among activities and travel is essentially the same as calculating the own and cross travel time price elasticities of maintenance and discretionary activities, as well as the time equivalent of income elasticities (to examine the effects of a change in total time available on allocation to activities).

The paper is organized as follows. In Section 2, we review the empirical evidence on the time allocation between activities and travel. In Section 3, we review various microeconomic frameworks that have been developed in modeling time allocation. In Section 4, we discuss the notion of using the travel time price instead of the nominal values of time allocation to activities and travel. We propose our model framework in Section 5. The database used for this study is described in Section 6. Estimation results are presented in Section 7, followed by a discussion in Section 8. A companion paper (Mokhtarian and Chen, 2004) reviews the literature on travel time budgets, that is, studies investigating whether the total amount of time individuals devote to travel is relatively stable, either at the disaggregate or aggregate level.

2. Empirical Evidence

Starting from the early 1990s, a substantial number of activity-based studies have emerged, in which tradeoffs between activity duration and travel time are studied. The tradeoffs can be made for a single activity episode, or for multiple episodes. The former studies the relationship between travel time to and the activity duration at the destination. A common consensus is that for a single activity, the travel time and the activity duration at the destination are positively

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[4] Although the direct measure of travel time does reflect the spatial distribution of activity locations, the implicit relationship between the time spent on activities and on travel is not acknowledged.

[5] Our reasons for excluding mandatory or subsistence activities are discussed in Section 3.

[6] An increase in the total amount of time available for maintenance and discretionary activities and travel may result from a reduction either in commute time or in work duration.

related (Hamed and Mannering 1993; Kitamura et al. 1997). The latter studies the travel time to and the time spent on multiple episodes of a particular type of activity (e.g., maintenance or discretionary activities), as well as the tradeoffs between the time spent on different types of activities. In addition, the tradeoffs can also be analyzed at either the intra-person or the inter-person level (typically for household members; e.g., Pendyala, 2003). The study presented in this paper involves multiple activity episodes of the same type and intra-person comparisons.

The importance of time-use studies in the context of transportation has been well recognized in the field. Several review papers and editorials have been written in the area (Pas 1985; 1996; Bhat and Koppelman 1999; Pendyala and Goulias 2002; Kitamura, 2002; Pendyala 2003)[7]. In particular, Kitamura (2002) noted that the tradeoff between travel time and time allocation to activities has been insufficiently investigated, as many of the time-use studies examine the relationship between socio-economic characteristics and time allocation. The rest of this section provides a brief review of time-use studies on intra-person tradeoffs.

Levinson (1999) estimated single linear equations for the daily travel duration associated with the time allocated to different types of activities including home, work and related, shopping, personal business, school and church, doctor visits, visits to friends and relatives, social/recreation and other activities. Except for work and related activities, activity duration had a significant effect on the travel time expenditure for the corresponding activity type. Travel time expenditure decreased as the amount of time spent on home activities increased; and increased as the amount of time spent on all other activities (except for work and related activities) increased. The insignificant relationship between work duration and travel time to work is probably due to the generally fixed nature of work durations.

Golob and McNally (1997) found that the positive relationship between activities and travel applies only to one direction of causality (from activity duration to travel time), while a negative relationship prevails in the opposite direction. Specifically, they estimated a structural equation model system examining the tradeoffs in time expenditure on activities including work, maintenance, and discretionary and corresponding travel to each type of activity, separately by females and males residing in the same household. They found that the activity duration of a given type had a positive effect on the travel duration of that activity type, while travel time to a particular type of activity had a negative effect on the duration of the corresponding activity type (except for maintenance activities and their corresponding travel). Both results are natural – the positive influence of activity duration on travel duration reflecting the common finding that people are willing to invest in more travel to engage in a more important activity, and the negative influence of travel duration on activity duration reflecting the reality that additional time spent on one type of activity/travel must generally reduce the time spent on another type of activity/travel. In the same study, they also found a negative relationship between the time spent on various activities and travel in general except for the relationship between maintenance and discretionary travel for males.

Lu and Pas (1999) also employed a structural equation system to examine the interaction between individuals' in-home and out-of-home activity participation and travel behavior. They found that daily travel time increased with an increase in the time spent on out-of-home activities (and vice versa), but decreased as the amount of time spent on in-home activities increased.

In an effort to understand how past activity engagement affects future activity engagement, Ma and Goulias (1998) developed models for travel time expenditures on different

[7] None of the review papers cited here discusses the direction and/or the magnitude of the tradeoffs between time allocated to different types of activities, which is the focus of our review.

types of activities. The Two Stage Least Squares (2SLS) method was used to estimate the model due to the expected endogeneity of activity duration. They found that only travel time to subsistence activities was negatively related to the amount of time spent on past activity participation and travel on the same day. Additionally, travel time to subsistence activities was also positively related to the travel time to a previous subsistence activity on the same day and negatively related to the travel time to a previous leisure activity on the same day.

In an interesting study by Fujii et al. (1997, cited by Kitamura et al. 1997), a structural equation system was developed analyzing the tradeoffs between time expenditures on activities and travel. They found that a 10-minute reduction of commute time would increase average total out-of-home activity duration by 1.88 minutes, average total in-home activity duration by 7.11 minutes, and average total travel time by 0.36 minutes.

The time allocation to activities and travel may also change between weekdays and weekends. Using a 1985 time-use survey collected in the Netherlands, Bhat and Misra (1999) found that the time spent on a given activity during weekdays was negatively correlated with the time spent on the same activities on weekends. They further found that an increase in travel time to work decreased the time spent on out-of-home discretionary activities during weekdays.

Using household travel survey data collected in Washington, D.C. in 1994, Kuppam and Pendyala (2001) employed structural equation models to examine the tradeoffs between time allocated to different types of in-home and out-of-home activities. They found negative effects between almost all pairs (working out-of-home and out-of-home maintenance activities, working out-of-home and in-home recreation activities, out-of-home maintenance activities and in-home discretionary activities), which is expected because of the fixed total available time budget.

3. Considerations in Theoretical Model Development

When we observe our daily lives, we see that time consumption is often coupled with goods consumption and monetary expenditure. For example, in a shopping activity, we often purchase goods, which constitutes the consumption of goods in an economic sense. The consumption (use) of goods in a physical sense also consumes our time. In a travel activity, both time and money are consumed. Although the focus of our study is time allocation to both activities and travel, the intricate relationship among goods consumption, time allocation and monetary expenditure triggers two inter-related questions in our theoretical model development. First, should we include money in the constraint set? Second, should we include consumption of goods in the utility function?

We start from the classical microeconomic framework in which the utility function contains consumption of various goods/bundles as direct arguments and the constraint function is the monetary budget constraint. If consumption of time is also added into the framework, we may do one of several things. For the utility function, we may add consumption of time as a direct argument into the utility function. Alternatively, we may combine the consumption of time and the goods/bundle into some composite goods/bundle and use this composite goods/bundle in the utility function. For the constraint function, we may add time consumption as a separate time constraint into the constraint set. Alternatively, we may combine time consumption and money expenditure into a single dimension.

A search in the economics literature uncovers several studies that attempt to model both goods/bundles consumption and time consumption. Each of these studies falls into one of the categories described above. Becker (1965) assumed that households combine time and market goods to produce some basic household commodities, denoted as Z[8]. He also combined both money and time constraints into a single constraint. Becker used two terms in his paper: full price and full income, where full price refers to the sum of the monetary price and the monetary value of the time used per unit of the commodity Z, and full income refers to the maximum amount of income "that can be obtained by devoting all the time and other resources of a household to earning income, with no regard for consumption" (Becker 1965, pp. 497-498). The value of time is equated to the opportunity cost, which is equal to the wage rate (since time could be used to earn money, at the wage rate).

Instead of combining money and time into a single dimension, DeSerpa (1971) added the consumption of time into the utility function as a direct argument and into the constraint set as a separate constraint in addition to the monetary constraint. He also added an inequality technological constraint, stating that in order to consume good X during activity type i (denoted as X_i), at least T_i amount of time must be consumed. The Lagrangian multipliers generated (λ, μ, and ν) represent the marginal utility of money, the marginal utility of time, and the marginal utility of relaxing one unit of the minimum amount of time required to allocate to goods consumption during activity type i. The ratio μ/λ is the value of time; the ratio ν/λ is the value of the additional time gained by decreasing the minimum amount of time required to allocate to goods consumption during activity type i.

Kockelman (2001) had a framework similar to DeSerpa's (1971). Her direct utility function includes activity participation (measured by number of activities conducted), time allocation to activities, travel time to activities, and goods consumption. There are two constraints: total monetary budget and total time budget. The indirect utility, which was used to derive her demand functions via Roy's Identity, includes three arguments: pre-tax household income, amount of available time (24 hours less work- and school-related time), and travel time to access zones of opportunities at different distances (immediate, near, moderate, and far). The demand functions (number of discretionary activities in zones of opportunities at different distances by person) were derived as a function of these three variables. The value of time is again the marginal utility of time divided by marginal utility of money, μ/λ.

In Evans (1972), time allocation to activities and travel is the only argument in the utility function. Although goods consumption is excluded from the utility function, it is in the constraint. The usual monetary budget: $\mathbf{P'X} \leq \mathbf{0}$ (where P is the price vector and X is the goods vector), is replaced by $\mathbf{P'QT} \leq \mathbf{0}$, where $\mathbf{Q}$ is the vector of fixed coefficients that converts time consumption, $\mathbf{T}$, into goods consumption, $\mathbf{X}$. Evans (1972) equates $\mathbf{X}$ with $\mathbf{QT}$, indicating that by the fixed set of coefficients $\mathbf{Q}$, time allocation is equivalent to goods consumption. In addition, Evans also included a linear constraint between time allocation to activities and to travel, requiring a minimum amount of time spent on travel for every unit of time spent on activities.

Jara-Diaz (1998) argued that only objects that do not necessarily require the consumption of others should enter the utility function – those variables that act through other variables should not enter the utility function. Thus, goods should not enter the utility function, as the consumption of goods always requires the consumption of time; whereas time allocation to activities and travel should enter the utility function as those do not always require the consumption of goods. Jara-Diaz proposed a unified framework for trip generation, distribution, mode choice and time allocation. The direct arguments in the utility function include time allocated to various activities and their associated travel as well as both fixed and variable

[8] Z can also be viewed as a composite commodity.

working hours. There are four constraints in the model: the time constraint, the money constraint, the transformation function that converts goods into activities/travel and vice versa, and the number of trips as a function of a set of goods X_{id}, the amount of good i bought in zone d. The consumption of goods and time are linked via a transformation function in the constraint set. Given that the individual has a fixed salary and fixed working time, the value of time is equated to the opportunity cost, which is also the wage rate.

Jara-Diaz (2003) rejected his own 1998 argument that only objects that do not necessarily require the consumption of others should enter the utility function. The utility function he developed in his 2003 work includes both time allocation and goods consumption. There are four types of constraints. The first two are monetary and time constraints. The third and fourth ones are transformation functions between goods consumption and time allocation. The third constraint imposes a minimum level of time allocation for goods consumption while the fourth imposes a minimum level of goods consumption for time allocation. The four Lagrange multipliers are λ, μ, κ_j, and ψ_i, representing the marginal utility of relaxing one unit of income, time, and technological constraints on time allocation and goods consumption. The ratio μ/λ is the value of time. The ratio κ_j/λ represents the monetary value of additional time gained by decreasing the minimum level of time allocation for the consumption of good j by one unit. The ratio ψ_i/μ represents the time value of the money saved by decreasing the minimum level of the monetary requirement for the consumption of good i by one unit.

Though seemingly feasible, a number of difficulties, both conceptual and practical, exist when one tries to implement any of the frameworks described above. Conceptually, these approaches share a common feature: time is treated in the same way as money. Graham (1981) argues that this feature of equating time with money is based on a view shared by many people in European-American culture. He referred to this view as the "linear-separable model" (p. 336), which treats time as a straight line extending into past, present and future. Time can be sliced into discrete units and then allocated to different tasks/activities. Directly resulting from this view, Graham argued, are the concepts of money value of time and time value of money.

Is time really like money? On the surface, we can note at least a few differences based on simple observations of time and money consumption in our daily lives. First, every one has 24 hours a day, rich or poor. One cannot purchase time from others so that he or she has more time in total than someone else. One may purchase maid service to do household cleaning to increase his or her *free* time, but the total amount of available time is still 24 hours per day. Second, the power one has over time allocation is not as much as one has over money. For example, one cannot decide to withhold spending time in the same way that one can choose not to spend money: our time continuously spends itself whether we like it or not. Similarly, saved time cannot be easily stored for future use. For example, if one arrives at a meeting 15 minutes earlier than expected, one cannot generally start the meeting immediately and store those 15 minutes to be used later – the 15 extra minutes are often "wasted" or "lost". By contrast, if one saves money by taking a bus instead of a taxi, one can store this saved money for future use. In addition to the temporal inflexibility of time, there is often a spatial inflexibility as well: the allocation of time among activities distributed in space is governed not only by one's activity preferences but also by the spatial separation of the activities, which one cannot always change in the short run.

If time is really like money, Leclerc et al. (1995, p. 110) argued that "consumers should perceive time as being an intangible resource that can be augmented or reduced. Moreover, situations that consumers perceive as a waste of time – such as waiting situations – should be encoded as losses, and the loss function should be convex". However, Leclerc et al. find that people reacting to waiting time do not behave as they do in the context of monetary loss. More specifically, they found that people attach different values to waiting time depending on the context. In addition, if the amount of waiting time is within people's expectation, people do not interpret it as a loss. In the context of money, it has been found that people tend to be risk averse with respect to gains and risk seeking with respect to losses. In the context of time, people tend to be consistently risk averse, or at most, risk neutral with respect to both extra time available and less time available. In sum, as Leclerc et al. concluded, time is not completely like money.

In addition to these conceptual differences between money and time, there exist practical difficulties in implementing those frameworks. The biggest difficulty is the lack of data on goods consumption (e.g., price vectors and monetary constraints) along with time allocation to activities and travel[9]. The frameworks described above require information not only on time allocation to both activities and travel, but also the amount of goods consumption and its price for each activity or travel performed, along with information on allowable assets. Most Metropolitan Planning Organizations (MPOs) in the U.S. collect information on time allocation to every activity and trip, but not the monetary information related to goods consumption and monetary budget. Conversely, programs such as the U.S. Consumer Expenditure Survey (http://www.bls.gov/cex/home.htm) collect data on monetary expenditures across all types of goods and services, but no information regarding time expenditures on activity and travel. Although there is definitely a need to collect information both on time allocation and on goods consumption, there is also a need to develop alternative model frameworks (in addition to those modified versions of the classical microeconomic framework reviewed earlier) to explicitly address differences between time and money.

As our initial interest is in how a change in the travel time price of performing an activity affects the time allocation to the activity, we decide to forgo goods consumption as well as the monetary constraint in our model framework. However, we recognize the role of income in time allocation (to maintenance as well as discretionary activities, as our results in Section 7 demonstrate). In addition to directly incorporating income into the model, we also develop separate models for people with different income levels. We further distinguish the time allocation to different kinds of activities and travel, to approximate different levels of satisfaction gained through consuming different kinds of goods.

In addition to forgoing goods consumption, we also forgo the time allocation to mandatory activities and their associated travel. We believe that once the job (including its location) and residential location are determined, there is relatively little that one can do to change work duration and its associated travel in the short term. In other words, the time spent at work and its associated travel are by-products of residential and job decisions, which are long-term choices. On the other hand, time allocation to both discretionary and maintenance activities are results of short-term choices; one also has much more control over these two kinds of activities than one has over mandatory activities, although this is a slight over-simplification (since many jobs have a certain amount of discretion with respect to working overtime or not).

4. Use of Travel Time Price

If travel is a derived demand and generates only negative utility, then the observed travel time should be treated as the minimum amount of travel required to perform individuals' activities

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[9] Kockelman's (2001) work is the only study, among those cited, with an empirical implementation. The variable "pre-tax household income" is the only goods consumption-related variable in her study.

distributed in space. In this study, we apply a travel time price, which is calculated as the sum of travel times to a particular type of activity (maintenance or discretionary in this study) divided by the total amount of time (excluding travel) allocated to that particular type of activity (whether in-home or out-of-home, and possibly over multiple episodes during a given period). This ratio can be viewed as the price in travel time for performing activities; a higher travel time price indicates a greater travel time required per unit of time spent on activities.

The travel time price reflects a balancing process between the time spent on travel and activities (Dijst and Vidakovic 2000). During such a balancing process, the choice of allocating time between activities and travel is partly a choice of preference and partly a result of necessity. Due to the spatial separation of various activities, people are not able to allocate time to travel completely as they wish (if they could, under the presumption of a completely negative utility, everyone would allocate zero time to travel). For example, if one wants to go to a recreational park for some fun, he or she will have to travel for a minimum amount of time no matter how much he or she likes or hates travel. The fact that constraints exist within the balancing process is not a new idea. Both DeSerpa (1971) and Evans (1972) associated a minimum amount of traveling time with the amount of time spent at the destination for an activity.

If we observe people's travel time price from day to day, we would expect the travel time price to vary comparatively little for a single individual if the units of time are relatively large (e.g., a week or a month). The variation of the travel time price from day to day for a single individual would be larger; the variation of the travel time price within a group of individuals would be even larger as there exist many individual/household differences (e.g., residential and job locations, lifestyles). We found only two published studies that explicitly used a travel time price (ratio) concept. Both studies used the term "travel time ratio", instead of travel time price, but the two concepts are similar (although not identical). The denominator of the travel time ratio includes both activity duration and round trip travel time, while for our travel time price, only activity duration is included[10]. Using data collected in the Netherlands in 1992, Dijst and Vidakovic (2000) calculated the travel time ratio for work and work related activities to be 0.18 to 0.27, meaning that an 8-hour work duration is associated with a one-way travel time between 52 and 88 minutes. In another study by Schwanen and Dijst (2002), using the 1998 Dutch National Travel Survey, the travel time ratio for work activities was calculated to be around 0.105, meaning 28 minutes (each way) for an 8-hour workday. They also noted that travel time ratios are affected by a wide range of variables such as household and person characteristics and urban/suburban contexts.

Other studies, though not directly calculating a travel time price, reported the amount of travel time associated with an activity of a certain duration. In the study cited earlier, Golob and McNally (1997) found that about 22.6 minutes of travel each way were involved for every eight hours of out-of-home work activity (similar to Schwanen and Dijst's 28 minutes), and about 7.8 minutes of travel each way were involved for every hour of out-of-home maintenance activity, indicating travel time ratios of 0.086 and 0.21 for out-of-home work activities and out-of-home maintenance activities, respectively.

[10] Also, those studies empirically analyzed travel time ratios only for single activities at a time, whereas we combine the travel and activity time across multiple activities of a given type.

5. Proposed Model

In this section, we propose a model framework for modeling the time spent on both activities and travel, incorporating a time constraint. We establish a linear constraint between the time spent on activities and the time spent traveling.

Evans' model (1972) mentioned earlier is to our knowledge the only model whose utility function has time allocation to activities[11] and travel as the only arguments. We take his model as the starting point for our purpose, which is formulated as follows:

Max

$U = u(a_w; a_t, a_c; a_i)$

Subject to:

$a_w + a_t + a_c + \sum a_i = T$

$ba_c - a_t \leq 0$

$r_w a_w + r_t a_t + r_c a_c + \sum r_i a_i = 0$

where

i is the i-th activity,

a_w is the time spent on working,

a_t is the time spent on traveling to the cinema,

a_c is the time spent at the cinema,

a_i is the time spent on the i-th activity,

$r_w < 0$ is the individual's rate of pay,

$b > 0$ is the amount of time that must be spent on traveling to the cinema per unit of time spent at the cinema,

T is the total time available, and

r_t, r_c, and $r_i > 0$ and are the direct financial costs per hour of the time spent traveling, the time spent at the cinema, and the time spent on the i-th activity respectively.

In the model described above, the individual is assumed to maximize a utility function that includes time spent on work, cinema, other activities, and time spent on traveling to the cinema. The utility function is subject to three constraints. The first is a total time budget constraint. The second constraint states that for every hour the individual spends at the cinema, he or she must spend at least b hours traveling. For example, if $b = 0.1$ and $a_c = 2$ hours, then $a_t \geq$ 12 minutes, meaning that for two hours' time at the cinema, the individual must spend at least 12 minutes traveling. This constraint is in response to the notion that people are not completely free in allocating their time to activities and travel. Evans (1972, p. 10) commented that "the amount of time [an individual] decides to spend traveling [should not be] assumed to be completely independent of the amount of time he [or she] chooses to spend in any other activity" because sometimes an individual may not want to travel (that much) but must travel a minimum amount in order to perform another activity. The third constraint is a monetary budget constraint, indicating that all expenses must not exceed the total income available, which is expressed as the product of rate of pay and hours of working.

Evans' model essentially matches our desired model framework. Instead of accounting for every single activity, we account for two categories of activities (maintenance and discretionary)

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[11] Evans only considered time spent on two types of activities: working and the cinema – the latter presumably an arbitrary choice for illustrative purposes.

in addition to travel. In our case, the time spent on travel is not the time spent on going to a single activity, but the total travel time spent on going to all maintenance and discretionary activities throughout a certain period. These considerations lead to a modified Evans' model as follows:

Max

$$V(a_m, a_d, a_t)$$

subject to:

$$a_m + a_d + a_t = \tau ,$$

$$a_t = b_m a_m + b_d a_d , \qquad b_m, b_d \geq 0,$$

where

a_m is the time spent on maintenance activities,

a_d is the time spent on discretionary activities,

a_t is the time spent on travel,

τ is the total time available minus the time spent on mandatory activities and their associated travel, and

b_m and b_d are the number of units of travel time (generally fractional) associated with one unit of time spent on maintenance and discretionary activities, respectively.

In the above formulation, the first constraint is the total time budget constraint. In the second constraint, we assume a linear equality relating the time allocated to activities and the travel to engage in those activities[12]. The linear specification is probably quite a simplification of reality, nevertheless it serves as a first step toward recognizing the constraint in reality that individuals do not have complete control over their allocation to activities and travel.

Our next task is to derive demand functions for the arguments of V from the above model framework. We decided to derive demand functions from a cost function because then the derived demand functions are "first order approximations to any set of demand functions derived from utility-maximizing behavior" (Deaton and Muellbauer 1980, p. 315). There are different ways to derive demand functions from a cost function, such as the Almost Ideal Demand System (AIDS), (Deaton and Muellbauer 1980), the Rotterdam model (Theil 1965; Theil 1976) and the translog model (Christensen, et al. 1975). Due to its overall advantages over other models (Deaton and Muellbauer 1980)[13], we decided to use the AIDS model. We briefly describe the derivation of the AIDS demand system below.

By expressing a_t in the first constraint in terms of a_m and a_d as required by the second constraint, we obtain the following:

$$(1 + b_m)\, a_m + (1 + b_d)\, a_d = \tau .$$

Let

$$p_m = 1 + b_m, \text{ and}$$

[12] Note that in Evan's formulation, the b is associated with a single activity episode, which is going to the cinema, while in our formulation, b_m and b_d are associated with potentially multiple episodes of maintenance and discretionary activities.

[13] Deaton and Muellbauer (1980) cited several advantages of using an AIDS system, including: a) its demand functions can approximate a large variety of demand functions; b) it aggregates well over individuals; and c) the common constraints in microeconomic theory (symmetry, homogeneity) can be tested.

$p_d = 1 + b_d$.

We then can re-write the constraint as: $p_m a_m + p_d a_d = \tau$. Following the notation of Becker (1965), we may define p_m and p_d to be full time prices of maintenance and discretionary activities, showing that the full time price of performing an activity includes both the activity time price (normalized to 1) and the travel time price of performing the activity, expressed as b_m (for maintenance activities) or b_d (for discretionary activities).

Following the approach of Deaton and Muellbauer (1980), any arbitrary cost function can be approximated by the following function, provided that $\sum_i \alpha_i = 1, \sum_j \gamma_{ij} = \sum_i \gamma_{ij} = \sum_i \beta_i = 0$:

$$\log c(u,p) = \alpha_0 + \sum_i \alpha_i \log p_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \log p_i \log p_j + \mu\beta_0 \prod_i p_i^{\beta_i},$$

where

$\log c(u,p)$ is the logarithm of the cost function,

u is the utility level, $0 \le u \le 1$,

p is a vector of prices for various goods and services, and

$\alpha_0, \alpha_i, \gamma_{ij}, \mu, \beta_0$, and β_i are parameters.

Any cost function has the fundamental property: $\partial c(u,p)/\partial p_i = a_i$, where a_i is the quantity of the i-th good or service or, in our context, the duration of performing the i-th activity. From $\partial c(u,p)/\partial p_i = a_i$, we can obtain $\frac{\partial \log c(u,p)}{\partial \log p_i} = \frac{p_i a_i}{c(u,p)} = w_i$, where w_i is the budget share of good i. From this property, Deaton and Muellbauer (1980) derived the AIDS demand functions for the budget share of good i. As our formulation of the model has conformed to the classical microeconomic problem, we can now apply the AIDS system in our context. The demand functions for a_m and a_d in the share form can be derived as follows:

$$w_m = \alpha_m + \gamma_{mm} \log p_m + \gamma_{md} \log p_d + \beta_m \log(\tau / P),$$

$$w_d = \alpha_d + \gamma_{dm} \log p_m + \gamma_{dd} \log p_d + \beta_d \log(\tau / P),$$

where

$$\tau = p_m a_m + p_d a_d,$$

$$w_m = \frac{p_m a_m}{\tau},$$

$$w_d = \frac{p_d a_d}{\tau}, \text{ and}$$

$$\log P = \alpha_0 + \sum_{i=m,d} \alpha_i \log p_i + \frac{1}{2}\sum_{i=m,d}\sum_{j=m,d} \gamma_{ij} \log p_i \log p_j.$$

In the above system of demand functions, parameters to be estimated include the α_is, β_is, and γ_{ij}s[14]. One advantage of the AIDS system is that the demand functions do not require the assumption of utility maximization. If utility maximizing behavior is not assumed, the budget shares can be viewed as "unknown functions of log p_i and log [τ]" (Deaton and Muellbauer

[14] In the actual estimation of the more general model system, there will be issues related to the time-to-money conversion. Since our model does not have a monetary constraint, we need not discuss those issues here.

1980, p. 315). In this case, we relax both the homogeneity[15] and symmetry[16] restrictions: $\sum_j \gamma_{ij} = 0$ (homogeneity constraint) and $\gamma_{ij} = \gamma_{ji}$ (symmetry constraint). These restrictions are usually imposed to make the model consistent with the utility maximization framework. In an actual estimation of the AIDS model, these restrictions may be checked to see if the demand functions reflect behavior under the utility maximization framework[17]. This represents a significant advantage over many other models because we are not restricted to demand functions based on utility maximization and yet we have the freedom to test the empirical validity of the restrictions that make the model consistent with the utility maximization model.

6. Data Base

The database used in this study comprises responses to the 1996 San Francisco Bay Area Household Travel Survey. The survey consisted of a two-day activity and travel diary, and questions obtaining data on household and person characteristics as well as vehicle characteristics. The sample contains about 3618 households and 7990 people. The average household size is 2.2; the average number of vehicles per household is 1.8; and the average number of workers in a household is 1.3.

The activities that are included under the maintenance and discretionary categories are listed in Table 1. Cases having activities that were coded as “out of area” or “do not know/ refused” or “other” were dropped from our sample. Travel time was also distinguished by activity category. Those observations with zero values for any one of the four variables of interest (time allocation to maintenance and discretionary activities and to travel for each of those types of activities) were given a random number with uniform distribution between 0 to 0.01[18] for the variable in question.

[Table 1 insert here]

The travel time price for maintenance activities, b_m, is calculated as the total travel time for all maintenance activities[19] over two days divided by the total time spent on the maintenance

[15] Homogeneity of degree zero is usually assumed for demand functions. This means that if we double both price and budget, the quantity demanded will be doubled too.

[16] The symmetry constraint is: $\partial a_i/\partial p_j = \partial a_j/\partial p_i$, meaning that the change in the consumption of the *i*-th good in response to a change in the price of the *j*-th good must equal the change in the consumption of the *j*-th good in response to a change in the price of the *i*-th good.

[17] Empirically, both the symmetry and homogeneity constraints are frequently violated (Deaton and Muellbauer 1980).

[18] This is to solve the problem that zero value observations lead to inconsistent estimates. An alternative way to solve this problem is via a tobit model with selection (Greene 2003). However, the selection model requires a number of instrumental variables, typically household and person socio-economic characteristics, to represent one’s decision whether to allocate any time at all to a particular type of activity. The tobit-model-with-selection method was attempted during this study, using various socio-economic characteristics as explanatory variables. The resulting coefficients were insignificant, meaning that in this data set there probably does not exist a strong relationship between socio-economic variables and the binary decision of whether to allocate any time at all to a particular type of activity.

[19] If the activity at the destination is a maintenance (discretionary) activity, then the travel time to the destination is counted toward the total travel time to maintenance (discretionary) activities. This can result in some distortions, e.g. in a case where the individual stops for breakfast close to work, in which case the home-to-restaurant link would be counted as maintenance (eat meal) rather than as part of the commute to work. Return-home travel is neglected, which leads to an underestimation of travel time prices. This can be viewed as one of the limitations of using the travel time price measure.

activities themselves (whether in-home or out-of-home)[20], and similarly for discretionary activities. For the modeling, the study excluded observations with a travel time price for maintenance activities (b_m) or for discretionary activities (b_d) that was greater than 1[21]. The final sample used for this study comprised 3906 observations[22].

[Table 2 insert here]

Table 2 shows descriptive statistics for the travel time prices for both maintenance and discretionary activities, as well as the share information for maintenance and discretionary activities. The average travel time price for maintenance activities is lower than that for discretionary activities, which is well expected. The minimum value for the maintenance share is 0.24 while the minimum value for the share of time spent on discretionary activities/travel is close to 0. In other words, for everyone in the sample, at least 24% of the time is spent on maintenance activities and associated travel, whereas there are some people who spend essentially no time on discretionary activities/trips. On average, about 3 times as much time is spent on maintenance activities/trips as on discretionary ones. Note that since both in-home and out-of-home activity time is counted, the travel time price is capturing tradeoffs between in-home and out-of-home activity – as those tradeoffs currently stand across the sample as a whole.

7. Estimation and Statistical Results

The AIDS model can be estimated with standard statistical software; we used SAS. Both symmetry and homogeneity restrictions were tested. We found that both constraints were satisfied, indicating that the null hypothesis that the model is consistent with utility maximization theory is not rejected. The model results are reported in Table 3. The adjusted R^2s of 0.47 for both models are considered a good fit for disaggregate cross-sectional models (Greene, 2003[23]).

Estimates on the socio-demographic variables indicate that females, younger people, the unemployed, non-black[24], and people with higher household income (household incomes equal to or higher than $100,000) tend to spend a larger share of their total available time on maintenance activities and a smaller share of time on discretionary activities than other people do[25]. The model further shows that not just total travel time for a given activity type, but also the

[20] This dataset does not provide coding for multiple activities. Thus, if the activity code for the activity is classified as a maintenance (discretionary) activity, the amount of time allocated to it is counted toward the total amount of time allocated to maintenance (discretionary) activities. In some cases, a trip serves more than one activity with different purposes (as when one shops for clothing – maintenance – and goes to a movie – discretionary – in the same retail center). In this case, separating travel time for different purposes will be difficult. Although this issue cannot be dealt with in this dataset, we recognize that this is indeed one problem with the utilization of travel time price.

[21] Only one observation had a b_m greater than 1, and about 100 observations had a b_d greater than 1.

[22] We also excluded observations with a total duration for all activities for two days exceeding 2880 minutes.

[23] Greene (2003, p.37) commented that a R^2 of 0.5 is relatively high on a cross-sectional dataset.

[24] Simple cross-tabulations on the data confirm that on average, non-blacks reported spending more time (in absolute terms) as well as a larger share of their total available time (after subtracting the time spent on mandatory activities) on maintenance activities than did blacks. In particular, non-blacks spent more time (in absolute terms) and a greater share of their total available time on sleeping, day care/after school care, personal business, and household maintenance/chores.

[25] Note that in the demand functions, the dependent variables are w_m and w_d (shares of maintenance and discretionary activities), which are equal to $[m(1+b_m)]/\tau$ and $[d(1+b_d)]/\tau$, where m and d are the time spent on maintenance and discretionary activities respectively and τ is the total available time after subtracting the time spent on mandatory activities. τ, b_m, and b_d vary by individual. Although people with higher incomes allocated, on average, less time (in absolute terms) to maintenance activities than others did, the travel time price (b_m) for people

number of trips of that type plays an important role in time allocation, all else equal. Holding total maintenance travel time constant, the more maintenance trips one makes, the more time is allocated to maintenance activities, and similarly for discretionary trips/activities.

[Table 3 insert here]

Estimates of the parameters β_m and β_d provide information on the time equivalent of income elasticities, referring to the percentage change in the time spent on maintenance and discretionary activities, respectively, in response to a percentage change in the total amount of time available. The time equivalent of income elasticity is calculated as: $e_i = \frac{\beta_i}{w_i} + 1$, where e_i is the time equivalent of income elasticity of good i, and w_i is the budget share of good i. In general, a negative β_i indicates that e_i is between 0 and 1 and thus the i-th good is a necessity; a positive β_i indicates that e_i is greater than 1 and thus the i-th good is a luxury. In our model as shown in Table 3, β_m is negative, meaning that maintenance activities belong to the category of necessary goods (if one had more time, he or she would not increase the amount of time spent on maintenance activities by as much, proportionally, as the total increase in time). β_d is positive, meaning that discretionary activities belong to the category of luxury goods (if one had more time, he or she would increase the amount of time spent on discretionary activities by proportionally more than the total increase in time).[26]

Since changes in the full time prices, which are equal to $(1+b_m)$ and $(1+b_d)$ respectively for maintenance and discretionary activities, would only come from changes in the travel time prices (the b_m and b_d)[27], we calculate and plot the travel time price elasticities directly. To avoid confusion, estimates associated with the γs shown in Table 3 will not be discussed. Our interpretation of the results will concentrate on the calculated own and cross travel time price elasticities described below.

Calculations of the own and cross travel time price elasticities (that is, the percent change in time spent on activity *i* given a percentage change in the travel time price of activity *j*) are based on the following formula:

with higher incomes is larger than that for others and τ for people with higher incomes is smaller than that for others. Both contribute to the allocation of a larger *share* of the total available time to maintenance activities for people with higher incomes than for others.

[26] We estimated the same model for people with different income levels. For people whose income falls under \$15,000, it was found that their β_d is 0.14, which is slightly higher than for the rest of the sample (0.13). All other estimates are similar. This suggests that for people with low incomes, discretionary activities are even more of a luxury than for people with higher incomes, but not much more so.

[27] It is important to note that though changes in the activity time prices will not change the first part of the full time prices (since the activity time price will remain normalized to 1), they will indeed change the latter part, the travel time prices (since a given amount of travel time is now divided by a changed amount of activity time) and consequently the full time prices.

$$\varepsilon_{ij} = \frac{\partial \ln a_i}{\partial \ln b_j} = -\delta_{ij} + \frac{\partial \ln w_i}{\partial \ln b_j}$$
$$= -\delta_{ij} + \frac{1}{w_i} \cdot \frac{\partial w_i}{\partial \ln b_j}$$
$$= -\delta_{ij} + \frac{b_j}{w_i} \cdot \frac{\partial w_i}{\partial b_j}$$
$$= -\delta_{ij} + \frac{b_j}{w_i} \cdot \frac{\gamma_{ij} - \beta_i w_j}{1 + b_j}.$$

In the above formulation for elasticity, a_i is the amount of time allocated to performing the i-th type of activity; b_j is the amount of time one has to travel in order to perform one unit of time of the j-th type of activity; w_i is the share of time spent on traveling to and performing activity i, $\frac{(1+b_i)a_i}{\tau}$; and δ_{ij} is the Kronecker delta which is equal to 1 when i = j and 0 when i ≠ j. Evaluation of ε_{ij} with the above formula shows that the elasticity (either the own or the cross travel time price elasticity) varies not only with the shares w_m and w_d (which can also be expressed as 1 - w_m), but also with b_j, the travel time price of traveling to perform activity type j. In other words, it is a three-dimensional graph. Figures 1-4 plot the four ε_{ij}s as functions of the cost and share variables, using the estimates of the β_is and the γ_{ij}s in Table 3.

[Figures 1-4 insert here]

The own travel time price elasticities for maintenance and discretionary activities (ε_{mm} and ε_{dd}) are both negative and increase in magnitude when the corresponding travel time price increases (Figures 1 and 2). In terms of the magnitude, both ε_{mm} and ε_{dd} appear to be smallest when the corresponding travel time price (b_m or b_d) is low. Then, both increase in magnitude as the corresponding travel time price increases. This indicates that when the travel time price of performing either type of activity is low, people adjust their time allocation (in response to a change in the travel time price) to a smaller degree compared to when the travel time price is high. If we interpret the change in the travel time price as coming from the denominator (travel time to activities), this latter observation is quite reasonable. When travel time is high, a given percentage change in travel time constitutes a larger absolute amount of time than when it is low. Further, when travel time is high, the amount of time originally allocated to activities must be relatively lower, and hence the larger absolute amount of time released by the percentage change in travel time constitutes a larger percentage of activity time, than when travel time is originally low and activity time is high.

Figures 1 and 2 also show that the rates of increase for both maintenance and discretionary activities appear to be quite stable along the axis of the share of maintenance and discretionary activities throughout, indicating that the current shares of maintenance and discretionary activities do not appear to play a significant role in their own travel time price elasticities. In addition, although the absolute values of both elasticities are generally greater than 1, the magnitude for maintenance activities is considerably smaller that that for discretionary activities, indicating less scope for adjustment of maintenance activities than for discretionary activities, when the travel time price of the corresponding type of activity increases.

The cross travel time price elasticities of maintenance and discretionary activities with respect to the travel time prices for discretionary and maintenance activities respectively, ε_{md} and

ε_{dm}, are positive and increase in magnitude when the travel time prices for discretionary and maintenance activities increase (Figures 3 and 4). That is, an increase in the travel time price of each type of activity leads to an increase in time spent on the other type of activity. A potential two-directional substitution effect between discretionary and maintenance activities may explain this result. People may obtain positive utilities by performing certain maintenance (discretionary) activities. Thus, a reduction in the utility associated with a maintenance (discretionary) activity (due to the increase in the time cost of activity performance) may be partially re-collected by performing more discretionary (maintenance) activities.

In sum, the negativity of ε_{mm} and ε_{dd} found in this study is mostly consistent with a number of studies in the literature which identified a negative relationship between time allocation to different types of activities and travel (e.g., Levinson 1999; Golob and McNally 1997; Lu and Pas 1999; Fujii et al. 1997, cited by Kitamura et al. 1997; Kuppam and Pendyala 2001). The positivity of ε_{md} and ε_{dm}, while not surprising, identifies a substitution effect between activity types *tied to a change in the travel time price of one type*, which to our knowledge has not been previously identified in this form.

8. Discussion

In this paper, we developed and estimated a simple model of the tradeoff behavior between maintenance activities/travel and discretionary activities/travel, including both in-home and out-of-home activities. Using 3906 responses to the 1996 San Francisco Bay Area Household Travel Survey, the empirical answers to our initial research questions are as follows. With respect to the time equivalent of income elasticities of maintenance and discretionary activities, we found the former to be less than unity and the latter to be greater than unity. That is, if one had a certain amount of additional time, one would increase the amount of time allocated to maintenance activities disproportionally less, but would increase the amount of time devoted to discretionary activities disproportionally more. In other words, maintenance activities are a necessity and discretionary activities are a luxury.

With respect to the own travel time price elasticities, if the travel time price of performing either type of activity increases (for reasons such as traffic congestion), one would reduce the time allocated to that type of activity itself. The negativity of the own travel time price elasticities for both maintenance and discretionary activities is consistent with the negative slope often observed in the demand curve for goods. As expected, the time spent on maintenance activities is less elastic than the time spent on discretionary activities.

As for the cross travel time price elasticities (changes in time allocated to activity i itself in responses to changes in the time price for activity j), we found both $\varepsilon_{md} > 0$ and $\varepsilon_{dm} > 0$, indicating that maintenance and discretionary activities are substitutes.

The present work can shed light on the tradeoff between in-home and out-of-home maintenance and discretionary activities. If people can and are willing to substitute nearly all their out-of-home activities with similar in-home activities (so that the travel time prices b_m and b_d become close to zero), we observe that the magnitudes of the own travel time price elasticities for both types of activities become the smallest (close to -1). In other words, the two elasticities become equal to each other and a percentage increase in the travel time price will result in an equal percentage reduction in the time allocation to the corresponding activity. When the travel time prices for maintenance (b_m) and discretionary activities (b_d) are close to zero, the cross travel time price elasticities for discretionary and maintenance activities are also close to zero, suggesting that an increase in the travel time price for maintenance or discretionary activities will not initiate any change in the time allocation to discretionary or maintenance activities, respectively.

There is still more to be investigated. As discussed earlier, the consumption of goods and consumption of time are probably interrelated with each other. The conceptual differences between time and money discussed above call for alternative model frameworks to be developed (other than the modified classical microeconomic models) for better incorporation of goods consumption and time allocation, as well as for the collection of information on monetary budget and goods consumption from the same sample as that providing time allocation information.

It is also important to understand that what is estimated in our paper (as is the case for any single model over an entire sample) are general population average relationships, for the spatial and demographic characteristics of the population from which our sample is drawn. The stability of the travel time prices as well as the estimated parameters over time, space and different populations calls for future investigation. The travel time prices as well as the parameters of the model could in fact be expected to vary by demographic (e.g., in this study we found that the time equivalent of income elasticity of discretionary activities for people with household incomes below $15,000 is slightly larger than that of the rest of the sample (see footnote 26) and geographic characteristics (e.g., the travel time price may be higher in rural areas than in urban ones). Travel time prices may also change over time. For example, with increasing use of Information and Communication Technologies (ICT), people may substitute many of their out-of-home activities with in-home activities (e.g., shopping activities, going to the bank). These changes will likely change the travel time prices for various kinds of activities (e.g., the travel time price for maintenance activities may be reduced).

Furthermore, this study strictly dealt with intra-person time allocation and shed no light on inter-person time allocation. However, inter-person time allocation (in particular between household members) is probably relevant to intra-person time allocation. Therefore, incorporation of the inter-dependence between household members into a time allocation study should be one of the next steps for future research.

Lastly, the dataset used in this study is a cross-sectional dataset, containing responses from multiple individuals at a single point of time. Although the tradeoffs identified in this paper are described as intra-person tradeoffs, they are actually derived from inter-person comparisons based on the strong assumptions that behavior is symmetric and reversible (Kitamura 1990; i.e., the behavior of a person whose travel time price *changes* from, say, b_{m1} to b_{m2} is the same as that of an otherwise identical person whose travel time price is *currently* b_{m2}). Furthermore, the use of a cross-sectional dataset does not allow us to distinguish between the consequences of short-term and long-term changes present in the sample. For example, some effects may be the result of the combination of a change in job/home location and a change in the time allocation to maintenance/discretionary activities/travel. Correction of this potential problem calls for a panel dataset collection that tracks individuals' time-use behavior as well as their long-term choices (home/job location choices) over time.

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Table 1: List of Activities Classified as Maintenance and Discretionary

Maintenance Activities	Discretionary Activities
Shopping	Recreation/rest
Meals/preparation	Recreation/play
Sleep	Amusement at home
Day care/after school care	Visiting
Personal service	Entertainment
Medical service	Religion/civic[2] services
Professional business	Civic /volunteer services
HH/personal service	Amusement outside home
HH/maintenance chores	Hobbies
HH/obligation and family care	Exercise/athletics
Sick/ill	Computer
Waiting	Get ready[1]
Morning routine	
Evening routine	
Get ready[1]	
Hygiene	
Diary	

[1] The code for "get ready" is not for getting ready in the morning and in the evening, which mainly involves personal hygiene activities and hence belongs to the maintenance category. Here, "getting ready" is interpreted as getting ready for the next activity and thus can be classified as either a maintenance or a discretionary activity, depending on the type of the next activity.

[2] In the data dictionary for the 1996 MTC household travel survey data, this is called "religion/civil services", which we took to be a typographical error.

Table 2: Descriptive Statistics for Travel Time Prices and Share Information

Variable	Minimum	Maximum	Mean	Median
b_m	8.9E-9	0.55	0.04	0.03
b_d	1.7E-8	1.00	0.12	0.08
w_m	0.24	0.99	0.74	0.75
w_d	1.0E-6	0.76	0.26	0.25

Table 3: Estimation Results of the AIDS Model for Time Allocation[1]

Variable	Estimate	t-ratio	p-value
Maintenance			
Intercept (α_m)	1.79	40.38	<0.01E-2
Lnm (γ_{mm})	-0.24	-25.13	<0.01E-2
Lnd (γ_{md})	0.24	25.13	<0.01E-2
Lnp (β_m)	-0.13	-22.57	<0.01E-2
Male	-0.03	-9.85	<0.01E-2
Age	-0.04E-2	-4.71	<0.01E-2
Employ	-0.01	-3.21	0.13E-2
Black	-0.03	-3.91	<0.01E-2
Highinc	0.01	2.64	0.84E-2
Ntripsm	0.02	25.99	<0.01E-2
Ntripsd	-0.03	-40.32	<0.01E-2
Adjusted R-squared: 0.47			
Discretionary			
Intercept (α_d)	-0.79	-40.38	<0.01E-2
Lnm (γ_{dm})	0.24	25.13	<0.01E-2
Lnd (γ_{dd})	-0.24	-25.13	<0.01E-2
Lnp (β_d)	0.13	22.57	<0.01E-2
Male	0.03	9.85	<0.01E-2
Age	0.04E-2	4.71	<0.01E-2
Employed (1 if employed and 0 otherwise)	0.01	3.21	0.13E-2
Black	0.03	3.91	<0.01E-2
Highinc (1 if household income is ≥ $100,000)	-0.01	-2.64	0.84E-2
Number of maintenance trips	-0.02	-25.99	<0.01E-2
Number of discretionary trips	0.03	40.32	<0.01E-2
Adjusted R-squared: 0.47			
Constraint Tests			
Adding up	2.19E-10	0.00	1.00
Symmetry	-3.42E-11	-0.00	1.00
Homogeneity (m)[2]	-22.26	-1.08	0.28
Homogeneity (d)[3]	22.26	0.40	0.69

[1] Both symmetry and homogeneity constraints are imposed and satisfied.
[2] Homogeneity constraint for maintenance activities.
[3] Homogeneity constraint for discretionary activities.

Figure 1: Own Travel Time Price Elasticity of Time Spent on Maintenance Activities, as a Function of Travel Time Price for Maintenance Activities (b_m) and Share of Time Spent on Maintenance Activities/Travel (w_m)

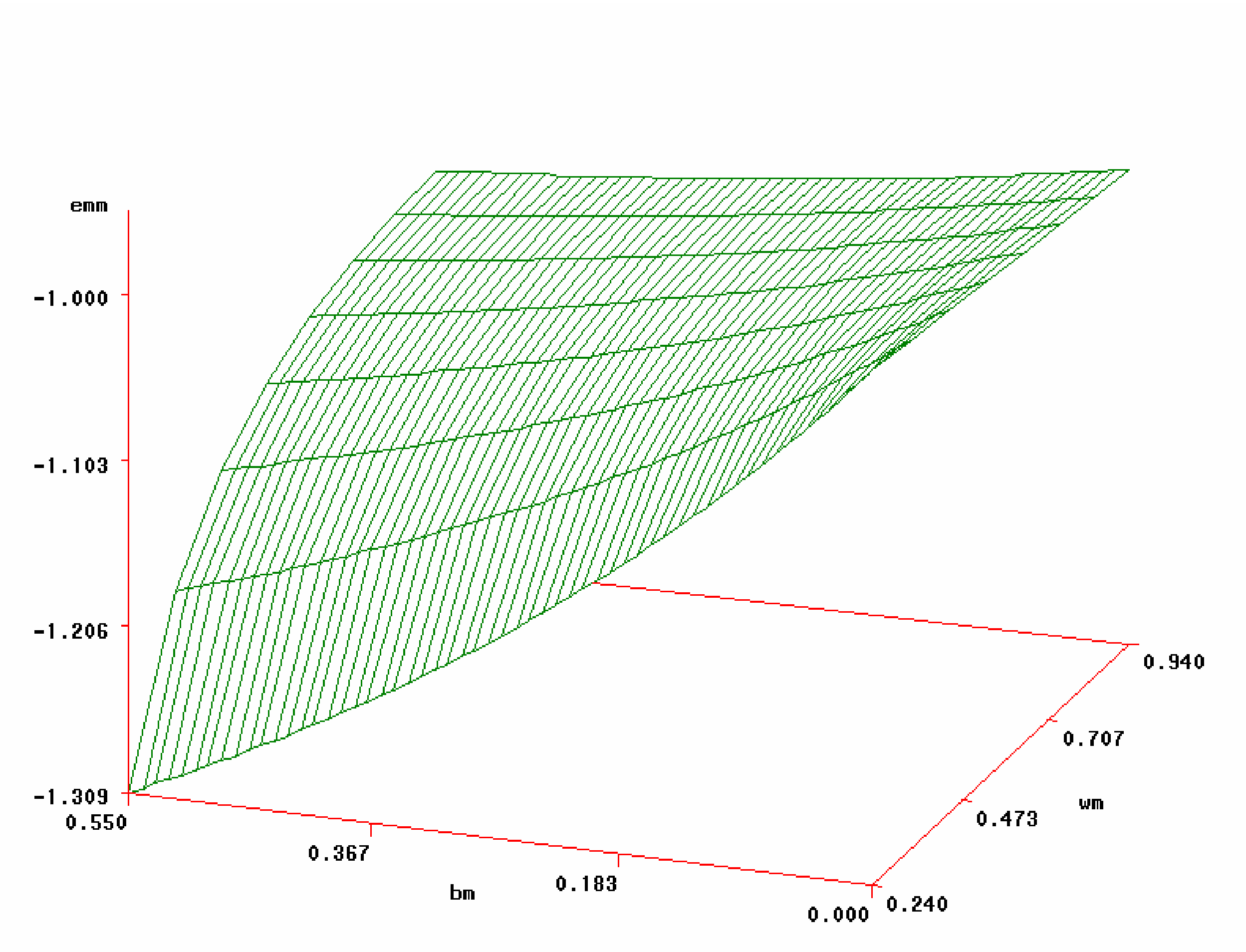

Figure 2: Own Travel Time Price Elasticity of Time Spent on Discretionary Activities, as a Function of Travel Time Price for Discretionary Activities (b_d) and Share of Time Spent on Discretionary Activities/Travel (w_d)

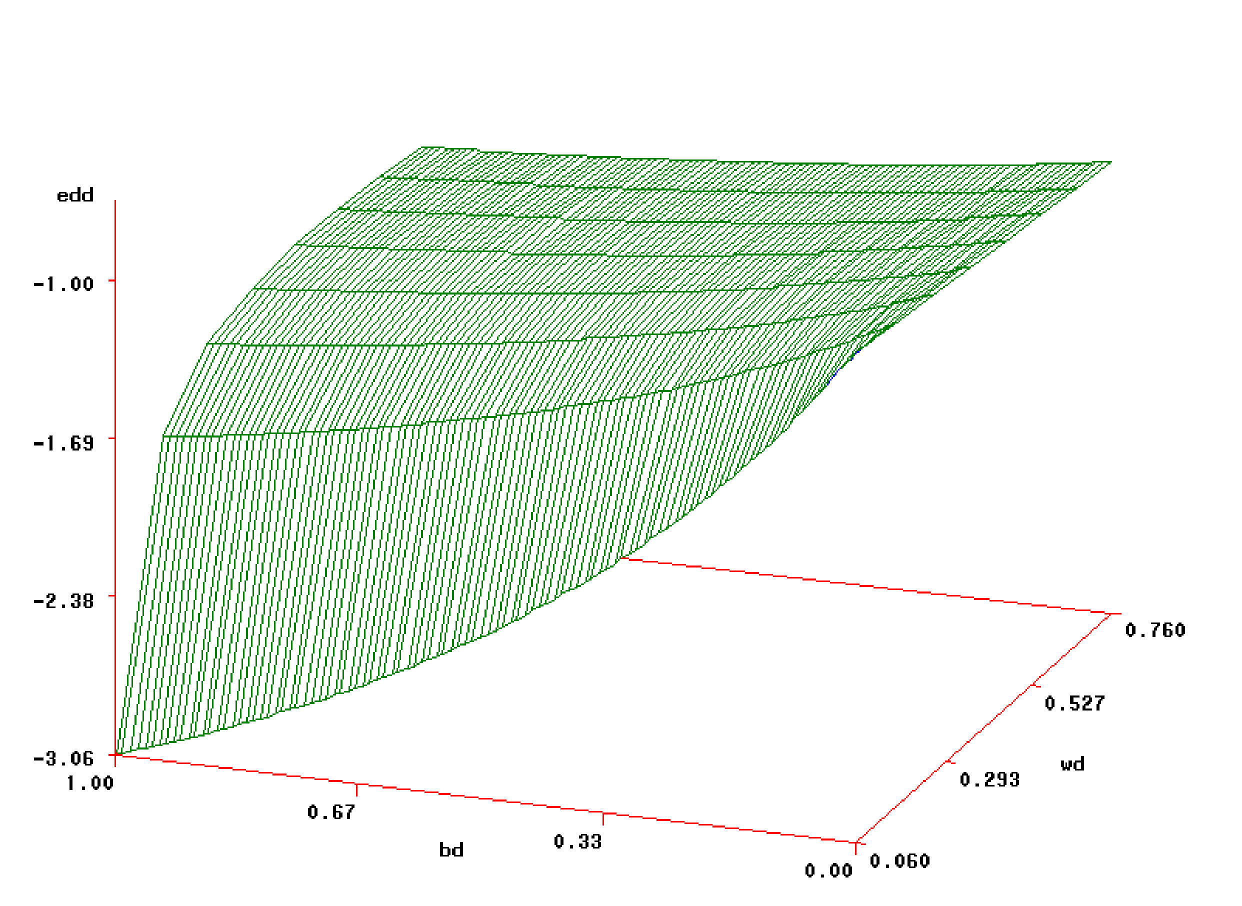

Figure 3: Cross Travel Time Price Elasticity of Time Spent on Maintenance Activities, as a Function of Travel Time Price for Discretionary Activities (b_d) and Share of Time Spent on Maintenance Activities/Travel (w_m)

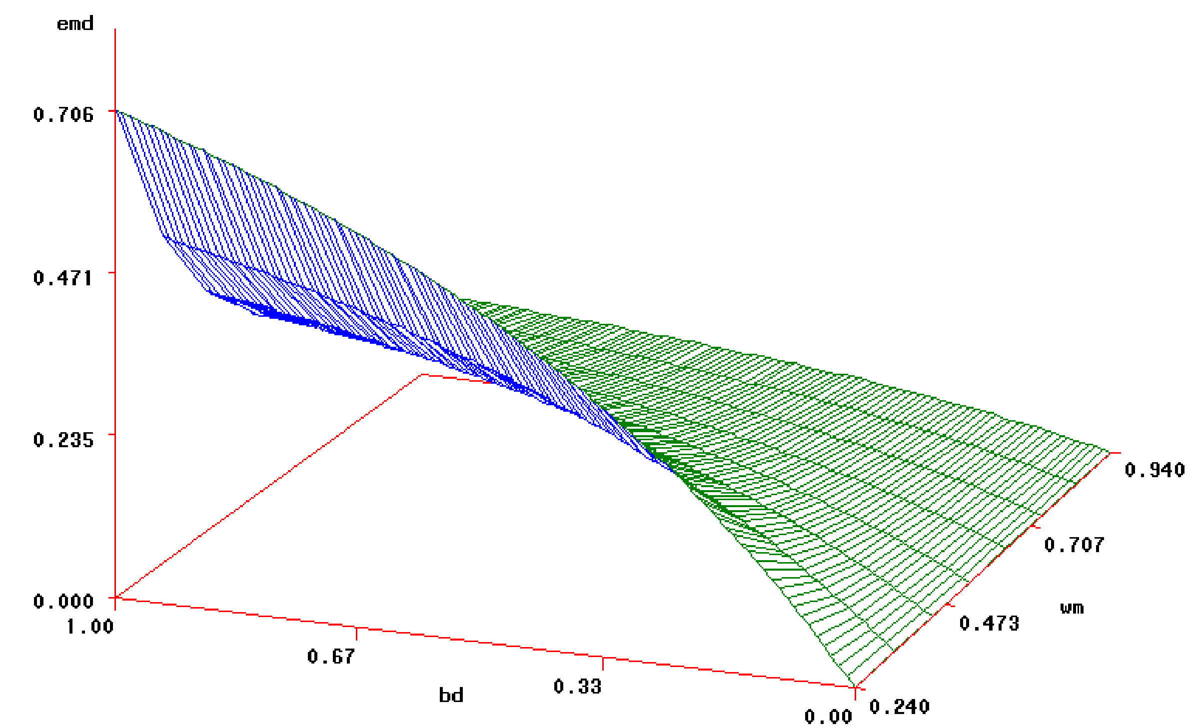

Figure 4: Cross Travel Time Price Elasticity of Time Spent on Discretionary Activities, as a Function of Travel Time Price for Maintenance Activities (b_m) and Share of Time Spent on Discretionary Activities/Travel (w_d)