Road Capacity and the Allocation of Time

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ABSTRACT

Additional highway capacity gained by increasing travel speed affects the share of time an individual allocates to daily activities, such as commuting and time spent at work, shopping, or at home. Some activities will be undertaken more, others less. Using the 1990 and 1995 Nationwide Personal Transportation Surveys and Federal Highway Administration data, this paper extends previous research that identified and quantified induced demand in terms of vehicle-miles traveled, by considering what type of demand is induced and which activities are consequently reduced. While total travel times did not significantly change between 1990 and 1995, there was a significant change in activity duration. Further, as a result of additional capacity, workers spent less time working and commuting and more time at home and doing other activities. Nonworkers, in contrast, traveled more and spent more time shopping and at home, but less time at other activities. This points out the differences in discretionary and nondiscretionary activities for workers and nonworkers. It also suggests increased highway capacity provides real gains for people, at least in the short term, because time, not vehicle-miles traveled, is the deciding factor for which activities are undertaken and which are eliminated.

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INTRODUCTION

The impact of increasing the capacity of highways is a topic of recent interest. New and faster roads may attract more traffic than is currently diverted from existing roads. This *induced* or *latent* demand can be viewed as a boon or a bane. In the short term, highway expansion is expected to increase travel speeds. In the long run, traffic congestion may approach or exceed earlier levels. If the sole aim of capacity expansion is to reduce congestion, expansions that increase traffic may prove counterproductive. However, that same road construction may increase accessibility and affect people's daily activity patterns. Time savings in travel attained from increased highway capacity enables individuals to allocate more time to their activities and even increase their number, rather than spend time traveling. This ability to take advantage of new opportunities without increasing travel time enables people to achieve greater satisfaction from consumption, change to a better job, or move to a larger house. At a minimum, they should be no worse off. However, this additional travel may have negative environmental consequences, externalities that individuals do not usually consider in their travel decisions.

The objective of this research is to observe the nature of the changes in activity and travel patterns of individuals as a result of additional highway capacity. Time savings from travel due to highway expansion will give individuals more time to spend engaged in different activities. Travel is often referred to as a derived demand, as it reflects an individual's interest in taking advantage of a resource, in this case, increased road capacity. Carefully measuring changes in individuals' travel behavior will facilitate accurate travel forecasting. This research examines the nature of and change in activities that capacity expansion induces and develops a model to quantify the change (in terms of minutes per day) for workers and nonworkers.

A factor complicating the analysis of preferences is whether "time budgets" exist for work travel, all travel, or various activity categories. These time budgets, perhaps just very inelastic preferences, have appeared as empirical regularities in long-term examination of travel behavior. For instance, Levinson and Kumar (1994) found that in Washington, DC, commuting times from home to work averaged 28.5 minutes in 1958, 1968, and 1988. Similar results were found in the Twin Cities of Minneapolis and St. Paul (Barnes and Davis 1999). Furthermore, major changes in metropolitan population, demographics, female labor force participation, and suburbanization suggest that over the long term, individuals adjust their location to maintain approximate constancy in their commute durations, but not necessarily their distances.

Examining all travel, Levinson and Kumar (1995a) did not find the same kind of regularity. First, the share of workers increased, so more individuals traveled to and from work. Second, the additional proportion of workers had more nonwork travel. Previously, in the era of the one-worker, two-adult household, nonwork activities would have been the responsibility of the homemaker. Third, mobility and the near universal presence of a car for each licensed driver has changed the ability to perform nonwork activities outside the home, and as the cost of a favorable activity declines, the amount demanded increases. So while there may be a "commute travel budget," there is some evidence against a "comprehensive travel budget."

Despite the questions about commute and comprehensive travel budgets, there is one type of budget that is inarguable, the daily time budget. The 24-hour day, along with constraints associated with necessary daily activities (working, sleeping, eating, etc.), provide an upper limit on the possible amount of time a person can spend traveling. While the potential for induced time spent traveling may be large, it is not unlimited due to daily time budget constraints. We approached this question, using the Nationwide Personal Transportation Survey (NPTS) and Federal Highway Administration (FHWA) data to measure individual changes and activity patterns, controlling for network changes in each state. We used travel survey data to understand which types of activities and travel are being induced by capacity changes, and consequently, which activities and travel types are being reduced. We developed estimates of time spent in travel and at activities for major activity classifications (home, shop, work, and other) for 1990 and 1995. In our analysis, we controlled for socioeconomic and demographic strata including gender, work status, age, and income, as well as lifecycle categories and population density. For our capacity data, we adopted an approach similar to that used by Noland (1999), employing measures from the *Highway Statistics* series of FHWA. The significant independent variable is lane-miles of roadway, while other independent variables control for population growth, gasoline prices, and income.

This paper begins with a review of the key literature in the induced demand debate, which quantifies the effects of roadway capacity on some aspects of travel demand. This is followed by a brief description of the data used in the analysis. Then travel times and activity durations are compared between 1990 and 1995 using NPTS data. We discuss the theory of time use posed by economists and extend it to better account for the real spatial and temporal constraints that transportation analysts must consider. We pose a set of specific hypotheses concerning how time use should change with increased capacity. Then we develop a model to examine the change in time use between 1990 and 1995 as a function of growth in the highway network, controlling for demographic, spatial, temporal, and socioeconomic characteristics. This requires estimating a time-use model for individuals in the 1990 dataset. We then apply that model to the 1995 survey respondents as an approximation of the latter population's 1990 behavior. The subsequent section applies the difference model approach to determine the impact of highway capacity expansion on travel behavior using seemingly unrelated regression estimation models. A summary of study results concludes the paper.

INDUCED DEMAND RESEARCH

Researchers are trying to identify the extent to which trips are induced, shifted, and lengthened due to capacity expansion. The literature on induced demand suggests the overall elasticities of vehicle-miles traveled (VMT) with respect to lane-miles of capacity to be between 0.5 and 1.0, indicating that a 1% increase in capacity will increase the demand for VMT by between 0.5% and 1.0%.

Dunne (1982) used a representative individual approach to express aggregate demand but ignored the distribution of elasticities across the sample. He then determined point and arc elasticities and compared the weighted elasticity with the elasticity of a representative individual.

Goodwin (1996) conducted a study to verify the presence of induced traffic due to road capacity expansion. Comparing the observed and forecast traffic flows, taking into account the traffic reduction on alternative routes, he found the demand elasticity with respect to travel time (based on short- and long-term timeframes) to be –0.5 and –1.0, respectively.

McCarthy (1997) studied travelers' responses and attitudes toward market-based road pricing, showing that capacity expansion attracted diverted traffic and increased traffic growth induced by improved travel conditions. He found demand elasticity with respect to auto travel time using two different models for four primary modes of travel. By using linear logit and linear captivity models, he determined the demand elasticities to be –0.008 and –0.002, respectively.

Dowling and Colman (1998) studied behavioral change—including mode switch, rescheduling, trip chaining, destination change, and additional trips—responding to the travel time savings as a result of increased highway capacity for the San Francisco and San Diego metropolitan areas. They found that the existing travel forecasting practice probably resulted in an underprediction of 3% to 5% in the number of trips due to time savings that may have been induced by highway capacity expansion.

Hansen and Huang (1997) estimated the induced traffic as a consequence of adding capacity over the short or long run. At the area-wide county and metropolitan level, he found the elasticity of VMT with respect to lane-miles of capacity between 0.62 and 0.94 for periods of 2 and 4 years, respectively. Over a longer run of 10 years, he estimated the elasticity between 0.3 and 0.4 on the highway-segment level.

Noland (1999) studied relationships between lane-miles of capacity and induced VMT by specific road types and estimated long- and short-term elasticities using four different models. The results obtained corroborate the influence of induced travel, at the same time establishing a significant relationship between lane-miles of capacity and VMT. Induced travel was found to have varying influence by road type (Interstates, arterials, and collectors) and by region (urban and rural). He found that with a 1% increase in lane-miles of capacity, VMT grows annually from 0.79% to 1.73% over a period of five years. Using a distributed lag model, he also found that 28.7% of the VMT resulted from an increase in capacity expansion over the five-year period. The same model predicted that induced demand caused 23.7% of the increase in VMT. Noland and Cowart (2000) studied the impact of additional lane-miles on VMT growth using urbanized land area as the instrumental variable for lane-miles of capacity. They found that the impact of lane-mile additions on VMT growth is greater in urbanized areas that had a larger percentage of increases in total capacity and showed that lane-mile elasticities are smaller in the short run (0.284) as compared with the long run (0.904).

Barr (2000) studied Nationwide Personal Transportation Survey data to estimate relationships between average household travel time and VMT and found that individuals would spend 30% to 50% of the time savings from additional capacity on travel.

Fulton et al. (2000) studied county-level data from Maryland, Virginia, North Carolina, and Washington, DC, that related daily VMT to road capacity. They found the elasticities of VMT with respect to lane-miles of capacity to be 0.1 to 0.4 in the short run and 0.5 to 0.8 in the long run.

Marshall (2000), using the Texas Transportation Institute's urban congestion study data for 70 U.S. urban areas, found the elasticities for roadway demand relative to roadway supply as 0.85 for highways and 0.76 for principal arterials using simple regression techniques.

DATA

The travel behavior data used in this analysis come from the 1990/91 and 1995/96 Nationwide Personal Transportation Surveys. These telephone interview surveys collected data on household demographics, income, vehicle availability, location, and all trips made on the survey day. The 1990 NPTS survey was conducted between March 1990 and March 1991 and consisted of almost 22,000 household interviews and over 47,000 persons making almost 150,000 trips. The 1995 NPTS was conducted between May 1995 and June 1996 and consisted of 42,000 household interviews and over 95,360 persons making almost 409,000 trips. While the 1995 NPTS was conducted by giving the respondents a travel diary in advance of their scheduled interview, the 1990 NPTS was conducted over the telephone, which caused some problems. For example, identifying the origin and destination of trips was difficult. We assumed that all tripmakers began and ended their day at home. Due to some improbably high shopping times, we also excluded travelers with a daily shopping time greater than 420 minutes. Given the methodology adopted as a part of this paper, we have tried to minimize the biased nature across both the datasets. We did not drop any data on the basis of day of week, but rather considered both weekday and weekend trips in the analysis and use day of week as an explanatory variable. Table 1 summarizes the number of observations dropped and the reasons for dropping specific records for the 1990 and 1995 NPTS data.

TABLE 1 Summary of Data Analysis Adopted for the 1990 and 1995 NPTS

Description of constraints	1990	1995
Sample size—total trips	**159,832**	**381,388**
Reasons for dropping records		
Invalid destination	3,314	43
Trip in miles >200	23,372	27,455
Travel minutes >120	3,015	5,254
Age >65 years	9,210	35,399
Age <18 years	21,470	63,832
Shop duration >420	707	70
Total dropped	**61,088**	**132,053**
Subtotal at trip level (after records are dropped)	**98,744**	**249,335**
Subtotal at person level	**15,870**	**52,341**
Travel + duration minutes >1,440	7,652	656
Travel + duration minutes <1,440	2,643	17,119
Duration <0	654	2,237
Total dropped	**10,949**	**20,012**
Net total at person level	**4,921**	**32,329**

The time spent at each activity (excluding travel), defined as that activity's duration, was not reported directly in the NPTS. Only the times of the beginning and end of the travel portion of the trip

FIGURE 1 Activity Duration Calculations

Person ID	Origin	Destination	Travel time	Origin time	Destination time	Activity duration (minutes)
1	Home	Other	15	8:30	8:45	30
1	Other	Work	15	9:15	9:30	360
1	Work	Other	15	15:30	15:45	105
1	Other	Other	10	17:30	17:40	20
1	Other	Home	10	18:00	18:20	850
2	Home	Work	20	8:00	8:20	340
2	Work	Other	15	14:00	14:15	

were reported. The activity duration data were obtained by subtracting the destination time of a particular trip from the origin time of the next trip for the same individual, as shown in figure 1. All the activity durations and travel times for an individual add up to the daily time budget of 1,440 minutes (24 hours). The activity duration for the final return home requires that we assume the person's first activity the next day begins at the same time as today's. Thus, we subtracted the time the individual arrives home for the last time in the day from the time of origin of the first trip and add 1,440 minutes. Only those tripmakers whose daily time budget is equal to 1,440 minutes were considered for the study.

The highway data used in the analysis consist of roadway and state characteristics (e.g., lane-miles for all roadways, state's average fuel price, and state population) by state for 1990 and 1995. The data for VMT and lane-miles were obtained from *Highway Statistics* published by the Federal Highway Administration for each roadway type (Interstates, arterials, and collectors) by urban and rural region. We also used data on the population, per-capita income, and cost per energy unit (million Btu) of gasoline by state for all 50 U.S. states for 1990 and 1995. The income and fuel price data are in current year dollars.

COMPARISON OF 1990 AND 1995 TIME-USE DATA

This research classifies activities into eight basic categories: time spent at and traveling to the activities of home, work, shop, and other. For a preliminary data comparison of activity patterns in 1990 and 1995, table 2 reports time use by gender and work status. To illustrate, the first row shows that the average female nonworker spent 1,172 minutes at home, 42 minutes at shop, 166 minutes at other, and 60 minutes of travel per day (averaged across all 7 days of the week). In our modeling, we used gender as an explanatory variable. Tables 3 and 4 elaborate the data for 1990 and 1995.

TABLE 2 Time-Use Comparisons for 1990 and 1995 Data

	Home	Work	Shop	Other	Travel
FEMALE					
Nonworker					
1995	1,172		42	166	60
	(186)*		(64)*	(170)*	(44)
1990	1,220		35	127	58
	(209)		(70)	(172)	(61
Worker					
1995	944	313	25	93	65
	(226)*	(249)*	(49)*	(132)*	(44)
1990	928	284	30	132	65
	(357)	(357)	(69)	(191)	(64)
MALE					
Nonworker					
1995	1,171		30	177	62
	(200)*		(55)	(184)*	(46)
1990	1,222		29	130	59
	(211)		(60)	(183)	(65)
Worker					
1995	900	365	15	90	70
	(233)	(262)*	(37)*	(136)*	(48)
1990	903	338	20	110	69
	(360)	(367)	(59)	(189)	(71)

* denotes significance at 95% level by difference of means test between 1995 and 1990 results. Standard deviations are in parenthesis.

To determine whether these activity durations and travel times for 1990 and 1995 differ for each

TABLE 3 Summary of 1990 Time Use for Different Characteristics of Individuals

Description	Sample size	Time spent at: Travel	Home	Work	Shop	Other
Gender						
Male	1,590	68	929	319	18	107
Female	1,834	65	1,004	217	28	125
Work status						
Worker	2,740	68	906	328	21	117
Nonworker	684	61	1,225	0	31	124
Day of week						
Weekend	1,026	68	1,114	114	30	115
Weekday	2,398	66	907	329	21	117
Lifecycle (number of adults, age of youngest child)						
1, no children	807	73	930	278	22	137
2+, no children	915	65	935	309	21	111
1, 0–5	88	53	1,068	140	25	154
2+, 0–5	524	62	975	282	26	95
1, 6–15	184	76	934	235	26	169
2+, 6–15	423	62	966	277	26	109
1, 16–21	37	66	1,020	227	25	102
2+, 16–21	122	64	980	295	15	86
1, retired, no children	55	70	1,217	27	30	96
2+, retired, no children	269	61	1,128	123	26	102

of these categories, a difference of means (t-test) is performed. The following null and alternate hypothesis were tested:

$$H_o : E(X_1) = E(X_2)$$
$$H_a : E(X_1) \neq E(X_2) \qquad (1)$$

The null hypothesis H_o tests for the population means of activity duration and travel time as equal whereas the alternate hypothesis H_a tests for the population means as not equal. Based on the hypothesis above, a t-statistic is calculated to infer whether two data samples differ from one another. It is defined as:

$$t = \frac{E(\overline{X}_1) - E(\overline{X}_2)}{\sqrt{\frac{S_1^2}{N_1} = \frac{S_2^2}{N_2}}} \qquad (2)$$

where

$E(\overline{X}_1), E(\overline{X}_2)$ = the expected mean's value of X_1 and X_2 for first and second dataset,

S_1, S_2 = the variance of the first and second sample set, and

N_1, N_2 = the number of observations in the first and second sample set.

Then, the decision rule is to reject the null hypothesis H_o if $|t|$ is greater than 1.96 (at a 95% confidence interval) and accept otherwise. That rule is applied to all the coefficients to compare the change in time use of individuals between 1990 and 1995.

The time spent at home decreased for nonworkers, remained essentially constant for male workers, and rose for female workers. The time spent at work increased for both male and female workers, which is consistent with the 1990–1991 recession and an expanding economy in 1995. For workers, particularly females, time at home in 1990 substituted for time at work in 1995. The time spent at shop decreased for male and female workers but increased for male and female nonworkers. Similarly, the time spent at other declined for workers but increased for nonworkers. Both are consistent with a strengthening economy in 1995, as workers chose to work more and nonworkers to spend more. The total travel time has either remained stable or slightly increased for all categories, as people in 1995 pursued more out-of-home activities.

TABLE 4 Summary of 1995 Time Use for Different Characteristics of Individuals

Description	Sample size	Time spent at: Travel	Home	Work	Shop	Other
Gender						
Male	12,687	72	917	333	15	103
Female	13,532	65	994	245	28	108
Work status						
Worker	21,512	69	911	351	19	91
Nonworker	4,707	63	1,169	0	37	172
Day of week						
Weekend	5,914	63	1,089	94	34	160
Weekday	20,305	70	918	344	18	89
Lifecycle (number of adults, age of youngest child)						
1, no children	2,084	66	927	321	19	108
2+, no children	8,598	68	936	318	20	97
1, 0–5	260	74	997	192	31	146
2+, 0–5	5,266	68	974	277	21	100
1, 6–15	505	68	950	286	25	111
2+, 6–15	5,227	71	945	296	22	107
1, 16–21	238	68	950	277	24	121
2+, 16–21	1,994	66	936	302	18	118
1, retired, no children	157	64	1,179	0	43	154
2+, retired, no children	1,890	66	1,073	145	33	123

Based on t-test values, although the change in activity durations (time spent at home, work, shop, and other) is significant for almost all categories, travel times are, interestingly, insignificant. This supports the "Rational Locator" hypothesis that people adjust their travel choices and relocate their homes and workplaces to maintain their travel commute over time (Levinson and Kumar 1994). The results obtained from a difference of means test showed that the value of t <1.96 for travel, which means we cannot reject the null hypothesis. Thus, the 1990 and 1995 travel times by gender and work status are not different from one another and, thus, this conclusion does not contradict the Rational Locator hypothesis. The rest of the paper aims to determine how individuals reallocate their time due to increased capacity.

CONCEPTUAL MODEL

Becker (1965) proposed a model to study how households use time and market goods to produce useful commodities under the constraints of daily time budgets and income. He suggested that total time could be disaggregated into work and leisure (nonwork) time, but that while people earned money during work time, money was not only not earned but rather was spent in leisure time. Further, both money and time are required to produce household commodities (e.g., preparing dinner, washing dishes, and watching television). Additional time could be assigned to work to increase income or to leisure to increase pleasure. The value of additional income (requiring additional time) is diminishing because the amount of time available to produce household commodities decreases as time allocated to work increases. Jara-Díaz (2000) synthesizes much of the subsequent research on time allocation models, suggesting the following utility maximization equation, subject to separate money and time constraints:

$$Max U(G, T_L, T_W, t) \quad (3)$$

subject to

$$wT_W - G \geq 0 \quad (\lambda) \quad (4)$$

$$\tau - (T_L + T_W + t) = 0 \quad (\mu) \quad (5)$$

where

U = utility function,

G = aggregate consumption in money units,

T_W = time assigned to work,

T_L = time assigned to leisure,

t = exogenous travel time,

w = wage rate (work),

τ = total time available,

μ = Lagrange multiplier of time restriction,

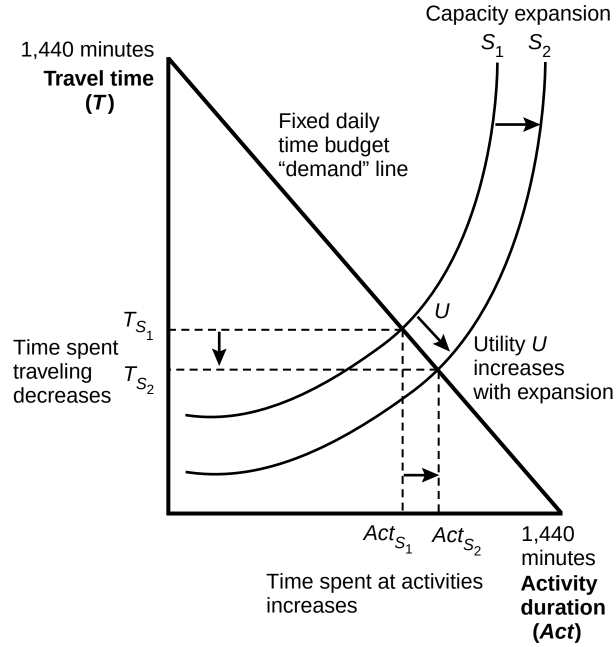
λ = Lagrange multiplier of income restriction.

Such a model should be extended to separate out leisure from necessary non-income producing activities, such as shopping or going to school. In addition, scheduling of activities is also a critical factor (Small 1983). This model makes no representations of nonworkers and their time allocation, as nonworker revenue is independent of daily time spent in the paid labor force, although it may be a function of previous time in the labor force. While the economic framework is informative, it cannot tell us how individuals actually substitute travel and activity time, as that depends on the empirical valuations that people place on work, leisure, travel, etc. Thus, the allocation of time to activities is a complex phenomenon that does not lend itself easily to nonempirical analysis.

Nevertheless, we accept the premise of the economic model that individuals balance time at and travel time to activities to maintain their utility, acting to attain economies in activity consumption. The relationship between travel times and activity durations can be shown in the form of a production function subject to a constraint that all travel times and activity durations sum to 1,440 minutes as shown in figure 2. This figure assumes that travel time is the price for consuming activities. The downward sloping time budget line also acts as a fixed demand function. With an increase in supply (highway capacity) from S_1 to S_2, under a constrained demand function, the travel times T_{S_1} reduce to T_{S_2} due to higher speeds, leading to an increase in time spent at nontravel (work, nonwork) activities. Thus, highway expansion is expected to reduce total time traveling and induce more time spent at nontravel activities.

However, if the journey is its own reward, or other benefits from travel alone are achieved, an increase in speeds may lead to an increase in time spent traveling (just as speeds increase VMT and

FIGURE 2 Daily Travel and Activity Time Production Function



number of trips). This interpretation would be consistent with Redmond and Mokhtarian's (2001) research that there is some positive benefit from traveling.

The mix between work and nonwork activities is indeterminate from the figure 2 analysis and requires empirical estimation. Furthermore, a distinction should be made between time at work and time spent working (presumably paid). As most employees can tell you, payment is usually based on arrangements with the employer to work a fixed number of hours. Time arriving early at the place of work is not necessarily compensated time, whether or not work is actually performed.

For obvious reasons, we evaluate separate models for workers and nonworkers. The total travel time to work and the time spent at work are zero for nonworkers, while they form a significant part of the daily time budget for workers, hence nonworkers will use this time for travel or spend it at other activities.

The methodology determines time use separately for workers and nonworkers with income as one of the independent variables in the model. We note that not all workers work full-time, but since ours is a daily analysis, we only know how much time a worker puts in on a given day, whether or not that is typical. Our analysis of the empirical data (shown in table 2) illustrates the differences in time spent at work between 1990 and 1995. Also, the estimation of different models for 1990 and 1995 embeds the differences in time spent at work in the coefficients, which is critical for our comparison of the effects of roadway capacity, discussed in subsequent sections. We conducted additional analysis to measure differences in underemployment between 1990 and 1995.[1]

The lane-miles of capacity increased for all road classes between years 1990 and 1995 (Interstates, arterials, and collectors). The research initiative proposed by this paper is to measure changes in individual time use with increase in capacity over a short-term period. We expect capacity increases are associated with positive time savings over a short time period.

HYPOTHESES

Workers

Our first concern is to determine the significance of additional capacity expansion on individual travel patterns for workers. Due to increasing highway capacity, the cost of travel drops as drivers attain higher speeds and reliability, which enables individuals to travel longer distances in the same amount of time. Since work travel is something workers would prefer to avoid (notwithstanding Mokhtarian and Redmond, since we are looking at short-term changes), we expect that every additional unit of highway capacity will decrease work trip travel times.

Time spent at work is somewhat more complicated. The economic models' suggestions are ambiguous as to where travel time savings will be spent. We assume that there is no concomitant income or work productivity change. Thus, we do not believe there will be any associated change in time spent in paid work. However, as noted above, paid work and time at work differ. Our hypothesis is thus related to scheduling and road reliability. Road capacity increases reliability (reduces variance in travel time). With increased capacity and faster speeds, the time spent at work will decrease due to reduced peak spreading. It is expected that the more reliable the roads, the more likely people get to work at their desired arrival time. This may lead to fewer early departures from home to avoid potential congestion. Thus, people will naturally spend less time early at work when they depart from home later.

In the evening, the desired departure time from work is unchanged, and due to time savings from travel (and increased reliability), workers will arrive home a few minutes earlier. (Some travelers may have departed earlier to avoid congestion in the evening; others may have departed later: these effects are thought to be offsetting). Thus, workers will be able to arrive at their work place later in the morning (but still on time), no longer needing to leave early to escape the brunt of traffic congestion, and will leave at about the same time in the evening. In all, it is expected that with increased capacity, there will be less variability in commuting travel times, resulting in less time spent at work.

Travel time to shop decreases with highway expansion because of faster roadways. Less time is spent shopping due to fewer shopping trips at larger more comprehensive stores. We expect road changes to be largely independent of income changes. However, time spent shopping is not simply a discretionary or nondiscretionary activity, and we have no reason to expect a priori that shopping is the province of high-income individuals. For instance, shoppers with less income should bargain hunt at more places in order to get the most value per dollar spent, which would increase their time spent shopping. On the other hand, individuals with higher income shop in part as a leisure activity. Thus, it is expected that income on average will have a largely nullifying affect for time spent at shopping activities among workers.

The 1990 to 1995 period saw the emergence of "big box" retailers that created scale economies on both the production and consumption side. These retailers were enabled by large, new truck-based

[1] We used time spent at an activity (including time at work) as an instrument to estimate travel time to an activity (and vice-versa) but the coefficient estimates using instrumental regression were not found to be significantly different. This was done by using Hausman's specification error test to check whether a regressor is truly exogenous to the equation. (The results are detailed in Kanchi 2001). For both workers and nonworkers it is observed that the p-value corresponding to χ^2 was significantly higher than that of the $\alpha = 0.1$ (90% confidence interval). Thus, in order to keep our model simple we did not use instrumented variable regression in our analysis, because the results were not significant at the 90% confidence interval.

just-in-time distribution systems and suburban freeways. So instead of many small stores, there are fewer but bigger retail stores, which sell a wider variety of goods. Time at shopping may be more often restricted to one big store rather than many smaller stores, and thus should decline as shoppers achieve economies of scale in consumption.

Travel time to other, as with travel time to work and to shop, decreases with capacity expansion because of time savings from faster roadways. Capacity expansion, which is mostly in fast growing suburbs, leads to the establishment of new activity centers. Because the nature of other activities for workers tends to be for pleasure and entertainment, the time spent at these activities will increase with highway capacity.

The flip side of travel time to work is travel time to home, which will similarly decrease with each unit increase in highway capacity. Workers are expected to spend part of the travel time saved at home. Travel is the cost associated with pursuing activities of interest and, hence, it can be considered the price (means) for undertaking activities (ends). Of the four activity durations (home, work, shop, and other), work and shop are necessary to fulfill an individual's daily needs and are "constrained" activities, while home and other are pleasure-maximizing "unconstrained" activities.

Nonworkers

In addition to the obvious difference in time spent at work, the major difference between the travel pattern of workers and nonworkers is that nonworkers spend more time at other activities (enabled by avoiding 300 minutes a day of work). This provides nonworkers more time and flexibility to take additional trips than workers. The qualitative meaning of some activities differs for nonworkers. In contrast to workers, nonworkers' shopping is a much more recreational or unconstrained activity. On the other hand, other activities may be less discretionary for nonworkers, as that population includes full-time students. School would be a primary activity, which can be considered similar to work for a worker. Hence, "other" is a more constrained activity. Time savings in transportation may relax the peak spreading for other activities for nonworkers as it did for work activities for workers.

On the whole for nonworkers, the frequency of home and shopping trips was higher than that for other activities. Thus, as capacity increases, nonworkers are expected to pursue more shopping-related activities. Hence, the destination travel times for home and shop tend to rise with increasing capacity, while the travel time to "other" decreases due to travel time savings associated with higher speeds. As with workers, time spent at home is a pleasure-maximizing unconstrained activity, and due to travel time savings from highway expansion, the time spent at home is expected to increase.

MODEL

Though we want to know how an individual in the 1995 survey would have behaved in 1990, unfortunately, the NPTS was not conducted as a panel survey. To compensate for this, we engaged in a two-stage procedure whereby we first estimated a model of 1990 individuals and then applied that model's coefficients to 1995 individuals. This enabled us to measure changes in behavior, controlling for as much variability as possible in socioeconomic, demographic, spatial, and temporal variations. The model to estimate time at each of the eight activities for a 1990 individual is:

$$T_{90i} = f\,(A,D,G,H,L,M,S,W) \qquad (6)$$

Subject to

$$\left(\sum_{i=1}^{8} T_{90i}\right) = 1{,}440 \qquad (7)$$

where

T_{90i} = time spent at activity i;

i = index of activities (travel time to and duration at home, work, shop, and other);

A = age;

D = local population density;

G = gender;

H = household income levels;

L = family lifecycle characteristics;

M = month of year interview was conducted;

S = state-specific variables;

W = day of week interview was conducted.

We selected these variables because of their availability and their significance in previous analyses of travel behavior by the authors (Levinson 1999; Levinson and Kumar 1995a, 1995b, 1997). The above model analysis was performed at the individual level rather than at the state level. This approach was employed because aggregation at the state level would yield 33 observations (1 for each state, with a number of states suppressed in the analysis because they had too few observations), which, due to many fewer degrees of freedom, would diminish the explanatory power of the model. We used states as explanatory variables to estimate the individuals' time use in 1990 and 1995. Dummy variables (0,1) were employed for each of the characteristics. The variables were entered linearly into the model.

The final model for T_{90i} was estimated using Zellner's seemingly unrelated regression subjected to the daily time budget constraint of 1,440 minutes. Seemingly unrelated regression estimation (SURE) models use asymptotically efficient, feasible, generalized least squares estimation (Greene 1997). The daily time budget constraint makes the covariance matrix of residual errors singular, which cannot be determined directly by SURE, so we dropped one equation and estimated the other seven simultaneously. The final dropped equation can then be calculated using the mathematical constraint equation, because the remaining coefficients and their sums are known. The SURE model is preferred over ordinary least squares (OLS) regression, because it overrules the assumption that error residuals are not interrelated. SURE estimates the whole model as a system of equations rather than one by one as in OLS. The coefficients from this model are shown in appendix table A1.

The equations for T_{90i} for 1990 obtained from the first stage were used to determine $\hat{T}_{90i}$ (an estimate of the travel times and activity duration that 1995 individuals had in 1990) subject to the reported socioeconomic, demographic, spatial, and temporal characteristics of each 1995 respondent. Simply put, we took the estimated 1990 time-use equations and applied them to the 1995 data.

We used $\hat{T}_{90i}$ to estimate a difference model of change in travel behavior between the 1995 individuals reported (or computed) activity times and the best estimate of their 1990 behavior. We evaluated two models (one for workers and one for nonworkers) in the form given below.

$$\Delta T_i = f\left(\Delta C / C_{90}, \Delta F / F_{90}, \Delta I / I_{90}, \Delta P / P_{90}, D_{95}, G_{95}, L_{95}\right) \quad (8)$$

Subject to

$$\sum_{i=1}^{8} \Delta T_i = 0 \quad (9)$$

where

$\Delta T_i = T_{95I} - \hat{T}_{90i}$ Change in time at activity i between 1995 (reported) and 1990 (estimated),

i = index of activities,

ΔC = difference in lane-miles for all roadway types between 1995 and 1990,

C_{90} = sum of lane-miles for all roadway types in 1990,

ΔF = difference in state average fuel prices between 1995 and 1990,

F_{90} = state average fuel price in 1990,

ΔI = difference in state average per capita income between 1995 and 1990,

I_{90} = state-level per capita income in 1990,

ΔP = difference in state population between 1995 and 1990,

P_{90} = state population in 1990,

D_{95} = local population density estimates in 1995,

G_{95} = gender as noted in 1995 survey,

L_{95} = family lifecycle characteristics in 1995.

Since all eight activities in the 1990 and 1995 surveys are constrained by the individual daily time budget of 1,440 minutes, their differences sum to 0 minutes. A SURE is run on the above system of equations considering the ΔT_i (for each of eight activities (six for nonworkers)) as dependent variables. Again, all variables are entered linearly. Because the system of equations forms a singular error variance matrix, one of the equations is dropped and a SURE model is run on seven equations for workers (five equations for nonworkers) and the final dropped equation is obtained from the mathematical constraint. The full results are shown in appendix table A2 for workers and appendix table A3 for nonworkers.

TABLE 5 Elasticity of Time with Respect to Capacity

Dependent variable:	Workers		Nonworkers	
Change in:	Elasticity	Minutes	Elasticity	Minutes
Travel time to				
Home	–3.17E–04	–0.0108	1.48E–02	0.528*
Work	–7.06E–03	–0.123*	NA	NA
Shop	–4.71E–02	–0.190*	3.39E–02	0.235*
Other	–9.80E–03	–0.160*	–2.91E–02	–0.606*
Activity duration at				
Home	7.27E–03	6.56*	2.19E–03	2.60*
Work	–1.80E–02	–5.66*	NA	NA
Shop	–3.44E–02	–.767*	2.54E–02	1.19*
Other	2.72E–03	0.349	–2.83E–02	–3.95*

* Denotes significance of the variable at 95% level.

RESULTS

A summary of the final SURE results is displayed in table 5, which shows the elasticity of travel times and activity durations with respect to lane-miles of capacity. The elasticity η of independent variable x with respect to its dependent variable y is given by

$$\eta = \frac{dy / y}{dx / x} \qquad (10)$$

The elasticities described here represent the percentage increase in change in time use with a 1% change in capacity. Thus, to illustrate table 5, for every 1% increase in capacity, workers decrease their travel time to home by 0.000317% or 0.0108 minutes, travel time to work by 0.00706% or 0.123 minutes, and so on. Hence, these represent the change in time use with respect to capacity.

While the numbers may appear small, a 1% increase in capacity increases time spent at home by over 6 minutes and reduces time at work by 5 minutes. As these numbers are estimated from state capacity data, it can be expected that local effects from a new or expanded roadway would be much greater. The results displayed in table 5 are consistent with the underlying hypotheses for both workers and nonworkers. The difference between worker and nonworker models is primarily due to the presence of an extra 300 minutes for nonworkers to pursue additional activities.

It is found that nonworkers, when given additional capacity, prefer shopping while workers pursue other activities. This is due to the qualitative shift in behavior between shop and other for workers and nonworkers, which yields such travel and activity behavioral patterns. Thus, it is important to model each category separately to determine its respective effect. Also, we found that with capacity expansion, individuals pursue more unconstrained activities (home and other for workers, home and shop for nonworkers), which presumably increases their utility. A somewhat surprising result is that additional roadway capacity leads to a net increase in time spent traveling by nonworkers (in contrast with workers). This lends credence to the idea that travel itself has a positive utility for nonworkers.

CONCLUSIONS

We observed that overall travel times have remained statistically unchanged between 1990 and 1995, while a significant change is observed in activity durations, both of which are in agreement with previous analyses. Linking a panel of highway data for the first time with time series travel behavior data suggests that while VMT may increase with capacity, the time spent traveling remains fairly stable. Furthermore, the effects on workers and nonworkers are different.

Using a simultaneous equation estimation difference model approach, this research shows how travel times and activity durations are affected by increasing highway capacity. We found that increases in highway capacity bring about small but statistically significant changes in individual daily travel behavior. Workers use the capacity expansion to spend more time at home and other activities, and spend less time at work. Nonworkers choose to use the additional capacity both for activities at home and for shopping. These observations may be somewhat surprising; however, we have found no alternative hypothesis consistent with the data, nor have we found (to date) any data that contradict the hypothesis. This analysis is the first to measure these variables as a function of road capacity. As such, it serves as a marker for future research to corroborate or refute. While there is clearly induced travel, we now have a better understanding of which travel and activities are induced with capacity and which are reduced.

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TABLE A1 Coefficients from the Estimated Model of 1990 Time-Use Behavior

Independent variables	Workers								Nonworkers					
	Travel to				Time at				Travel to			Time to		
	Home	Work	Shop	Other	Home	Work	Shop	Other	Home	Shop	Other	Home	Shop	Other
States														
Alabama	4.08	8.22	0.10	–1.58	7.49	–10.65	–17.26	9.59	–7.75	–0.93	1.24	–42.54	0.73	49.26
Arizona	4.64	10.25	–0.61	–2.52	–69.08	63.95	–6.98	0.35	16.00	–0.07	4.02	–89.63	37.90	31.79
Arkansas	–4.45	–2.56	–0.69	–0.37	–13.45	–35.20	–11.95	68.67	–18.51	3.22	–5.88	37.64	–7.03	–9.44
California	5.79	3.78	0.53	–0.42	–28.74	–10.22	4.51	24.76	–7.19	–1.34	2.01	–5.71	2.82	9.41
Colorado	5.30	6.01	0.87	–5.15	–6.26	8.85	–3.93	–5.68	2.58	–2.96	–2.07	36.56	–11.58	–22.53
Connecticut	2.35	0.70	0.33	–0.18	–16.61	20.37	–5.23	–1.72	–6.72	–3.79	–4.30	53.85	–7.43	–31.59
Florida	0.89	2.53	–0.49	–1.97	–20.05	–3.71	–2.76	25.56	–9.10	–0.93	–4.40	15.50	–1.56	0.49
Georgia	0.24	3.63	–0.88	2.15	–62.20	59.71	–4.79	2.14	1.73	0.86	–1.21	20.93	–1.92	–20.39
Illinois	1.84	4.87	–1.73	–1.97	–52.87	49.98	–7.78	7.66	10.16	–1.49	2.50	–11.40	–5.59	5.83
Indiana	4.83	3.37	–0.85	–0.59	–52.60	22.70	–3.18	26.32	–0.14	–1.54	–2.74	31.41	–1.26	–25.73
Iowa	3.36	1.32	–0.66	–5.49	–9.14	–2.51	–13.13	26.25	–18.58	6.09	0.83	–26.06	38.96	–1.24
Kansas	–8.43	–5.48	–1.63	–1.33	117.28	–125.98	13.72	11.86	13.82	3.45	–7.14	–84.28	3.32	70.83
Kentucky	7.09	3.51	–2.77	4.33	–64.75	54.95	–16.49	14.13	–11.54	–0.88	18.34	30.37	–1.80	–34.49
Louisiana	–3.32	1.50	–1.20	5.07	–25.95	21.57	–12.05	14.38	–12.03	–3.46	–6.17	66.76	–4.13	–40.98
Maryland	8.23	7.90	–0.51	0.64	–74.10	14.91	–7.21	50.14	–9.23	–2.13	–4.82	41.47	–13.44	–11.84
Massachusetts	6.62	0.50	0.12	–0.98	25.53	–46.75	–8.60	23.56	–1.91	0.68	–10.04	73.53	5.18	–67.44
Michigan	11.67	0.42	0.09	–2.36	–55.63	–4.24	1.22	48.83	–9.94	–0.45	–8.35	46.06	20.95	–48.27
Minnesota	0.50	2.24	0.74	–3.68	–9.41	–12.18	1.80	20.00	8.83	–0.63	–8.08	–3.43	12.58	–9.27
Mississippi	–4.26	8.99	2.64	7.87	–81.30	16.14	6.07	43.85	–1.91	0.53	5.17	–4.10	0.22	0.10
Missouri	–2.06	8.29	–1.75	–4.17	–65.69	126.57	–18.81	–42.38	–2.26	6.54	–14.02	62.68	63.93	–116.87
New Jersey	8.14	10.02	–0.30	–2.09	–43.83	32.02	–11.02	7.05	–2.99	–1.45	–11.13	66.98	–12.07	–39.33
New York	8.02	6.24	2.40	–0.44	–49.95	33.45	–4.57	4.84	0.52	–2.25	–2.80	32.44	–2.72	–25.18
North Carolina	–5.12	3.69	–1.32	1.60	–42.68	70.62	–10.94	–15.85	–14.83	–2.01	3.39	41.56	–2.76	–25.36
Ohio	3.18	–1.02	1.69	1.14	–8.93	–22.73	–3.32	29.99	–7.08	–0.73	–4.04	0.37	1.38	10.10
Oklahoma	–5.36	0.89	–2.39	–2.00	62.88	–60.23	–14.28	20.50	1.03	0.53	–6.75	33.20	13.43	–41.44
Oregon	–5.24	0.00	–1.45	–3.67	–54.69	80.52	–6.32	–9.14	–18.90	7.77	–4.72	33.24	40.54	–57.93
Pennsylvania	–0.24	2.15	–1.06	–1.74	–33.18	35.11	–13.03	11.99	2.43	0.01	–4.46	28.57	9.22	–35.77
South Carolina	–2.81	–0.49	0.88	–4.82	–8.06	48.09	–12.18	–20.60	–14.55	–2.64	–10.12	46.80	2.35	–21.84
Tennessee	–5.19	0.52	0.44	–3.31	–26.33	41.12	–3.67	–3.58	–13.07	–0.69	–8.02	55.22	–6.33	–27.11
Texas	5.88	2.28	0.22	1.06	–16.49	–5.60	–7.20	19.86	–7.20	–1.02	–2.70	42.42	–10.12	–21.39
Virginia	2.76	1.86	–0.25	–2.52	2.10	–1.84	–1.96	–0.16	–12.43	–0.27	–9.36	37.95	–5.82	–10.08
Washington	4.94	7.82	3.79	1.12	–60.56	20.67	–7.39	29.61	0.00	–0.34	4.04	1.87	–14.80	9.22

continues

TABLE A1 Coefficients from the Estimated Model of 1990 Time Use-Behavior (*continued*)

Independent variables	Workers: Travel to Home	Workers: Travel to Work	Workers: Travel to Shop	Workers: Travel to Other	Workers: Time at Home	Workers: Time at Work	Workers: Time at Shop	Workers: Time at Other	Nonworkers: Travel to Home	Nonworkers: Travel to Shop	Nonworkers: Travel to Other	Nonworkers: Time to Home	Nonworkers: Time to Shop	Nonworkers: Time to Other
Population density														
0–99	6.27	1.50	0.69	–11.13	51.64	11.52	–1.56	–58.92	0.72	–3.20	–4.80	99.93	–42.69	–49.96
100–249	3.21	1.53	1.53	–12.05	45.45	14.39	4.31	–58.37	3.42	–3.04	–2.63	67.04	–36.60	–28.20
250–499	2.63	2.17	0.65	–11.81	46.23	12.74	6.19	–58.78	–8.99	–2.23	–7.62	80.54	–32.35	–29.35
500–749	4.82	1.11	0.32	–11.29	57.90	16.56	2.26	–71.68	4.48	–1.85	–0.66	55.25	–21.79	–35.42
750–999	–3.02	–0.59	2.03	–11.10	52.86	8.84	12.68	–61.70	2.15	1.89	3.94	35.78	–26.67	–17.09
1,000–1,999	0.68	1.91	0.29	–9.60	60.44	3.11	1.46	–58.29	–4.60	0.57	–1.34	54.86	–32.11	–17.38
2,000–2,999	1.28	0.09	0.91	–11.37	82.81	–26.88	6.13	–52.98	–9.63	–1.92	–2.55	78.60	–37.71	–26.78
3,000–3,999	2.66	1.27	0.26	–13.74	33.88	28.64	1.30	–54.27	1.07	–3.07	–7.54	54.27	–30.42	–14.30
4,000–4,999	0.37	2.26	1.17	–11.23	33.87	17.89	8.71	–53.04	–13.85	–1.35	–11.32	113.92	–31.33	–56.06
5,000–7,499	1.62	4.86	0.56	–10.17	56.93	–2.72	0.21	–51.29	–4.59	–1.51	–0.92	39.32	–21.93	–10.37
7,500–9,999	–1.39	2.42	1.45	–8.35	106.74	–41.52	1.81	–61.17	1.72	–1.70	–6.95	101.79	–38.47	–56.39
10,000–49,999	9.31	6.42	–0.18	–12.91	86.64	–8.91	2.29	–82.66	–5.14	0.92	–4.45	71.79	–24.54	–38.58
50,000+	4.63	18.45	–0.58	–12.53	36.88	24.46	12.18	–83.48	–6.63	1.17	3.17	124.52	–7.43	–114.80
Household income														
Less than $5,000	–1.21	–1.40	0.32	0.11	100.80	–103.15	6.70	–2.18	–7.77	0.46	–5.61	38.15	8.01	–33.25
$5,000–$9,999	–8.08	–0.65	0.29	1.74	–1.09	15.02	10.49	–17.71	–2.33	0.19	–4.55	20.55	–0.63	–13.23
$10,000–$14,999	–5.47	–0.58	0.28	1.65	18.65	–21.63	–1.09	8.19	1.33	–0.06	–1.43	22.08	2.00	–23.92
$15,000–$19,999	–5.34	0.04	0.70	0.54	25.48	–34.85	0.07	13.37	–1.81	1.31	–1.72	34.05	–0.97	–30.85
$20,000–$24,999	–3.89	–1.66	0.17	1.93	6.71	–27.35	2.27	21.82	0.09	1.49	–1.11	16.15	11.32	–27.93
$25,000–$29,999	–2.77	–1.12	0.64	5.19	–4.72	–36.87	7.87	31.78	1.42	2.66	8.55	–19.02	8.42	–2.03
$30,000–$34,999	–0.14	–2.00	1.44	4.14	–14.58	–42.35	10.77	42.72	–0.64	1.44	0.70	29.57	8.16	–39.23
$35,000–$39,999	–2.11	–0.21	1.10	4.05	–17.21	–17.94	8.11	24.19	1.57	0.38	2.28	–4.00	9.01	–9.24
$40,000–$44,999	2.50	1.98	0.22	4.30	–14.24	–22.04	–0.96	28.24	–2.42	2.19	2.53	–52.43	27.00	23.14
$45,000–$49,999	7.20	1.07	2.70	11.24	6.25	–83.07	10.01	44.59	3.26	2.19	1.43	–11.87	7.10	–2.12
$50,000–$54,999	4.36	2.83	1.43	3.62	0.70	–52.36	7.90	31.51	2.89	0.51	2.77	5.16	15.48	–26.80
$55,000–$59,999	7.30	3.82	1.14	6.85	15.51	–67.76	16.44	16.70	14.92	6.70	–0.12	–71.95	41.57	8.88
$60,000–$64,999	9.76	3.41	0.52	4.90	–21.25	–86.72	7.32	82.07	–10.14	2.45	–3.75	4.34	15.16	–8.06
$65,000–$69,999	3.87	–2.12	1.08	10.39	–32.03	–46.54	10.28	55.08	–3.01	–2.18	2.57	–20.73	24.28	–0.93
$70,000–$74,999	9.78	5.23	6.73	9.01	–49.11	–71.92	26.28	64.00	0.21	–3.20	9.88	–38.62	22.65	9.09
$75,000–$79,999	–2.96	0.35	–0.53	9.32	27.93	–83.91	–1.98	51.77	–20.04	1.91	–9.29	96.07	28.85	–97.50
$80,000+	6.39	2.63	0.78	8.88	–1.96	–67.55	–0.92	51.76	10.31	3.01	16.78	–37.46	1.29	6.06

continues

TABLE A1 Coefficients from the Estimated Model of 1990 Time-Use Behavior (*continued*)

Independent variables	Workers								Nonworkers					
	Travel to				Time at				Travel to			Time to		
	Home	Work	Shop	Other	Home	Work	Shop	Other	Home	Shop	Other	Home	Shop	Other
Lifecycle														
(Adults, youngest child age)														
1, NA	–62.98	2.41	3.90	–34.23	22.65	74.38	–29.52	23.39	–10.53	–3.93	–9.25	7.20	–28.25	44.77
2+, NA	–68.04	4.03	2.70	–38.88	9.27	133.11	–37.27	–4.91	–5.88	–2.32	–8.54	12.26	–27.58	32.05
1, 0–5	–65.13	0.85	3.79	–33.00	36.75	31.22	–39.53	65.05	–12.46	–5.12	–11.00	35.16	–26.74	20.15
2+, 0–5	–69.53	6.55	2.68	–39.59	39.76	105.05	–36.00	–8.93	–15.23	–3.37	–11.76	39.04	–28.63	19.96
1, 6–15	–59.88	3.43	2.74	–33.36	13.98	59.15	–33.00	46.94	–11.05	–2.05	0.34	–78.44	–21.88	113.08
2+, 6–15	–66.99	3.07	2.81	–40.53	41.95	105.62	–35.33	–10.60	–8.21	–1.68	–10.14	–15.78	–20.75	56.56
1, 16–21	–66.99	3.03	2.81	–37.59	97.23	38.36	–37.64	0.78	–4.59	–3.07	–20.35	63.81	–31.67	–4.12
2+, 16–21	–67.34	–0.64	2.04	–39.22	45.49	109.62	–40.56	–9.40	–4.06	–3.63	–9.81	–34.44	–31.49	83.43
1, retired, NA	–35.88	–7.34	–0.11	–18.44	222.12	–77.56	–59.52	–23.28	–6.24	–2.62	–8.33	17.80	–26.21	25.58
2+ , retired NA	–64.05	4.55	1.92	–38.51	55.79	78.88	–37.43	–1.14	–8.44	–2.21	–16.74	61.69	–25.69	–8.59
Sex														
Male	2.40	3.26	–1.02	–2.04	–22.61	49.63	–10.63	–18.99	1.78	0.18	–1.04	3.78	–7.38	2.68
Month														
January	–0.30	–1.60	–1.43	–1.34	27.78	–15.43	–5.34	–2.34	–3.35	–0.44	–3.75	42.06	–16.66	–17.86
February	2.36	–0.29	–0.82	1.96	15.83	–34.58	–3.85	19.38	0.27	–0.45	–0.15	14.47	–13.59	–0.54
March	1.28	0.33	–0.30	2.64	–42.50	34.04	–5.88	10.41	–2.56	–1.96	4.78	–28.12	–16.65	44.50
April	3.53	1.08	–1.42	3.96	–13.38	–14.46	–7.68	28.39	2.41	–0.11	5.04	–16.04	–14.99	23.69
May	2.36	2.36	–0.41	6.00	2.09	–40.57	–4.75	32.92	–0.14	–0.16	5.11	–12.94	–16.69	24.83
June	3.16	0.14	–0.89	3.50	–13.64	–10.26	–5.48	23.49	1.31	0.17	12.74	–58.21	–17.13	61.11
July	10.68	2.91	–1.10	6.49	–21.10	–0.21	–8.28	10.61	0.78	–0.99	1.36	12.20	–8.08	–5.28
August	5.12	–0.10	–0.60	1.02	–7.21	–6.00	–7.60	15.36	–4.25	–0.17	–0.27	45.86	–13.86	–27.30
September	1.19	1.65	0.24	3.47	–20.52	1.06	–4.44	17.36	–3.20	–1.35	–1.21	53.01	–22.83	–24.42
October	0.67	0.44	–0.61	1.99	16.52	–7.91	–7.46	–3.64	2.55	–1.39	–2.73	27.57	–12.20	–13.80
November	4.12	–0.63	–0.34	1.78	15.82	–24.39	–0.62	4.25	–0.61	–0.20	1.21	–14.53	–6.24	20.37
Day of week														
Sunday	–0.48	–3.09	–2.10	–0.54	50.90	–40.69	–12.02	8.03	–6.11	–0.95	1.38	–1.75	–23.43	30.87
Monday	–8.48	12.15	–3.59	–8.98	–200.82	234.13	–17.30	–7.11	–2.22	–2.26	5.25	3.52	–27.37	23.08
Tuesday	–8.18	11.57	–3.26	–6.96	–223.99	254.35	–19.95	–3.57	–8.32	–0.51	0.48	–17.42	–16.67	42.43
Wednesday	–11.29	15.46	–3.89	–7.59	–239.79	257.03	–20.48	10.54	–5.51	0.49	4.45	–52.39	–11.03	63.99
Thursday	–8.82	12.22	–3.79	–7.57	–238.03	268.90	–16.65	–6.27	–12.26	0.81	–0.97	–11.81	–14.50	38.73
Friday	–5.59	12.29	–2.93	–4.75	–228.55	235.15	–21.02	15.41	–12.21	0.29	1.42	–15.73	–6.47	32.71
Constant	95.33	–4.48	3.10	64.60	1,023.01	41.81	82.25	134.38	55.96	10.77	33.67	1,103.21	118.11	118.27
r–squared	0.035	0.092	0.039	0.042	0.122	0.141	0.034	Derived	0.060	0.075	0.076	0.091	0.067	Derived

Note: Derived indicates the model was derived based on constraint equations, not estimated.

TABLE A2 Model for Change in Time Use Between 1990 and 1995: Workers

	Travel to								**Time at**						
Independent variables	**Home** Coefficient	*t*	**Work** Coefficient	*t*	**Shop** Coefficient	*t*	**Other** Coefficient	*t*	**Home** Coefficient	*t*	**Work** Coefficient	*t*	**Shop** Coefficient	*t*	**Other** Coefficient
% change in															
Lane-miles	–1.08	–0.23	–12.34	–2.16	–18.96	–6.47	–16.05	–2.83	656.17	12.63	–566.04	–10.27	–76.65	–6.96	34.95
Population	25.37	4.40	–0.58	–0.08	19.88	5.65	21.28	3.12	–105.22	–1.69	34.92	0.53	32.40	2.45	–28.06
Income	5.64	0.89	6.22	0.83	–13.81	–3.59	–9.66	–1.30	653.33	9.57	–688.50	–9.50	–17.95	–1.24	64.72
Gas prices	–44.33	–14.99	–7.53	–2.14	–20.39	–11.29	–15.38	–4.39	504.62	15.76	–354.00	–10.41	–26.57	–3.91	–36.43
Sex															
Male	0.75	2.90	4.22	13.59	–0.96	–6.06	0.01	0.05	–31.83	–11.28	11.84	3.96	–0.84	–1.41	16.80
Lifecycle															
(Adults, youngest child age)															
1, NA	–5.10	–3.36	0.57	0.35	–0.20	–0.24	–4.24	–2.64	1.30	0.08	7.79	0.45	–6.45	–2.07	6.34
2+, NA	–0.39	–0.27	–0.69	–0.44	0.51	0.64	–2.35	–1.53	30.98	1.95	–46.06	–2.72	1.59	0.53	16.42
2+, 0–5	0.32	0.22	–4.61	–2.94	0.01	0.01	1.33	0.85	22.09	1.37	–38.10	–2.23	0.43	0.14	18.53
1, 6–15	–5.55	–3.25	0.90	0.48	0.10	0.10	–1.61	–0.87	12.70	0.69	6.07	0.31	–1.69	–0.47	–10.92
2+, 6–15	–1.03	–0.70	–0.88	–0.56	0.38	0.48	2.10	1.35	4.39	0.27	–33.21	–1.95	1.40	0.47	26.86
2+, 16–21	–3.34	–2.18	0.88	0.54	0.90	1.08	–0.78	–0.48	–14.16	–0.85	–28.85	–1.64	3.29	1.05	42.06
2+, retired, NA	–3.22	–2.03	–3.87	–2.27	1.52	1.75	–0.90	–0.53	4.34	0.25	–31.25	–1.72	3.53	1.08	29.86
Month															
January	–0.28	–0.41	4.11	5.05	–2.10	–5.05	0.73	0.91	–24.83	–3.36	32.55	4.15	–5.70	–3.64	–4.48
February	–2.05	–3.34	2.20	3.01	–1.18	–3.14	–0.84	–1.16	–32.95	–4.96	65.12	9.23	–8.43	–5.98	–21.89
March	–0.93	–1.62	2.61	3.83	–1.41	–4.03	–2.43	–3.59	18.94	3.05	5.35	0.81	–5.60	–4.26	–16.53
April	–3.96	–6.43	0.88	1.20	–0.65	–1.72	–2.96	–4.06	–9.67	–1.45	49.56	7.00	–4.44	–3.14	–28.76
May	–2.33	–3.96	–1.46	–2.08	–1.06	–2.95	–5.84	–8.39	–11.04	–1.73	58.26	8.61	–4.03	–2.99	–32.50
June	–2.09	–3.34	1.64	2.21	–0.39	–1.03	–1.98	–2.67	–17.08	–2.52	42.83	5.96	–2.70	–1.88	–20.24
July	–9.54	–14.57	–2.34	–3.00	0.22	0.56	–3.95	–5.10	4.67	0.66	1.69	0.23	0.55	0.37	8.70
August	–2.55	–3.65	1.65	1.98	0.19	0.44	0.86	1.03	–16.40	–2.17	27.15	3.38	0.73	0.46	–11.62
September	0.51	0.78	–0.02	–0.03	–2.13	–5.28	–2.40	–3.08	6.33	0.89	15.29	2.02	–6.87	–4.54	–10.71
October	0.66	1.05	2.57	3.44	–1.05	–2.75	–0.91	–1.23	–44.24	–6.52	44.26	6.14	–2.96	–2.06	1.68
November	–3.42	–5.51	2.57	3.47	–0.39	–1.03	–1.98	–2.69	–35.80	–5.32	56.17	7.87	–4.68	–3.28	–12.46

continues

TABLE A2 Model for Change in Time Use Between 1990 and 1995: Workers (*continued*)

Independent variables	Travel to								Time at						
	Home Coefficient	*t*	**Work** Coefficient	*t*	**Shop** Coefficient	*t*	**Other** Coefficient	*t*	**Home** Coefficient	*t*	**Work** Coefficient	*t*	**Shop** Coefficient	*t*	**Other** Coefficient
Day of week															
Sunday	–2.86	–5.55	–1.24	–2.02	–1.64	–5.23	1.74	2.86	10.65	1.91	–21.55	–3.65	–3.60	–3.05	18.49
Monday	8.19	17.68	3.31	6.00	–2.46	–8.70	0.63	1.16	39.87	7.95	25.56	4.80	–10.93	–10.28	–64.17
Tuesday	8.39	18.19	5.85	10.65	–2.54	–9.03	–1.34	–2.46	35.40	7.09	33.43	6.31	–7.48	–7.07	–71.70
Wednesday	11.09	23.79	1.91	3.45	–2.33	–8.19	–0.30	–0.54	46.79	9.27	33.28	6.21	–7.95	–7.43	–82.50
Thursday	15.40	2.19	5.54	0.66	–3.18	–0.74	–3.41	–0.41	–217.37	–2.86	97.46	1.21	–13.11	–0.81	118.67
Friday	7.46	15.96	3.64	6.53	–2.12	–7.42	–0.99	–1.79	36.42	7.20	32.67	6.08	–1.49	–1.39	–75.59
Population density															
250–499	–3.30	–6.69	–2.04	–3.46	–0.51	–1.69	11.84	20.23	–48.88	–9.14	–7.49	–1.32	–4.16	–3.67	54.55
750–999	1.33	2.34	1.17	1.72	–1.92	–5.50	10.86	16.06	–57.47	–9.29	–7.14	–1.09	–8.39	–6.40	61.55
1,000–1,999	–3.77	–7.01	–2.59	–4.05	–0.60	–1.83	8.82	13.87	–61.71	–10.61	3.11	0.50	0.94	0.77	55.79
3,000–3,999	–6.28	–12.41	–2.32	–3.85	–0.80	–2.60	12.37	20.64	–32.56	–5.94	–18.75	–3.22	1.88	1.62	46.47
5,000–7,499	–4.45	–9.28	–5.43	–9.50	–1.04	–3.54	9.21	16.22	–67.05	–12.91	18.07	3.28	3.40	3.09	47.29
Constant	–13.95	–8.50	–1.62	–0.91	3.42	3.77	–8.09	–4.59	92.41	5.20	–24.44	–1.30	4.96	1.45	–52.69
r–squared	0.106		0.089		0.0385		0.068			0.0813		0.1022		0.513	Derived

Note: Derived indicates the model was derived based on constraint equations, not estimated.

TABLE A3 Model for Change in Time Use Between 1990 and 1995: Nonworkers

Independent variables	Travel to: Home Coefficient	*t*	Travel to: Shop Coefficient	*t*	Travel to: Other Coefficient	*t*	Time at: Home Coefficient	*t*	Time at: Shop Coefficient	*t*	Time at: Other Coefficient
% change in											
Lane-miles	52.79	6.01	23.55	3.65	–60.64	–5.09	260.35	3.14	119.27	4.46	–395.32
Population	2.11	0.20	–17.46	–2.28	–5.13	–0.36	196.09	1.99	–64.83	–2.04	–110.78
Income	65.41	5.98	6.52	0.81	–20.29	–1.37	–60.35	–0.59	118.18	3.55	–109.47
Gas prices	6.06	1.25	8.06	2.26	–29.14	–4.43	41.98	0.92	55.71	3.77	–82.66
Sex											
Male	0.94	1.76	–2.33	–5.91	3.81	5.25	–28.94	–5.72	–6.92	–4.23	33.42
Lifecycle											
(Adults, youngest child age)											
1, NA	4.40	1.52	–3.66	–2.47	–12.35	–3.15	87.62	4.60	–9.35	–1.52	–66.65
2+, NA	–2.41	–0.88	–5.67	–4.28	–16.36	–4.40	80.81	4.74	–9.34	–1.70	–47.03
2+, 0–5	6.33	2.30	–5.35	–4.03	–12.54	–3.36	82.08	4.81	–13.17	–2.39	–57.34
1, 6–15	6.28	1.97	–8.07	–4.53	–16.24	–3.75	130.03	5.69	–16.19	–2.19	–95.81
2+, 6–15	0.95	0.34	–7.15	–5.27	–14.15	–3.77	117.73	6.76	–20.66	–3.67	–76.72
2+, 16–21	–3.66	–1.28	–5.12	–3.51	–13.64	–3.52	111.32	5.96	–9.37	–1.55	–79.54
2+, retired,NA	0.89	0.32	–2.97	–2.22	–9.14	–2.46	68.39	3.98	–5.38	–0.97	–51.80
Month											
January	2.09	1.60	–3.10	–3.23	5.48	3.09	–38.16	–3.10	–4.55	–1.14	38.24
February	0.51	0.44	–2.45	–2.86	5.16	3.26	–31.89	–2.89	–1.18	–0.33	29.85
March	3.11	2.81	–1.06	–1.31	–0.70	–0.47	14.21	1.36	–2.00	–0.59	–13.55
April	–1.66	–1.43	–2.97	–3.50	1.52	0.97	–11.80	–1.08	–4.74	–1.34	19.64
May	0.57	0.52	–2.31	–2.87	–0.93	–0.63	–0.61	–0.06	1.25	0.38	2.04
June	0.71	0.61	–3.25	–3.76	–6.34	–3.97	39.81	3.58	–0.70	–0.19	–30.24
July	0.71	0.58	–2.50	–2.77	3.65	2.19	–26.39	–2.28	–11.87	–3.17	36.39
August	5.27	4.00	–1.54	–1.59	5.35	2.99	–46.88	–3.77	0.14	0.04	37.67
September	3.94	3.16	–1.64	–1.80	5.60	3.31	–81.20	–6.90	7.61	2.00	65.70
October	0.46	0.39	–0.50	–0.57	8.38	5.22	–13.61	–1.22	–4.23	–1.17	9.49
November	1.17	0.99	–1.73	–1.99	1.91	1.19	–6.88	–0.62	–1.46	–0.41	6.99

continues

TABLE A3 Model for Change in Time Use Between 1990 and 1995: Nonworkers (*continued*)

Independent variables	Travel to: Home Coefficient	*t*	Travel to: Shop Coefficient	*t*	Travel to: Other Coefficient	*t*	Time at: Home Coefficient	*t*	Time at: Shop Coefficient	*t*	Time at: Other Coefficient
Day of week											
Sunday	4.39	4.66	–3.20	–4.62	–2.54	–1.99	12.43	1.40	3.84	1.34	–14.91
Monday	–0.49	–0.53	–1.14	–1.68	–5.45	–4.37	19.28	2.22	11.36	4.05	–23.57
Tuesday	7.63	8.38	–2.41	–3.60	1.17	0.95	28.65	3.33	1.48	0.53	–36.53
Wednesday	5.93	6.48	–2.44	–3.64	–3.77	–3.04	63.25	7.33	3.24	1.16	–66.20
Thursday	11.82	12.73	–2.92	–4.27	2.27	1.80	20.50	2.34	1.90	0.67	–33.58
Friday	12.88	13.89	–0.59	–0.87	0.70	0.56	15.87	1.81	0.86	0.30	–29.72
Population density											
250–499	7.85	8.70	1.62	2.45	7.41	6.05	–78.93	–9.26	35.54	12.91	26.50
750–999	–5.04	–4.79	–2.10	–2.72	–7.81	–5.48	–25.28	–2.55	34.69	10.83	5.53
1,000–1,999	1.39	1.43	–1.91	–2.69	–0.71	–0.54	–50.09	–5.48	39.74	13.46	11.58
3,000–3,999	–5.20	–5.75	0.92	1.39	5.09	4.15	–60.48	–7.08	32.82	11.90	26.85
5,000–7,499	0.66	0.79	–0.23	–0.38	–0.76	–0.66	–40.22	–5.06	28.89	11.24	11.66
7,500–9,999	4.15	4.40	–2.06	–2.96	5.17	4.04	–92.32	–10.36	34.55	12.00	50.50
Constant	–23.79	–7.81	14.23	8.62	13.13	3.18	–56.75	–2.68	–22.63	–3.31	75.81
r–squared	0.161		0.101		0.123		0.138		0.148		Derived

Note: Derived indicates the model was derived based on constraint equations, not estimated.