TTB or not TTB, that is the question: a review and analysis of the empirical literature on travel time (and money) budgets

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Patricia L. Mokhtarian and C Chen, "TTB or not TTB, that is the question: a review and analysis of the empirical literature on travel time (and money) budgets" (2004). Transportation Research Part A-Policy and Practice. 38 (9-10), pp. 643-675. Postprint available free at: http://repositories.cdlib.org/postprints/38

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Abstract

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December, 2003

Transportation Research Part A **38(9/10)**, 2004, pp. 643-675

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ABSTRACT

This paper summarizes and analyzes findings from more than two dozen aggregate and disaggregate studies of travel time (and sometimes money) expenditures, exploring the question of the existence of a constant travel time budget. We conclude (with prior researchers) that travel time expenditures are not constant except, perhaps, at the most aggregate level. Nevertheless, individuals' travel time expenditures do show patterns that can be partly explained by measurable characteristics**.** Travel time expenditure is strongly related to individual and household characteristics (e.g., income level, gender, employment status, and car ownership), attributes of activities at the destination (e.g., activity group and activity duration), and characteristics of residential areas (e.g., density, spatial structure, and level of service). To the extent that travel time expenditures *are* constant at the aggregate level, the underlying mechanisms explaining that regularity are not well understood. Consequently, further research into explaining travel time and money expenditure patterns is justified.

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1. INTRODUCTION

Over the last forty years of travel demand analysis, time has been a variable of central importance to our understanding of the demand for travel (Pas, 1998). A frequently-studied time-related measure is the amount of time allocated to travel. The concept of a "travel time budget" (TTB) refers to the idea that individuals' average daily travel time tends to be relatively constant. The behavioral hypothesis is that people have a certain (generally non-zero) amount of time that they are willing (or may even want) to spend on travel, and that they will make adjustments to minimize departures from that budget in either direction. Proponents of a travel time budget generally go beyond the suggestion of an individual-specific budget, however, to the observation that the actual size of that budget, as an average taken at a regional or national scale, is relatively stable across time and space. At the extreme, the TTB is viewed almost as a universal constant: 1.1 – 1.3 hours per traveler per day (Zahavi and Ryan, 1980; Zahavi and Talvitie, 1980), about 430 hours per person per year (Hupkes, 1982), 50 minutes to 1.1 hours per person per day (Bieber *et al.*, 1994), 1.1 hours per person per day (Schafer and Victor, 2000), or 1.3 hours per person per day (Vilhelmson, 1999). (The distinction between person and traveler bases is discussed further in Section 2.2 below).

The position of the TTB concept in the transportation planning and modeling profession is paradoxical. On the one hand, the concept has shown a stubborn persistence in the literature, despite the fact that (as has been noted by others and will be demonstrated below) the more closely it is examined, the more elusive it becomes. Clearly there is something about the TTB idea that resonates with us. One reason is the common observation that at the aggregate level, when travel speeds increase over time – whether due to improvements in technology or additions of capacity to the system – travel distances tend to increase so as to keep travel times approximately constant (Zahavi and Ryan, 1980; Hupkes, 1982; Marchetti, 1994; Barnes and Davis, 2001). This links the TTB concept to the induced demand debate (e.g., Noland and Lem, 2002), with one extreme arguing that, at least from energy and air quality standpoints, it is useless at best and counterproductive at worst to add network capacity (or, presumably, to implement any operational efficiencies that increase overall speeds, as Taylor, 2002 notes), since people will simply take advantage of the improvement to travel more.

On the other hand, the TTB idea appears, at least at first glance, to clash with one of the most fundamental tenets of conventional travel behavior theory: that travel time is a disutility to be minimized. The travel time minimization principle underlies a great deal of policy-making as well as virtually all regional travel demand forecasting models, and is used to justify monetizing the benefits of transportation improvements on the basis (primarily) of travel time savings. But obviously, under a TTB, travel time is not minimized but is kept constant. If that is true, then, for example, the typical travel demand model is asking the wrong question. Rather than assuming the individual to be asking, "What is the least amount of travel I can do in order to accomplish a given set of activities?", the individual instead should be viewed as asking, "What is the most attractive set of activities/ destinations I can achieve, given a certain travel time budget?"[1]

Some researchers, therefore, have expressed discomfort with the TTB concept on the grounds that it conflicts with utility maximization, or with the principle that travel is a derived demand (see, e.g., Giuliano, 1997; Tanner, 1981). In and of itself, however, the TTB concept does not seem to conflict with these principles (see, e.g., Golob, et al., 1981; Goodwin, 1981; Hupkes, 1982). Even under conventional modeling assumptions, traveling greater distances is entirely predictable (has higher utility) when the greater attractiveness of the more distant destination outweighs the disutility of the additional travel required to reach it. Thus, if individuals use travel time saved (through higher speeds or greater accessibility) to visit more destinations, and/or destinations that are farther away but more attractive, they are still increasing their utility and their demand for travel is still purely derived. The TTB concept simply adds a hypothesized behavioral constraint to the form that utility is expected to take. Specifically, the utilities of alternative activities/destinations can still (as is commonly the case now) be modeled as being directly proportional to their attractiveness, and inversely proportional to the travel time (or generalized travel cost) required to reach them, subject to an escalating penalty for violating the desired TTB in either direction for an entire day's (or other unit of time) set of activities. In principle, it is simply this latter penalty function that current models lack. In practice, establishing such a penalty function is non-trivial, since eliciting data from individuals on the abstract concept of a "desired travel time budget" would present a considerable challenge (see the further discussion of this point in Sections 4 and 5).

Thus, the apparent paradox of the TTB concept may be due simply to a failure to make the models realistic enough, rather than to an actual contradiction of the basic principles on which the models are based. Nevertheless, if the TTB is a fundamental principle of its own, it should be important for the models – on which many policy and investment decisions are based – to reflect that principle. Not surprisingly, several researchers have addressed ways of incorporating the TTB concept into some travel behavior models (Golob, et al., 1981; Goodwin, 1981; Gunn, 1981), and some have actually operationalized such models. An early proponent of the TTB, Yacov Zahavi (1979), developed a "Unified Mechanism of Travel (UMOT)" process for travel demand forecasting based on a TTB. Greene (1986) also explored ways of estimating vehicle-miles traveled via incorporating the travel time budget concept. Much more recently, researchers at MIT have used the concept to predict future worldwide mobility as incomes rise and slower modes are replaced by faster modes (Schafer, 1998, 2000; Schafer and Victor, 2000).

In view of the elemental nature of the TTB concept, the profound implications for modeling and policy/planning depending on whether it is valid or not, and the ambiguous status it currently holds in our thinking, it is worthwhile to undertake an analytical review of the current body of evidence on the subject. That is the primary purpose of this paper. Although much less attention

[1] Essentially this observation is attributed to Zahavi by Gunn (1981) and by Michael Wegener as a participant at the European Science Foundation/National Science Foundation Social Change and Sustainable Transport (SCAST) conference at Berkeley, California, March 10-13, 1999.

has been devoted to travel money budgets, we also review the evidence on that subject[2]. Throughout this paper, we attempt to distinguish between "budget" and "expenditure". Following Goodwin (1981, p. 97), the word "expenditure" simply refers to the amount of quantitative resources spent on consuming a good or service or performing an activity (including travel); it does not imply stability. On the other hand, the word "budget" implies stability, referring to an "allocation of time, money or generalised resources to travel which would not be influenced by policy, trends or costs."

The paper is organized as follows. In Section 2, we provide an overview of the studies reviewed, including a discussion of the complexities of this cross-study comparison. In Section 3, we present a number of variables related to travel time and money expenditures in various studies, and summarize the nature of those relationships. Tables 1-3 summarize the studies reviewed; a brief synopsis of each individual study is available in Chen and Mokhtarian (1999). Section 4 discusses several explanations advanced in the literature for the existence of a constant TTB, and Section 5 offers some concluding remarks and directions for further research. This paper focuses on empirical descriptive results with respect to travel time and money expenditures. In a companion report (Chen and Mokhtarian, 2000), we focus on ways of modeling an individual's time and money expenditures on travel. There we review disaggregate methodological approaches (single linear equations, structural equations, duration models, and utility maximization models) found in the literature, together with key results, and develop a new utility maximization model of travel time and money expenditures that utilizes the Almost Ideal Demand System (AIDS) approach to demand analysis (Deaton and Muellbauer, 1980).

2. OVERVIEW OF LITERATURE REVIEWED

2.1. Progression of Research Motivations and Approaches

The research into travel time and money budgets was originally motivated by dissatisfaction with the Urban Transportation Planning System (UTPS) modeling approach. In the 1970s, the traditional four-step model used to forecast regional travel demand was increasingly viewed as inadequate for modeling changes in individuals' travel behavior. For example, a change in trip rates could well be because of changes in the transportation service levels (e.g., costs of travel), and independent of those variables considered in the conventional trip generation models (e.g., income growth, vehicle purchase, etc.). The traditional four-step model's implicit assumption of stable trip rates given certain household characteristics prevented such changes in travel behavior from being modeled accurately. In addition to the inability of traditional four-step models to handle certain behavioral changes, there was also increasing dissatisfaction with the statistical inaccuracies of these models (Gunn, 1981) and the difficulty in fitting the model to observed data (Robbins, 1978, cited in Gunn, 1981).

Tanner (1961, cited in Kirby, 1981) was perhaps the first person to raise the concept of a stable travel time budget, with Robinson *et al.* (1972) furthering the idea. Around the late 1970s and

[2] The same group of researchers who proposed the existence of a travel time budget also proposed the existence of a travel money budget. They argued that people spend a fixed percentage of their income on travel: about 10 to 11% of income for car-owning households and 3 to 5% of income for carless households (Zahavi and Ryan, 1980).

early 1980s, researchers looked for the regularities in time and space that travel behavior may exhibit. It was hoped that travel time and money budgets, if they existed, could significantly improve the behavioral sensitivities of the traditional four-step modeling procedure. Zahavi (1979), who also added the concept of the travel money budget, developed a Unified Mechanism of Travel (UMOT) process for travel demand forecasting. The UMOT concept was based on the assumption that travel time and money expenditures exhibited regularities that can be attributed to certain factors such as socio-economic characteristics of households, transportation system supply, and urban structure, and that these regularities are spatially and temporally stable. Explicitly accepting these constraints in the modeling process, as Zahavi argued, would allow transportation planners to predict behavioral changes and make policy recommendations, for which "no lengthy calibration process to observed data is required" (Zahavi and Talvitie, 1980, p. 18). Chumak and Braaksma (1981) argued that the concept of a constant travel time budget can be used to check conventional forecasting results and to ensure that those results reflect an equilibrium between travel demand and the supply of the transportation facilities. Additionally, Goodwin (1981) discussed how time and money budgets, if they existed, might be incorporated into various components of the traditional four-step modeling procedure. Fourteen of the 22 aggregate studies we reviewed in detail for this paper were conducted between the late 1970s and the early 1980s.

In the 1980s, with the rapid development in econometric models and computing capability, disaggregate studies more and more dominated the field in travel behavior. The research objective was still to support policy recommendations, but the interest in travel time and money budgets declined dramatically. This may have been because disaggregate models themselves were considered to be an important improvement in forecasting capability, even without the additional assumption of travel time and money budgets. With improved computer capabilities, the motivation to simplify computation procedures was no longer as strong, and furthermore, there was perhaps a realization that the travel time budget theory was not as robust as had been hoped. Probably for these reasons, very few studies were found in the mid- and late 1980s on the stability of travel time and money expenditures.

From the late 1980s and early 1990s, activity-based research started to flourish. This was motivated by the long-recognized concept of travel as a derived demand and the recognition of history and future dependence among activities and travel within a certain period. Although the research objectives are still to forecast travel behavior and make transportation policy recommendations, the study focus has largely shifted from travel to activity. Activity-based researchers are placing a greater emphasis than ever on the behavioral aspects of observed patterns, particularly why people engage in activities distributed in space. Within this context, it is important to understand how individuals allocate time and money among activities and travel, not necessarily for the purpose of simplifying demand analysis as Zahavi first envisioned, but for the purpose of enhancing our behavioral understanding. It is hoped that an improved understanding of individuals' allocation behavior will enhance our knowledge of travel behavior, which will then allow us to construct more accurate travel demand models. All seven disaggregate studies formally reviewed in this paper were conducted in the 1990s, and four of them are particularly in the context of an activity-analysis orientation.

2.2. Complexities of Cross-Study Comparisons

In cross-study comparisons, it is desirable to compare results from different studies using similar dimensions. Unfortunately, this is almost impossible to achieve as researchers conducted their studies at different times and with different objectives. Consequently, differences, sometimes significant, exist. Thus, it is important to keep the differences described below in mind.

Modes Included. Not all studies are based on the same set of modes. In particular, modes at each end of the speed spectrum are often excluded: non-motorized modes (e.g., walking) and high-speed modes (e.g., airplanes and high-speed trains). Exclusion of any mode biases the estimation of daily travel time expenditures downward. The bias due to excluding non-motorized modes is especially severe for developing countries as well as for many European countries where the automobile is not as dominant and higher densities prevail compared to the US. For example, in Britain it was estimated that walking comprised about 30-40% of the total time spent traveling during the 1970s[3] (Goodwin, 1981). As for the exclusion of high-speed modes, although the frequency of taking airplanes and high-speed trains is quite low for most people, the travel distances they cover at one time are much higher than for the more frequent trips by slower modes.

Survey Period. Due to day-to-day variations (Prendergast and Williams, 1981; Kumar and Levinson, 1995), the length of the survey period could bias the estimate of the travel expenditures. Goodwin (1981) pointed out three causes of day-to-day variation. One type is pure random day-to-day variation. The second type is systematic variation, due to the fact that not all types of trips are made every day. For example, workers may do grocery shopping once a week. The third type is the lag effect. In other words, the travel behavior we observe during the survey period may be due to time and cost effects from the unobserved previous period. In short, these day-to-day variations suggest that a minimum desirable survey period might be one week, with periods of one month or even a year desirable to capture less frequent travel (e.g., major vacations) which may nevertheless contribute significantly to the total travel expenditure. However, the ideal of measuring all travel must be balanced against the burden on the survey respondent, and in fact survey periods almost never exceed one week, with periods of one to three days being quite common.

Survey Type. The way the question is asked will affect the response. Robinson (1997) argued that if subjects are asked to give a single answer to the total amount of time spent on activities and travel (e.g., "how much time did you spend traveling yesterday?"), the resulting answer can be very erroneous. Such questions require respondents, in a very short time, to sum up the travel times of all trips they took on the previous day. Alternatively, travel time estimates in most of the studies reported here have been obtained via a diary of some kind – either a trip diary, activity diary, or time use diary. Schafer (2000) points out that improvements in travel data collection over a period of several decades have led to increases in the amount of travel *measured*, which are then difficult to distinguish from any changes in the actual amount of travel itself.

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[3] The current percentage of time spent on non-motorized travel in Britain is presumably considerably less.

In a trip diary, subjects are asked to report every trip they made during a certain period. Researchers sum up the travel times of every trip respondents reported to obtain the total daily travel time expenditure. This often leads to an underestimation of the total travel times because trips with short duration tend to be forgotten by respondents. In an activity diary, subjects are asked to record the activities they engaged in during the study period, with travel times typically being inferred from the departure and arrival times for successive activities. Studies have shown that the activity diary format results in more trips being reported, especially non-work trips, suggesting that it does a better job in prompting respondents' recollections of shorter trips.

However, neither travel diaries nor activity diaries generally do a good job of separating wait time from either the travel or the activity with which it is associated, and both diary formats are subject to round-off error in the reported travel or activity times (see, e.g., Stopher, 1992; Axhausen, 1995). Arguably, wait time intrinsically associated with a given travel mode (e.g. time spent waiting for fellow carpoolers to arrive at a central departure point, or time spent on transit transfers) should be considered part of the travel time for that mode (although as Axhausen points out, this can skew estimates of travel speeds if those estimates are intended to refer to vehicular speeds rather than simply the distance covered in a given amount of time, on average). A bigger concern is with the proper allocation of wait time intrinsically associated with an activity (e.g. arriving several minutes prior to the scheduled start time, or time spent in socializing after the scheduled end time). It may be that an activity diary's focus on the activity rather than the travel will create the tendency for some respondents to report activity start and end times closer to the "official" start and end times rather than their actual arrival and departure times. To the extent that this is true, the wait times that should legitimately be associated with the activity would in fact be falsely attributed to the travel before or after the activity, thereby inflating the estimates of travel time expenditures.

Further, many activity diary formats do not obtain a great deal of detail on multimodal trips. In particular, they do not elicit the travel time associated with *each* mode segment of the trip, only the travel time for the trip as a whole. Obviously, this compromises the ability to analyze travel time expenditures by modes, in order to examine modal tradeoffs (for example, whether higher travel times by auto are associated with lower times by walking or transit).

Time use surveys ask respondents to record what they are doing at each point in time during the study period, using one of two common formats. In either format, unless the time use diary is specifically focused on recording travel (which is generally not the case), inaccuracies are likely to result. In the open-ended format, respondents simply record the start and end times of each activity, whereas in the preset interval format, respondents indicate what they are doing in each prespecified time interval, for example 15-minute increments. The latter format obviously runs the risks of underreporting for shorter trips, and substantial round-off error in estimating travel times for the trips that are reported. In either format, multimodal trips are likely to be reported simply as a "travel" activity, without distinguishing the time allocated to each mode separately.

Analysis Unit. Researchers used different analysis units based on different arguments. Zahavi's pioneering studies focused on travel time expenditure per traveler (those who made at least one motorized trip during the survey period). The reason behind the use of travelers as the unit instead of all people, as Zahavi explained, was that he found that using the former measure as the basis gave stable results whereas using the latter measure did not. However, without a prior conceptual justification of the superiority of the former measure, the choice appears to be a selective acceptance of results that fit a preconception and rejection of those that did not. Chumak and Braaksma (1981) also used the trip-maker as the unit of analysis, with trip-maker similarly defined as an individual who makes at least one mechanized trip per day.

Goodwin (1981), on the other hand, argued that the mean travel time expenditure per traveler would depend on the duration of the survey period, while travel time expenditure per person does not. For example, on any given day, some proportion of people may not travel, but a far smaller proportion will not have traveled in an entire week. Keeping the travel time expenditure per person constant, the daily travel time expenditure per traveler will be higher if the study period is one day than if it is one week. In general, given the differences between analyzing travel time expenditures on a per-person versus per-traveler basis, it is troubling that stability sometimes appears with one basis and sometimes with the other (Kirby, 1981), as shown by the estimates presented in the first paragraph of this paper – again suggesting that stability may be to some extent an artifact of researcher selectivity among various results.

Relatively few studies (Downes and Morrell, 1981; Purvis, 1994; Golob, 1990) used travel time expenditure per household, to account for interactions among household members. The argument is that tradeoffs in household responsibilities may mean that one member can travel less by having another member travel more. The travel time expenditure per household may have less variation compared to travel time expenditure per person because higher and lower travel time expenditures among household members balance out and thus provide a seemingly more stable travel time budget. However, such a measure would not provide insights into the specific nature of household tradeoffs and how they are made.

The use of different analysis units may also sometimes conceal possible interactions that travel time expenditures have with other variables. Consider the example of the interaction between travel time expenditures and gender. As indicated in Section 3.1.1 below, Zahavi and Talvitie (1980) found an insignificant relationship between the two. However, their analysis was based on travel time expenditures per traveler (a person who has made at least one motorized trip). If they had examined travel time expenditures per person instead, a significant relationship between the two may have emerged, as the proportion of males who were travelers was probably higher than the proportion of females who were travelers.

Types of Trips Included. Not all studies included all types of trips made during the study period. Some studies (e.g., Hamed and Mannering, 1993) included only post-work trips. Other researchers (e.g., Gordon et al., 1991) only analyzed commuting times. A recent study (Vilhelmson, 1999) models the time spent in traveling to activities that are flexible in time and space[4]. These studies are not readily comparable to other analyses that include all types of trips.

[4] The same study tabulates average total daily travel time for Swedish adults ages 20-64 (based on large-sample nationwide surveys), for several time points from 1978 to 1995. The result shows stability (about 80 minutes or 1-1/3 hours per person per day) from 1978 to 1991, with decreases in 1994 (to 74 minutes/day) and 1995 (to 69

However, the Hamed and Mannering study is included in our review because of the novel (in this context) methodology it employs.

2.3. Methodologies Employed

Basic information about the studies reviewed is summarized in Tables 1 and 2. The studies fall into two categories: aggregate and disaggregate. Aggregate studies analyze observations at a relatively large geographical scale (e.g., city, transportation analysis zone), whereas disaggregate studies analyze observations at the household or individual level. The methodologies employed in these two types of studies differ significantly. Aggregate studies mainly employed descriptive analysis techniques; a few also used linear regressions. On the other hand, disaggregate studies employed methodologies such as structural equations modeling and survival analysis. As indicated earlier, the analysis methodologies themselves are the focus of a companion report (Chen and Mokhtarian, 2000).

3. THE RELATIONSHIPS OF KEY VARIABLES TO TRAVEL TIME AND MONEY EXPENDITURE

3.1. Travel Time Expenditure

A number of aggregate studies beginning in the late 1970s and early 1980s explored the regularity of travel time expenditures in space and time. When these studies are compared with each other, the results do not support the concept of stability. Early studies claimed that daily travel time expenditure per traveler showed stability over time (Zahavi and Talvitie, 1980; Zahavi and Ryan, 1980; Chumak and Braaksma, 1981). This argument was supported by Hupkes (1982). But Hupkes examined the temporal stability of the daily travel expenditure per person instead of per traveler (whereas, as indicated in Section 2.2, Zahavi did not find stability on a per person basis). A more recent study that supports the claim of a travel time budget is reported in *Land Use and Travel Choices in the Twin Cities: 1958-1990*. As Zahavi examined the change of travel time expenditures in the Twin Cities (Minneapolis and St. Paul, Minnesota) between 1958 and 1970, Barnes and Davis (2001) extended Zahavi's study and examined the change in travel time expenditures in the Twin Cities between 1970 and 1990. They found (p. 11) that "since 1970 speeds increased, distance traveled increased, and time spent traveling remained essentially constant".

Kitamura, *et al*. (2003), however, found that per-person travel times increased between 1970 and 2000 in the Kyoto-Osaka-Kobe metropolitan area of Japan, and comment in their abstract and conclusions that "the universal rule in activity engagement and travel is not constancy, but expansion." Similarly, Armoogum, *et al.* (2003) found increases in total per-person travel times between 1976-77 and 1995-98 for three of the four largest metropolitan areas of France. Purvis (1994) found that the travel time expenditure per traveler showed instability over time (increased from 1965 to 1981 but decreased from 1981 to 1990) in the San Francisco Bay Area. Levinson and Kumar (1995) found that daily travel time significantly increased from 1968 to 1988 in the

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minutes/day). The decrease is attributed to the shift to faster modes of travel (auto), and to underestimation due to a shift in survey administration mode from personal interview to telephone.

metropolitan Washington area, using data collected for local planning purposes. The fact that the 1968 survey (conducted by Metropolitan Washington Council of Governments) excluded non-motorized trips could well account for part or even all of the increase. Another study by the same authors (Kumar and Levinson, 1995) using the Nationwide Personal Transportation Survey (NPTS) data found a different result; specifically, they found that at the national level, the daily travel time expenditure remained unchanged between 1954 and 1990. The discrepancies between these two studies could well be because of the different geographical scales used. The NPTS data used in the latter study is at the national scale. It is quite possible that the aggregate average travel time expenditure exhibited in the latter study would appear more stable than studies using data on a smaller geographical scale (e.g., the former study). Moreover, the metropolitan Washington, D.C. area (the subject of the former study) may have unique characteristics that do not stand out in the NPTS study. In short, an apparent temporal stability at higher levels of geographic aggregation (e.g., national level) may mask instability at a finer scale (e.g., metropolitan level).

In addition to temporal stability, Zahavi and his colleagues (1980) also argued for the spatial stability of the daily travel time expenditure per traveler. Robinson et al. (1972) examined travel time expenditure per person per day in twelve countries. Although the highest average travel time expenditure (90 minutes) is more than twice the lowest average travel time expenditure (39 minutes), the authors concluded (p. 117) that the variation fell into a "remarkably narrow range." Kitamura et al. (1992) examined time use patterns in terms of travel time per person per day in the Netherlands and California and found that Californians spent considerably more time on traveling than did the Dutch, a result that contradicts the spatial stability of travel time expenditures.

Even researchers who argued for the stability of travel time expenditures at the aggregate level acknowledged that there was considerable variation at the disaggregate level (e.g., Zahavi and Talvitie, 1980). Analysts have attempted to relate the observed variation to a number of potential explanatory variables. We discuss some of the commonly-studied variables below. Variables representing socioeconomic characteristics are presented first, followed by activity-related attributes and then area-specific attributes (density and network attributes). Only variables found significant in more than one study are included here. The results are summarized in Table 3.

3.1.1 Socioeconomic Characteristics

Age. More studies have found a significant effect of age on travel time expenditure than studies (Roth and Zahavi, 1981) that found it insignificant. Prendergast and Williams (1981) found that people of middle ages (between 21 and 64) spent more time on traveling than those who are either below school age or above retirement age. Kitamura, et al. (1992) found that people between 18 and 50 years old traveled significantly more than people older than 50. Gunn (1981) found that people between 17 and 24 years old spent more time traveling than people in other age groups. In addition, people younger than 16 or older than 60 traveled significantly less than people of other age groups. All these studies examined all modes together, so these observed results are probably not due merely to the reduced "automobility" of the young and the old. In other words, the young and the old presumably not only had lower daily travel time by automobile but also had lower total daily travel time by all modes. Rutherford et al. (1996) found mixed results for the effect of age on daily travel time. In any single cross-sectional study, the effect of age will be confounded with that of generation or cohort. That is, the observed effect may be due to the interaction of people in a certain age group with other influences specific to that group (for example, cultural expectations with respect to women driving or working, or the relative availability of different types of transportation infrastructure – e.g. highways versus rail). To the extent that is the case, it will not be appropriate to expect people who enter that age group a few decades from now to have travel patterns similar to those who are that age today. Nevertheless, the general pattern that working adults travel more than those younger and older has persisted through multiple cross-sectional studies spanning several decades and locations, and can be expected to continue, although with modifications (e.g. a flattening of the relative peak in middle ages, especially as older adults remain healthy and active longer).

Car Ownership. A clear linkage between travel time expenditure and car ownership often appears, but the direction of such linkage is not consistent. A positive influence of car ownership on travel time expenditure has been found in many studies (van der Hoorn, 1979; Prendergast and Williams, 1981; Godard, 1978, cited in Gunn, 1981; Purvis, 1994; Lu and Pas, 1999). A negative relationship between car ownership and travel time expenditure was also found (Zahavi and Talvitie, 1980; Roth and Zahavi, 1981; Robinson et al., 1972). Insignificant relationships have also been found (Downes and Morrell, 1981; Bullock et al., 1974, cited in Gunn, 1981; Purvis, 1994).

The contradictory results on the relationship between car ownership and travel time expenditures may be due in part to the mix of different modes in different studies, (not all of which report the modes included, as Table 1 shows). Car ownership could well cause an increase in travel time expenditure by auto modes but a decrease in travel time expenditure by other modes. Golob (1990) found that travel time by car increases with car ownership, but travel times by public transport and non-motorized modes decrease with car ownership. Travel time expenditure by mode was also studied by other researchers (Prendergast and Williams, 1981; Tanner, 1981; Goodwin, 1976).

A reverse causality from travel time expenditure to future car ownership is also possible (Golob, 1990). Large amounts of time spent on car travel may cause an increase in future car ownership, while large amounts of time spent on public transport may cause a switch from a slower mode to a faster mode within limits of constraints such as income.

Employment Status. The influence of employment status (employed vs. unemployed) on travel time expenditure is quite uniform. Most studies have found that employed people tend to spend more time traveling than unemployed people (van der Hoorn, 1979; Zahavi and Talvitie, 1980; Roth and Zahavi, 1981; Prendergast and Williams, 1981; Wigan and Morris, 1981; Bullock et al., 1974, cited in Gunn, 1981; Supernak, 1982; Kraan, 1996; Ma and Goulias, 1998; Lu and Pas, 1999). However, this result is moderated somewhat by interactions with gender, as discussed below.

Gender. Gender is another variable for which researchers have found contradictory results. A number of researchers have found that men spend more time traveling than women (Prendergast and Williams, 1981; Gunn, 1981; Wigan and Morris, 1981; Kitamura, et al., 1992; Levinson and Kumar, 1995; Robinson, 1997). Roth and Zahavi (1981) found no significant difference in travel time expenditure between men and women in Bogota, Columbia and yet in the same study they found men spent more time traveling than women in Singapore. The opposite relationship (women spent more time traveling than men) was found by Lu and Pas (1999). They suggested that this was due to the exclusion of many short and non-motorized trips (that were perhaps more often made by women) from many early traditional travel surveys. An insignificant relationship between gender and travel time expenditure was found by Zahavi and Talvitie (1980). The insignificant relationship found between gender and travel time expenditures by Zahavi and his colleagues may be due to their use of total travel time per traveler per day, as mentioned in the discussion of analysis units in Section 2.2.

Gender by Employment Status. There may be an interactive effect between gender and employment status on travel time expenditure. Prendergast and Williams (1981) found that a combination of gender and employment increased the range between the maximum value and the minimum value significantly; the maximum average travel time expenditure, which was attained by full-time employed males, was about three times the minimum average, attained by retired women. In another study, Robinson (1997) examined travel time expenditure between the employed and the unemployed within the same gender. He found that weekly travel time was higher for employed women than for unemployed women, but weekly travel time was lower for employed men than for unemployed men. In his 1985 data set, employed women spent more time traveling than employed men.

Household Size. Zahavi and his colleagues (1980s) observed that travel time expenditure per person decreased with increasing household size, whereas travel time expenditure per traveler varied little with household size. This was one aspect of their argument for the use of travel time expenditure per traveler instead of per person. Purvis (1994) found that the average travel time per person on a weekday increased significantly from 0.86 hours to 1.07 hours from 1965 to 1981, but decreased slightly from 1.07 hours to 1.03 hours from 1981 to 1990. Roth and Zahavi (1981) found a rather insignificant effect of household size on daily travel time expenditure per traveler.

Income. Similar to the influence of car ownership, findings on the influence of income on travel time expenditure do not agree with each other. A positive influence was found by a number of researchers (Prendergast and Williams, 1981; Zahavi and Talvitie, 1980; Lu and Pas, 1999; Barnes and Davis, 2001). Tanner (1981) also noted that total travel time expenditures per person per day rose with income, but his results suggest that the positive relationship mainly comes from the positive correlation between time spent in the private auto and income. Roth and Zahavi (1981) found a positive influence in Salvador, Brazil, but in the same article, they found a negative influence in Bogota, Colombia and Santiago, Chile. Using the same data set in Bogota, Colombia, a negative influence of income level was also supported by Zahavi and Talvitie (1980). But in studies using the Singapore data in 1975, an insignificant relationship between income level and travel time expenditure was found (Zahavi and Talvitie, 1980; Roth and Zahavi, 1981).

Reasons for the conflicting results on the relationship between income and travel time expenditure may be similar to those for the conflicting results on car ownership and travel time expenditure. Researchers may have neglected to examine the relationship of income to travel time by mode. Golob (1990, p. 461) used income dummy variables to examine the relationship between income and travel time by mode for members of the Dutch National Mobility Panel. He found that the high income dummy had a positive contemporaneous effect on travel time by publictransport, "indicating that public transport is a superior economic good", but a negative lagged effect "as a consequence of adjustments in car ownership". More research is needed to explore the complex relationship between income and travel time expenditures by mode.

Person Group. Researchers have used a variety of variables to group people into different categories, and examine average travel time expenditure by category. Golob and McNally (1997) examined travel time expenditures on different activities by male and female household heads. In addition to the demographic variables previously discussed, at least one study used lifestyle as a basis for segmentation. Principio and Pas (1997) argued that people exhibiting similar socio-economic characteristics may not exhibit similar travel behavior due to different lifestyles adopted. Hence, they divided their sample into seven lifestyle groups using cluster analysis on time-use patterns. The *Workaholics* group (20% of the sample) spent an average of 85% of their time on work and work-related activities and spent the least time on recreation, maintenance, and social activities. The *Active Workers* group (37% of the sample) spent an average of 63% of their time on work and work-related activities, but unlike the workaholics group, they divided the rest of their time evenly among other activity categories. The *Socializers* group (6.6% of the sample) spent an average of 59% of their time socializing and devoted little time to work and school activities. The *Leisure Enthusiasts* group (7.6% of the sample) spent most of their time on recreation and leisure. The *Domestic Caretakers* group (4.5% of the sample) spent most of their time maintaining their households. The *Diverse Participants* group (18% of the sample) divided their time among a variety of activities. The *Scholars*group (6.3% of the sample) spent most of their time on school and school-related activities. Among these seven different life style groups, Principio and Pas (1997) found that the *Workaholics* group made fewer than average trips and tours and were very efficient in trip chaining. The *Active Workers* group had the highest total trip times for the two consecutive study days and they had a high number of trips and tours as well. They were also quite efficient in trip linking. The *Socializer*group made the fewest trips and tours and was inefficient in trip linking. The *Leisure*group made few trips and spent the least amount of time traveling. The *Domestic Care* group made fewer than the average number of trips and the average trip length for this group is much shorter than those of the other groups. These results are useful as a reminder that different lifestyles lead to different travel patterns. However, as a tool to predict travel time this approach is not very helpful due to the inherent circularity of employing time use as a classification variable as well as the dependent variable of interest (i.e. one would certainly expect significant differences in time use if time use is used as a classification variable).

3.1.2 Activity-Related Characteristics

Activity Duration. There is an interaction between the amount of the time spent on travel and the amount of time spent on the chosen activity. In examining the travel time from work to another activity, Hamed and Mannering (1993) found that travel time from work to the other activity is positively related to expected duration at the activity location. The same observation was made by Kitamura et al. (1997). Ma and Goulias (1998) noted that the interaction between activity duration at the destination and travel was only pronounced for subsistence activities.

Time Spent on Other Activities (Variables: Total Time Available and Total Time on Out-of-Home Activities). Since each of us faces the same daily time budget, a negative relationship exists between travel time expenditure and the total amount of time spent on other activities. A related concept is the relationship between travel time expenditure and work duration (assuming that work duration is relatively fixed). Kitamura et al. (1992) found that work duration has an inverse effect on non-work travel. The more time a person spends on work, the less time he/she spends on non-work travel. In other words, travel time expenditure is roughly proportional to total available time, defined as 24 hours minus the work duration (Kitamura et al., 1992). Using structural equations modeling, another study found that a 10-minute reduction of commute time would increase the 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 only 0.36 minutes (Fujii, et al., 1997, cited by Kitamura et al., 1997).

Other researchers (Lu and Pas, 1999; Principio and Pas, 1997) found that travel time increases as the amount of time spent on out-of-home activities increases, and decreases as the amount of time spent on in-home activities increases. Golob and McNally (1997) conducted an in-depth analysis on the effect of out-of-home activity participation on travel time to the corresponding activity, as well as gender effects. They found that one hour of work activity generated about 2.8 minutes of travel to work for both men and women; one hour of maintenance activity generated about 7.8 minutes of travel to that activity for both men and women; one hour of discretionary activity generated about 5.5 minutes of travel to that activity for men and about 8.5 minutes for women. The reason behind the gender difference for travel to discretionary activities requires further analysis.

History Dependence (Variables: Duration of Previous Trips, Number of Past Activities Participated in, and Time Spent on Past Activity and Travel Participation). History dependence refers to the effect of past history on the current decision (e.g., travel time expenditure). Kitamura et al. (1997) proposed and tested the effect of history dependence on activity engagement and activity duration. They, however, did not test the effect of history dependence on travel time expenditure. This was carried out by Ma and Goulias (1998). They found that a) the longer the previous trip to a subsistence activity, or the shorter the previous trip to a leisure activity, the longer the travel time of the current trip would be; b) more time spent on past activity participation and travel on the same day or a higher number of activities in the past on the same day tended to decrease the travel time of the current trip.

3.1.3. Area-Specific Characteristics

Area Type. The effect of area type on travel time expenditure may be examined by simply dividing the area into urban versus suburban or large metropolitan area versus smaller cities. Van der Hoorn (1979) examined travel time expenditures in rural areas, industrialized rural areas, small towns, commuter towns, middle-sized cities, large cities, and dense urban areas such as Amsterdam in the Netherlands. He found that travel time per person per week was the highest in dense urban areas for all trip purposes except for school. Consequently, total travel time expenditure per person per week was the highest in dense urban areas. The result of high travel time expenditure for large dense urban areas was also supported by Landrock (1981) who found that people living in the London metropolitan area had significantly higher travel time expenditures than those living in other areas. Gordon et al. (1991) examined the commute times for the 20 largest metropolitan areas in the US and found that commute times were higher for large metropolitan areas (e.g., New York). Supernak (1982) noted that in Baltimore, Maryland, urban travel times were higher than suburban travel times.

Not all researchers support the notion of relatively higher travel times for dense urban areas than for suburban and rural areas. Downes and Morrell (1981) examined travel time expenditures in the inner area, middle area, and outer area of Reading, Britain and found that these area types made little difference in daily travel time per person. Barnes and Davis (2001) found that the only division of the sample that would yield significant differences in average travel times was by location; travelers living in the outlying rural areas of the Twin Cities, Minnesota travel an average of 80 minutes a day while travelers living in the central city travel an average of 68 minutes a day.

One explanation of the different travel time expenditures in different areas (urban versus suburban versus rural) is related to variation in activity opportunities and transport services, as well as in people's lifestyles. However, as contradicting correlations between different area types and travel time expenditures have been found, exactly how they are related is not well understood.

Another way to study the effect of area type on travel time is to categorize the area by some attributes such as population density and size. Landrock (1981) studied the effects of population size and population density on the daily travel time expenditure per person in Britain. For population size, he found that except for London with an average daily travel time of 68 minutes for all persons and 88 minutes for travelers only, all other areas fell between 56 minutes and 60 minutes for all persons and between 72 minutes and 76 minutes for travelers. The high travel time expenditure in London was mainly due to the large amount of time spent on work, shopping, and social activities. With respect to population density, he found that people living in low densities had a lower daily travel time than those living at higher densities. The effect of population density on travel time expenditure seems to be significant and non-linear. The interactive effect of population size and density seems insignificant except for people living in areas of low density but high population, who tended to have higher travel times compared to those living in other areas.

Gordon et al. (1989) reasoned that what caused people living in large cities to have higher travel time expenditures than those living in small cities was the spatial structure, not population density. They argued that the relationship between population density and travel time expenditure is ambiguous if spatial structure is ignored. For example, as they noted (p. 140), "In a monocentric city high densities imply shorter trips, and low densities mean longer trips. In a policentric city, low densities could mean either shorter or longer trips depending upon whether workers choose homes around employment subcenters … or whether cross-commuting across metropolitan areas is common."

Other measurements related to daily travel time expenditures include vehicle-miles traveled, distance traveled, mode share, and commute times. Researchers have extensively studied how different spatial designs of neighborhoods affect these measurements (e.g., Cervero, 1995, 1996; Ewing et al., 1994; Frank and Pivo, 1994; Handy, 1996a). Neo-traditional neighborhoods are sometimes referred to as transit-oriented neighborhoods (Ryan and McNally, 1995). Designed to be balanced and self-contained, these communities have mixed land uses for residential, commercial, and recreational opportunities. Streets within the community are highly interconnected and facilitate the use of walking and bicycles. Handy (1996b) noted that studies of the impact of neo-traditional neighborhood designs on travel behavior may be divided into three categories: traditional transportation models that are used to compare between typical suburban designs and hypothetical neo-traditional neighborhood designs, aggregate level data that are used to compare between cities with different designs or different densities, and disaggregate level data that are used to test differences in individuals' travel choices in different neighborhoods. Results from the first two types of analyses generally confirmed the initial claims that neo-traditional neighborhoods generate fewer automobile trips and shorter trip distances, but results from the last type of analysis indicated that results often depended on factors (e.g., individual or household level characteristics) that are not accounted for in the first two types of studies.

Results showing fewer automobile trips in neo-traditional neighborhoods certainly imply a lower level of total daily travel time by automobile, although when walk and other non-motorized trips are included, the total daily travel time may not be lower compared to that in typical suburban neighborhoods. In fact, in the other studies cited above, the dominant result appears to be that total travel time is higher in high-density areas, although evidence is mixed. However, the definitive study of this issue must control for income differences: if high-density urban dwellers have lower incomes on average, then the higher travel times may be due to their use of slower modes rather than to land use effects per se. On the other hand, as noted earlier, the influence of income on travel time expenditures is also ambiguous.

Time of Day. Other things being equal, time of day is a proxy variable for trip purpose, availability of activity opportunities, and accessibility to those activity opportunities (e.g., how fast one can travel to the activity opportunity). Hamed and Mannering (1993) found that when departing directly from work, travel time from work to an activity tended to be higher than if departing from home. The reason, they explained, was mainly that departing from work often took place during the peak period when travel speeds were relatively low. However, they did not appear to control for potentially different distances to activities accessed from work compared to those accessed from home. In examining travel time from work to home, Hamed and Mannering (1993) found a positive effect of departing during the peak period; in other words, when departing work for home during the peak period, the travel time was likely to be higher than if departing during the off-peak period. Ma and Goulias (1998) found that a late home departure (possibly during the off-peak period) reduced the travel time expenditure.

3.2. Travel Money Expenditure

Compared to travel time expenditure, travel money expenditure is a much less visited subject. Most of the studies that examined travel money expenditure were aggregate studies. They often used descriptive analysis and simple linear regression methods to examine the stability of travel money expenditure. Zahavi and his colleagues (1980s) argued for the stability of travel money expenditure, or a travel money budget. They indicated that an average car-owning household spends about 10-11% of its income on travel while an average non-car-owning household spends about 3-5% of income on travel. Other studies found a relationship that varied more continuously with income, time, or both. For example, in one data set (Annual Abstracts of Statistics), Gunn (1981) noted that from 1950 to 1977, there was a clear upward trend in the expenditure on transport as a percentage of total expenditure, consistent with Zahavi's finding that travel money expenditures rise with increasing motorization. Tanner (1961, cited in Gunn, 1981) noted that travel money expenditure initially rose with income, followed by a tailing off beyond middle income groups. This result was also confirmed by Oi and Shuldiner (1962, cited in Gunn, 1981) and Morris and Wigan (1978, cited in Gunn, 1981). Mogridge (1977, cited in Gunn, 1981), however, found fluctuations in the average percentage of total expenditures allocated to transport, but indicated that these fluctuations could be attributed mainly to public transit expenditures (perhaps due to variations in service levels and fares), with automobile expenditures remaining fairly stable.

Gunn (1981) also noted that the percentage of expenditure spent on transport varies at different times of the year; the transport expenditures tended to be higher in the 2nd and 3rd quarters, compared to those in the 1st and 4th quarters. Examining the percentage of travel expenditure over different days of the week, starting from Monday, it was found that the transport expenditure increased steadily and reached its peak during Friday and Saturday and then suddenly dropped to its lowest level on Sunday. Gunn (1981) concluded that there was about a ±10% variation for different seasons and different days of the week.

In addition to the relationship between travel expenditures and income, Tanner (1961, cited in Gunn, 1981) also examined travel money expenditure in areas with different densities. He found that travel expenditure in large urban areas was lower than in small urban areas, which was lower than in rural areas. Similar results were also found by Oi and Shuldiner (1962) who found that people living in small cities spent a larger proportion of their income on travel than those living in large cities, even though the expenditure on public transport was similar.

More recently, Osula and Adebisi (2001) modeled travel money expenditures in Nigeria, and found that the appropriate functional form was not stable across a significant energy policy change, specifically a fuel price increase in Nigeria. They concluded (p. 269) that "'travel budget' is as yet not usable as a term for travel expenditures in Nigeria."

4. EXPLANATIONS FOR A CONSTANT TRAVEL TIME BUDGET

Given the relationships described in Section 3, how can a sometimes apparently stable travel time and money budget at the aggregate level arise from highly variable individual decisions? A variety of suggestions have been made, including economic, behavioral, and even physiological explanations[5]. Goodwin (1981, p. 104) proposed viewing the travel time budget, if it exists, as the result of the "interplay of offsetting causes and effects" between various variables and travel time expenditures. This means that if the causes (e.g., the strength of some variables) change, the seemingly stable travel time and money expenditures may not be stable anymore. Therefore, travel time and money budgets, if observed, should be treated as alterable facts, not as inexorable behavioral laws.

Another explanation offered by Goodwin is that individuals' travel time budgets, though varying from each other and from day to day, interact with each other in such a way that some individuals' increases in travel time expenditures are offset by other individuals' decreases. If this explanation is valid and travel time budgets are observed, there must exist some kinds of mechanisms that would ensure such counteractions take place. Whether such mechanisms exist, and how they work with numerous changing factors over time and space (e.g., spatial structures, travel speeds) if they exist, are not well understood by researchers.

One possible explanation of such a mechanism postulates the existence of an unobserved, desired travel time budget. Hints of such a construct appear in Hupkes (1982) and Michon (1978, cited by Hupkes, 1982). Michon believed that the human being is a bio-psychological unit who seeks to maintain a reasonable fixed daily routine. A travel time budget is part of the routine. If the existing travel time expenditure exceeds his or her ideal travel time budget, stress will set in. When that takes place, one will look for various ways (e.g., change of work place or residential location) to reduce his or her current travel time expenditures. Hupkes (1982) explained the concept via the utility maximizing approach. He reasoned that at first, there exists an intrinsic utility that is positively related to travel. As travel time expenditures increase over time, both boredom and fatigue set in and the utility associated with travel time becomes negative. In other words, the utility curve associated with travel time first increases and then decreases. Therefore, an optimum travel time expenditure exists.

This concept is further articulated by Mokhtarian and Salomon (2001). They hypothesize the existence of an unobserved ideal travel time budget, which varies as a function of personality, lifestyle, travel-related attitudes, stage in lifecycle, and other socio-economic and demographic variables. The observed travel time differs from the ideal due to constraints, which can operate in either direction. If current travel exceeds the desired budget, one seeks to reduce it, but if currently traveling less than preferred, one seeks to increase it. In other words, individuals try to

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[5] Most recently, Kölbl and Helbing (2003) suggest that rather than a travel time budget, there is actually a law of constant human energy expenditure on travel or even constant total human energy expenditure (trading off, e.g., work and travel energy). However, some of the implications of their analysis appear to be at variance with independent observations, such as the overall rise in average automobile travel time (despite the concomitant rise in congestion, which in their analysis consumes more human energy than free-flow travel and hence is suggested to support slightly *reduced* average auto times) reported in a number of recent studies, and the overall decline in physical activity identified in recent decades (as discussed in Brownson and Boehmer, 2004).

adjust their current travel time expenditures toward the direction of their ideal travel time expenditures over time. For Mokhtarian and Salomon (consistent with Hupkes), an important aspect of the ideal travel time budget is that travel is to some extent valued for its own sake, not merely as a means for conducting a desired activity at another destination. However, this is not essential: even if the demand for travel is purely derived, given that travel is generally required in order to conduct valued activities, then as discussed in Section 1 it would still be reasonable (i.e. consistent with constrained utility maximization) for individuals to have a mental target for a desired amount of time to spend on reaching desired destinations. Chlond and Zumkeller (1997) use the principle of a (desired) travel time ratio (Dijst and Vidakovich, 2000) to model the disaggregate impacts on travel time of increases in income (and hence in the monetary budget for travel, in leisure time, and thence in the time spent in traveling to leisure activities). As out-of-home leisure time increased, the travel time ratio for those activities (travel time divided by the sum of travel and activity time) stabilized at around 25%, consistent with the results of Dijst and Vidakovich.

Under this formulation, a stable mean observed travel time budget may result from random deviations on either side of the ideal budgets consistently canceling each other out across the population. Thus, in places where a constant travel time budget is observed empirically, it might be reasonable to assume that the observed travel time budget represents the average unobserved ideal travel time budget. Might it be the case that average travel time expenditures represent the average unobserved ideal travel time budget, whether stable or not? Perhaps, although it may also be the case that there is an overall bias toward underachievement of the ideal in some (less mobile) populations, and overachievement of the ideal in others (perhaps in heavily congested urban areas). It could also be the case that the average ideal travel time budget for a population changes over time, as experience and aspirations change.

One may also try to understand the existence of a travel time budget at the aggregate level via using the concept of a “typical individual” or “representative agent” in microeconomics. The typical individual is an abstract but representative member of the entire population of interest and his or her travel time expenditure is the average travel time expenditure of the population. Acting like any real individual, the typical individual is faced with a time budget of 24 hours day. To maintain a sensible lifestyle, the typical individual must perform all normal functions like every one of us (e.g., eating, sleeping and working etc.), and all these activities take time. In the end, the typical individual may be left with about 1-2 hours of time for traveling per day. Thus, in this view, the apparently stable travel time expenditures may simply reflect the relatively small range of time out of a fixed 24-hour day that is “left over” for travel after other essential and more desired activities are accomplished. Given that there is generally some choice about the locations of those essential and desired activities, variations in travel time at the individual level may represent variations in (1) individuals’ views of what constitutes a reasonable time cost to pay in order to be able to engage in a desired activity pattern, (2) the extent to which various constraints are binding, and (3) the extent to which travel is desired for its own sake.

5. CONCLUSIONS AND DIRECTIONS FOR FURTHER RESEARCH

The question of the existence of a stable time and money budget was raised more than 40 years ago and has inspired many debates since that time. Review articles have been written summarizing empirical results up to the early 1980s (Gunn, 1981; Goodwin, 1981; Hupkes, 1982). The current literature review encompasses numerous additional studies but essentially confirms results that were observed 20 years ago. Here, we briefly summarize those results.

At the aggregate level, travel expenditures initially appear to have some stability. Similar travel time and money budgets may be found within a sub-population (e.g., travelers) and in certain areas. However, empirical studies that examine the existence of travel time and money budgets at different times and locations are often found to give widely different results.

At the disaggregate level, there is a high degree of variation in both travel time and money expenditures (Kirby, 1981). Even proponents of a constant travel time budget acknowledge this variation, which appears in aggregate studies as well. For example, Zahavi and Talvitie (1980, p. 18), after asserting "the inescapable conclusion that travel time and money budgets exist", express the "belief that travel time and money budgets are not constant, but they are functions of several variables".

Travel time expenditure is strongly related to individual and household characteristics (e.g., income level, gender, employment status, and car ownership), attributes of activities at the destination (e.g., activity group and activity duration), and characteristics of residential areas (e.g., density, spatial structure, and level of service). Aggregate studies have exclusively examined the first and the last groups of variables. Evidence about the effect of area characteristics (e.g., density) on travel time expenditure is not as strong as that for the effect of individual and household characteristics. The effect of the attributes of activities at the destination has been examined exclusively in disaggregate studies, mostly by activity-based researchers.

The overall conclusion we draw from these studies, then, is that the claim of the definitive existence of *constant* travel time and money budgets in time and space is not supported. However, we do believe that individual travel time and money expenditures are behavioral phenomena that can productively be modeled as a function of the kinds of variables described above. Several directions for future research appear to be fruitful.

For example, little has been done in examining the influence of lifestyle and attitudinal variables on travel time expenditures. Principio and Pas (1997) clustered their sample into seven lifestyle groups based on time use patterns with respect to activities and travel. It was observed that members in different lifestyle groups had very different travel time expenditures. Although this result is tautological as indicated in Section 3.1.1, it does suggest possible associations between lifestyles and travel time expenditures. Perhaps some alternative measures can be identified as classification variables, and the resulting classes be examined with respect to time expenditures on different types of activities. Attitudinal and personality variables may be other factors explaining significant differences in travel time expenditures and these areas deserve further investigation.

Goodwin (1981) noted that when time and money are added together to form a generalized expenditure, it appears to be fairly stable between different locations and over short periods of time. This was also supported by Tanner (1981) and Goodwin (1975; cited by Gunn, 1981). This implies possible trade-offs between travel money and travel time expenditure, a subject that merits additional study. It would also be desirable to see how demographic, attitudinal, and environmental changes affect those decisions at the disaggregate level over time.

Another interesting research question is: In estimating travel time expenditures, what is the impact of the shift from travel diaries to activity diaries for the large-scale measurement of disaggregate travel behavior that provides the raw data for many of the studies examined here (see the discussion of this point in Section 2.2)? To compare travel time estimates obtained by travel diaries versus activity diaries, it would be ideal to match pairs of statistically similar individuals engaged in (essentially) identical travel and activity patterns during a day, randomly assign one member of the pair to complete an activity diary and the other member a travel diary, and compare the travel times derived from each approach. Since it would be difficult to find a large number of such matched pairs in practice, another approach would be to randomly assign each type of diary in a large-scale data collection effort, check after the fact for comparability of the two subsamples on other variables of interest (distance traveled and number of trips by mode, demographic characteristics), and compare the resulting reported/inferred travel time expenditures for each group. If the two groups did happen to be significantly different in some important ways, one could artificially match subsamples from the two groups and compare travel times for the matched subsamples. The matching could be done by expressing each case as a vector of attributes on which it is important to match, calculating the distance of a given case in the travel-diary subsample to each case in the activity-diary subsample, selecting the activity-diary case that matches the given travel-diary case most closely, and discarding cases from both subsamples that do not have a "close enough" match in the other group.

Such studies would be important for putting in context any comparisons of travel time expenditures across time, where earlier measures may be based on travel diaries and later measures on activity diaries. Independently of such comparisons, however, it is of interest in its own right simply to understand any reporting biases that may be induced by the activity (or trip) diary format(s). Analyzing that would require some way of objectively obtaining activity/travel start and end times and comparing them to those reported by respondents. Over time, this issue may become less critical to the extent that technological advancements facilitate the real-time collection of precise location information, from which movements and hence travel times can be accurately deduced. In the meantime, however, it is important to be aware that elements of the diary design can affect the accuracy of the travel times implied from their application, and that variations in diary design will remain one confounding factor in attempting to compare travel time expenditures in different contexts.

Finally, assuming that an unobserved ideal travel budget exists, the research challenge is to capture the effect on travel and activity behavior of such a mental target. While eliciting a quantitative measure of the ideal total travel time budget may be difficult using a self-administered questionnaire, it may be possible to do so in an interview context. And it may be possible to elicit partial measures even in a questionnaire. In particular, because of the regularity, frequency and importance of the commute trip, responses to a question about the ideal commute time can be considered reasonably informative. Redmond and Mokhtarian (2001) analyzed the responses to such a question[6] for 1,300 San Francisco Bay Area workers, and found an average ideal commute time of about 16 minutes.

An alternate approach was also taken by Mokhtarian and her colleagues, in which they surveyed respondents with respect to their relative desired travel amount: a qualitative measure of how much the individual wants to travel compared to what she is doing now (both overall, and by purpose and mode, for short-distance and long-distance travel separately). Modeling those relative desired mobility responses as a function of the personal characteristics listed above, plus measures of observed mobility, is providing considerable insight into circumstances under which individuals will try to reduce, maintain, or even increase their travel in order to achieve their desired budget (Choo et al., forthcoming). A great deal more could be learned, however, about the nature of these ideal travel time budgets and their role in individual decision-making. In particular, as with observed travel time expenditures, it would be valuable to monitor and explain the changes in relative desired mobility for a panel of people over time.

ACKNOWLEDGEMENTS

This work was funded by the DaimlerChrysler Corporation; we especially thank Dr. Stefan Gnutzmann and Mr. Hans-Christian Winter. Comments of the anonymous referees have improved the paper.

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[6] To reduce the potential for a social desirability bias (deliberately or instinctively responding based on social expectations – in this case that people should view commuting as onerous), the question followed a series of attitudinal statements that related to both positive and negative aspects of travel, and was itself phrased to offer a balanced perspective: "Some people may value their commute time as a transition between work and home, whereas others may feel it is stressful or a waste or time. For *you*, what would be the ideal *one-way* commute time? ____ minutes".

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Table 1: Aggregate Studies
(In Chronological Order by Date of Publication)

Authors	Survey Type	Survey Period	Day of Week	Sample Size	Year	Location	Units of Analysis; Modes
Robinson, J.; Converse, P. E.; and Szalai, A. (1972)	Activity diary	1 day	All days	2077 people	9/1965-6/1966	Belgium	Per person per day; All modes
	Activity diary	1 day	All days	2096 people	9/1965-6/1966	Kazanilk, Bulgaria	Per person per day; All modes
	Activity diary	1 day	All days	2192 people	9/1965-6/1966	Olomouc, Czechoslov-akia	Per person per day; All modes
	Activity diary	1 day	All days	2805 people	9/1965-6/1966	Six cities, France	Per person per day; All modes
	Activity diary	1 day	All days	1500 people	9/1965-6/1966	100 electoral districts, Fed. Rep. Germany	Per person per day; All modes
	Activity diary	1 day	All days	978 people	9/1965-6/1966	Osnabrück, Fed. Rep. Germany	Per person per day; All modes
	Activity diary	1 day	All days	1650 people	9/1965-6/1966	Hoyerswer-da, German Dem. Rep.	Per person per day; All modes
	Activity diary	1 day	All days	1994 people	9/1965-6/1966	Györ, Hungary	Per person per day; All modes
	Activity diary	1 day	All days	782 people	9/1965-6/1966	Lima-Callao, Peru	Per person per day; All modes
	Activity diary	1 day	All days	2754 people	9/1965-6/1966	Torun, Poland	Per person per day; All modes
	Activity diary	1 day	All days	1243 people	9/1965-6/1966	Forty-four cities, USA	Per person per day; All modes

Table 1: Aggregate Studies (Continued)
(In Chronological Order by Date of Publication)

Authors	Survey Type	Survey Period	Day of Week	Sample Size	Year	Location	Units of Analysis; Modes
Robinson, J.; Converse, P. E.; and Szalai, A. (1972)	Activity diary	1 day	All days	778 people	9/1965-6/1966	Jackson, USA	Per person per day; All modes
	Activity diary	1 day	All days	2891 people	9/1965-6/1966	Pskov, USSR	Per person per day; All modes
	Activity diary	1 day	All days	2125 people	9/1965-6/1966	Kragujevac, Yugoslavia	Per person per day; All modes
	Activity diary	1 day	All days	1995 people	9/1965-6/1966	Maribor, Yugoslavia	Per person per day; All modes
van der Hoorn, T. (1979)	Activity diary	A week	All days	1100 people	10/1975	Netherlands	Per person per day; 1. car, motor, scooter [*sic*]; 2. moped; 3. bus, tram, train, ferry, taxi, boat, airplane; 4. walk, bike
Zahavi, Y. & Talvitie, A. (1980); Zahavi, Y. & Ryan, J. (1980)	Travel survey	NR	NR	450,680 hhlds (1955); 547,224 hhlds (1968)	1955, 1968	Washington, D.C	Per traveler per day; NR
	Travel survey	NR	NR	366,511 hhlds (1958); 433,460 hhlds (1970)	1958, 1970	Twin Cities, Minnesota	Per traveler per day; NR
Zahavi, Y. & Talvitie, A. (1980)	Travel survey	NR	NR	4757 travelers	1972	Bogota, Colombia	Per traveler per day; NR
	Travel survey	NR	NR	4352 hhlds.	6/1975	Singapore	Per traveler per day; Includes walking
	Trip diary	3 days	Weekdays	NR	1976	Munich, Germany	Per traveler per day; NR

Table 1: Aggregate Studies (Continued)
(In Chronological Order by Date of Publication)

Authors	Survey Type	Survey Period	Day of Week	Sample Size	Year	Location	Units of Analysis; Modes
Chumak, A. & Braaksma, J. P. (1981)	Travel survey	NR	NR	NR	1964, 1971	Calgary (1964, 1971), Montreal (1971), Toronto (1964, 1971)	Per trip-maker per day; Includes cars and transit
Downes, J. D. & Morrell, D. (1981)	Trip diary	1 day	Thursday	3288 households	1971	Reading, Britain	Per household per day; All modes but exclusion of incidental walks between modes; travel by commercial drivers is also excluded
Gunn, H. F. (1981)	Trip diary (National Travel Surveys)	NR	NR	NR	1966	Britain	Per person per day; NR
	Trip diary	7 day period (only 7th day data used here)	NR	12,347 people	1972-3	Britain	Per person per day; All modes
	Trip diary	Both 7 days and 1 day (only 7th day data used here)	NR	10,000 households	1975/ 1976	Britain	Per person per day; Only on the 7th day, short walk stages (over 50 yards and under 1 mile) and travel time were recorded
	NR (The County Surveyor's Trip Rate Data Bank)	NR	NR	NR	1974 and 1977	Britain	Per person per day; NR
	NR (The Family Expenditure Surveys)	NR	NR	NR	1959 onwards	Britain	Per person per day; NR

Table 1: Aggregate Studies (Continued)
(In Chronological Order by Date of Publication)

Authors	Survey Type	Survey Period	Day of Week	Sample Size	Year	Location	Units of Analysis; Modes
Gunn, H. F. (1981)	Activity diary	7 days	NR	348 people	1-3/ 1973	Reading	Per person per day; All modes
	NR (The Annual Abstract of Statistics)	NR	NR	NR	For various years	Britain	Per person per day; NR
Landrock, J. N. (1981)	Trip diary	Both 7 days and 1 day (only 7th day data used here)	NR	10,000 households	1975/ 1976	Britain	Per person per day; Only on the 7th day, short walk stages (over 50 yards and under 1 mile) and travel time were recorded
Prendergast, L. S. & Williams, R. T. (1981)	Trip diary	7 day period (only 7th day data used here)	NR	12,347 people	1972-3	Britain	Per traveler per day and per person per day; All modes
	Trip diary	1 day	Thursday	9,369 people from 3,368 hhlds.	10-11/ 1971	Reading	Per traveler per day and per person per day; Incidental walk trips and screenline counts are excluded
	Activity diary	7 days	NR	348 people	1-3/ 1973	Reading	Per traveler per day and per person per day; All modes
Roth, G. & Zahavi, Y. (1981)	Travel survey	NR	NR	NR	NR	Salvador, Brazil	Per traveler per day; NR
	Travel survey	NR	NR	44,928 travelers	NR	Santiago, Chile	Per traveler per day; NR
Tanner, J. C. (1981)	Trip diary	Both 7 days and 1 day	NR	10,000 households	1975/ 1976	Britain	Per person per day; Only on the 7th day, short walk stages (over 50 yards and under 1 mile) and travel time were recorded
Wigan, M. R. & Morris, J. M. (1981)	Time-use diary	NR	NR	NR	1965-1966	Melbourne and Albury-Wodonga, Australia	Per person per day; NR

Table 1: Aggregate Studies (Continued)
(In Chronological Order by Date of Publication)

Authors	Survey Type	Survey Period	Day of Week	Sample Size	Year	Location	Units of Analysis; Modes
Hupkes, G. (1982)	Travel survey	NR	NR	NR	1962	Netherlands	Per person per year; Motorcar, motor bike, bike, moped, walk, rail, public transport, taxi, airplane
	Travel survey	NR	NR	NR	1972	Netherlands	Same as above
Supernak, J. (1982)	Travel survey	NR	NR	NR	1970	Baltimore	Per person per day; NR
	Travel survey	NR	NR	NR	1977	Twin Cities	Per person per day; NR
Kitamura, R.; Robinson, J.; Golob, T.; Bradley, M.; Leonard, J.; & van der Hoorn, T. (1992)	Time use survey	1 day	NR	1564 people	1987-1988	California, USA	Per person per day; All modes
	Time use survey	7 days	NR	2,964 people	1985	Netherlands	Per person per day; All modes
Purvis, C. (1994)	Travel survey	NR	Both weekday and weekend	20,486 hhlds (weekday); 10,200 hhlds (weekend)	1965	San Francisco Bay Area	Per mobile person per day, per traveler per day, per mobile household per day, per traveling household per day; NR
	Travel survey	NR	Both weekday and weekend	6,209 hhlds (weekday); 882 hhlds (weekend)	1981	San Francisco Bay Area	Per mobile person per day, per traveler per day, per mobile household per day, per traveling household per day; NR
	Trip diary	1 day; 3 days; 5 days (only 1-day sample used here)	Weekday	9,438 hhlds (1-day); 1,486 hhlds (3-day and 5-day)	1990	San Francisco Bay Area	Per mobile person per day, per traveler per day, per mobile household per day, per traveling household per day; NR
Kumar, A. & Levinson, D. (1995)	Trip diary	1 day	Both weekday and weekends	47,499 people from 21,817 hhlds	3/1990 - 3/1991	USA	Per person per day; All modes

Table 1: Aggregate Studies (Continued)
(In Chronological Order by Date of Publication)

Authors	Survey Type	Survey Period	Day of Week	Sample Size	Year	Location	Units of Analysis; Modes
Levinson, D. & Kumar, A. (1995)	Trip diary	1 day	NR	23,000 hhlds	1968	Washington, D.C.	Per person per day; Excluded nonmotorized nonwork trips
	Trip diary	1 day	NR	7,400 hhlds	1987-1988	Washington, D.C.	Per person per day; All modes
Rutherford, G. S.; McCormack, E.; and Wilkinson, M. (1996)	Trip diary	2 days	NR	900 hhlds	11,12/ 1991	Kirkland, Wallingford, and Queen Anne in Greater Seattle Area	Per person per day; All modes
	Trip diary	NR	NR	NR	9-11/ 1989	Puget Sound Washington Area	Per person per day; All modes
Principio, S. L.; Pas, E. I. (1997)	Activity diary	2 days (only those assigned both weekdays used here)	Both weekdays and weekends	1,778 households (only 1,167 hhlds. used here)	1994/ 95	Research Triangle Region, North Carolina	Per person per day; All modes
Robinson, J. (1997)	Time use survey	1 day	NR	5,300 people	1985	USA	Per person per day; All modes
Barnes, G. and Davis, G. (2001)	Trip diary	1 day	Weekdays	9,746 hhlds; 24,510 people	Spring and fall of 1990	7-county Twin Cities metro area	Per person per day; excludes nonmotorized trips

NR: not reported

Table 2: Disaggregate Studies
(In Chronological Order by Date of Publication)

Authors	Survey Type	Survey Period	Day of Week	Sample Size	Year	Location	Units of Analysis; Modes
Golob, T. (1990)	Trip diary	7 days	NR	1334 hhlds	1985-1986	Netherlands	Per household per week; Car (driver and passenger), public transport (bus, tram, subway, and train), non-motorized modes (bike and walk)
	Trip diary	7 days	NR	1,393 hhlds	1986-1987	Netherlands	Per household per week; Same as above
	Trip diary	7 days	NR	1,689 hhlds	1987-1988	Netherlands	Per household per week; Same as above
Hamed, M. & Mannering, F. (1993)	Trip diary	1 day	Weekday	370 people	NR	Seattle, Washington	Post-work travel time to home per worker per day; All modes
Kraan, M. (1996)	Time-use diary	7 days	NR	3,000 people	Every 5 years since 10/1975	Netherlands	Per person per day; All modes
Golob, T. & McNally, M. (1997)	Activity diary	2 days	NR	5,120 people fr. 2,230 hhlds (only 1,292 couples used here)	1994	Portland, Oregon	Per person per day; All modes
Kitamura, R.; Fujii, S.; and Pas, E. (1997)	Activity diary	1 day	NR	1,257 people fr. 594 hhlds	1994	Osaka-Kobe metropolitan area, Japan	Per person per day; All modes
Ma, J. & Goulias, K. (1998)	Panel data	NR (only the 1st day of the 4th wave used)	NR	1,621 people	NR	Puget Sound, Washington Area	Time on various activities and travel per person per day; All modes
Lu, X. & Pas, E. (1999)	Activity diary	2 days	NR	2,514 people fr. 2,230 hhlds used here	1994	Portland, Oregan Metro. Area	Per person per day; All modes

Table 3: Key Variables and their Relationship to Travel Time Expenditure

Variable	Relation[1]	Reviewed Studies[2]
Activity Duration at the Destination	+	Hamed and Mannering (1993)[d]; Ma and Goulias (1998)[h]; Kitamura et al. (1997)
Activity Type	S	Hamed and Mannering (1993)[d]
Area Type	S	van der Hoorn (1979)[a]; Chumak and Braaksma (1981)[c]; Downes and Morrell (1981)[b]; Landrock (1981)[bc]; Tanner (1961)[b]; Supernak (1982)[b]; Kitamura et al. (1992)[a]; Rutherford et al. (1996)[b]
Density	0	Tanner (1981)[b]; Goodwin (1976)[b]; Gunn (1981)[b]
	+	van der Hoorn (1979)[a]
Age (Groups)	C	Prendergast and Williams (1981)[bc]; Gunn (1981)[b]; Kitamura et al. (1992)[a]; Rutherford et al. (1996)[b]
	0	Roth and Zahavi (1981)
Car Ownership	+	van der Hoorn (1979)[a]; Chumak and Braaksma (1981)[c]; Prendergast and Williams (1981)[bc]; Godard (1978)[b]; Purvis (1994)[e]; Lu and Pas (1999)[b]
	-	Zahavi and Talvitie (1980)[c]; Roth and Zahavi (1981)[c]
	0	Downes and Morrell (1981)[b]; Bullock et al. (1974)[b]; Purvis (1994)[b]
	?	Zahavi and Talvitie (1980)[c]; Goodwin (1976)[b]
Day of the Week	S	van der Hoorn (1979)[a]; Zahavi and Talvitie (1980)[c]; Prendergast and Williams (1981)[bc]; Kumar and Levinson (1995)[b]
Departure Time from Work (= 1 during Peak)	+	Hamed and Mannering (1993)[d]
Duration of Previous Trip to Different Activities	C	Ma and Goulias (1998)[h]
Employment Status	S	van der Hoorn (1979)[a]; Zahavi and Talvitie (1980)[c]; Chumak and Braaksma (1981)[c]; Roth and Zahavi (1981)[c]; Prendergast and Williams (1981)[bc]; Wigan and Morris (1981)[b]; Bullock et al. (1974)[b]; Supernak (1982)[b]; Robinson (1997)[a]; Ma and Goulias (1998)[h]; Lu and Pas (1999)[b]
Gender	S	Zahavi and Talvitie (1980)[c]; Roth and Zahavi (1981)[c]; Prendergast and Williams (1981)[bc]; Gunn (1981)[b]; Kitamura et al. (1992)[a]; Wigan and Morris (1981)[d]; Levinson and Kumar (1995)[b]; Robinson (1997)[a]; Lu and Pas (1999)[b]

Table 3: Key Variables and their Relationship to Travel Time Expenditure (Continued)

Variable	Relation	Reviewed Studies
Gender × Age	S	Prendergast and Williams (1981)[bc]
Gender × Area Type	S	Gunn (1981)[b]
Gender × Employment	S	Prendergast and Williams (1981)[bc]; Robinson (1997)[a]
Gender × Marital Status	S	Prendergast and Williams (1981)[bc]
Household Size	?	Zahavi and Talvitie (1980)[c]
	-	Purvis (1994)[b]
	+	Purvis (1994)[e]
	0	Roth and Zahavi (1981)[c]
Household Size × Car Ownership	?	Zahavi and Talvitie (1980)[c]
Income	+	Zahavi and Talvitie (1980)[c]; Roth and Zahavi (1981)[c]; Prendergast and Williams (1981)[bc]; Tanner (1981)[b]; Lu and Pas (1999)[b]
	-	Roth and Zahavi (1981)[c]
	S	Gunn (1981)[b]
	0	Zahavi and Talvitie (1980)[c]; Roth and Zahavi (1981)[c]
Late Home Departure Time	-	Ma and Goulias (1998)[h]
Mode	S	Chumak and Braaksma (1981)[c]; Roth and Zahavi (1981)[c]; Prendergast and Williams (1981)[bc]; Tanner (1981)[b]; Goodwin (1976)[b]; Golob (1990)[b]
Month of the Year	S	Kumar and Levinson (1995)[b]
Number of Activities Participated in Previously on the Same Day	-	Ma and Goulias (1998)[h]
Number of Workers	+	Lu and Pas (1999)[b]
Number of Children	+	Lu and Pas (1999)[b]

Table 3: Key Variables and their Relationship to Travel Time Expenditure (Continued)

Variable	Relation[1]	Reviewed Studies[2]
Occupation Type	S	Gunn (1981)[b]
Occupation Type × Age	S	Gunn (1981)[b]
Person Group	S	van der Hoorn (1979)[a]; Roth and Zahavi (1981)[c]; OECD (1977)[b]; Levinson and Kumar (1995)[b]; Kraan (1996)[a]; Golob and McNally (1997)[f]; Principio and Pas (1997)[g]
Population Density	+	Landrock (1981)[bc]
Population Size × Population Density	0	Landrock (1981)[bc]
Tenure in Residence	+	Hamed and Mannering (1993)[d]
Time	+	Godard (1978)[b]; Gunn (1981)[b]; Tanner (1961)[b]; Purvis (1994)[bce]; Levinson and Kumar (1995)[b]
	-	Purvis (1994)[bce]
	0	Kumar and Levinson (1995)
Time of Day	-	Ma and Goulias (1998)[h]
	If peak	Hamed and Mannering (1993)[d]
Time in Past Activity Participation and Travel on the Same Day	-	Ma and Goulias (1998)[h]
Total Time Available (24 hours)	-	Kitamura et al. (1992)[a]
Total Time on Out-of-home Activities	+	Lu and Pas (1999)[b]
Urban Size	+	Godard (1978)[b]

[1] "+" means positive relationship between the variable and travel time expenditure; "-" means negative relationship between the variable and travel time expenditure; "0" means insignificant relationship between the variable and travel time expenditure; "?" means that the direction of the relationship is not clear; "C" means that although the variable is ordinal and a significant relationship has been found, one cannot summarize the effect simply by "+" or "-". For the variable of age, one may find that people in their 20s and early 30s travel the most and people of other ages have less travel time to different extents; "S" means that the relationship is significant but the studied variable is a nominal categorical variable, so that the direction of the relationship cannot be summarized with a "+" or "-".

[2] Superscript "a" is travel time per person per week; "b" is travel time per person per day; "c" is travel time per traveler per day; "d" is daily commute time per person; "e" is travel time per household per day; "f" is total two-day travel time to out-of-home activities (by different activity types); "g" is two-day total travel time per person; "h" is travel time of the current trip per person.