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Whence Induced Demand: How Access Affects Activity

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by

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ABSTRACT

Additional highway capacity, by increasing travel speed, affects the individual share of time within a 24-hour budget allocated to various activities (time spent at and traveling to home, shop, work and other), some activities will be undertaken more, others less. This paper extends previous research that identified and quantified induced demand in terms of vehicle miles traveled, by considering questions of what type of demand is induced and which activities are consequently reduced. This paper uses the 1990 and 1995 Nationwide Personal Transportation Survey and Federal Highway Administration highway statistics data. While total travel times have not seen any significant change between the years 1990 and 1995, there is a significant change in activity durations. Further, as a result of additional capacity, workers spend less time traveling. Workers also spend more time at home and other activities and less at work and shop. Non-workers, in contrast, travel more, and spend more time shopping and at home, but less time at other activities. This points out the differences in discretionary and non-discretionary activities for workers and non-workers. It also suggests that there are real gains from capacity in people's lives, at least in the short term, as it is time, and not VMT, that individuals base decisions on.

1. INTRODUCTION

There has been recent interest in the impact of additional highway capacity. New and faster roads may attract more traffic than is simply diverted from existing roads. This "induced 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, the traffic congestion may approach its earlier levels. If the sole aim of capacity expansion were to reduce congestion, such expansions appear redundant, however road construction may increase accessibility and affect people's daily activity patterns. By changing the number and nature of non-home opportunities (working, shopping, other), we expect individuals to alter their activities and thus their travel. This ability to take advantage of new opportunities in the same 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 consider in their travel decisions.

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 overall demand elasticities between –0.5 and –1.0, indicating that a 1% increase in capacity or reduction in travel time will increase vehicle miles traveled, by between 0.5% and 1.0% (Dunne 1982, Goodwin 1996, McCarthy 1997, Dowling and Colman 1998, Hansen and Huang 1997, Luk and Chung 1997, Hansen et al. 1998, Noland 1999, Noland and Cowart 2000, Barr 2000, Fulton et al 2000, Marshall 2000). Clearly, this is still a broad range, and results vary with assumptions, methodologies, locations, and other background information.

However, just because we can show that capacity increases induce demand, we still do not know the nature of demand changes. A complicating factor 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 have been 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 location to maintain approximate constancy in their commute durations, but not necessarily their distances.

Examining all travel, Levinson and Kumar (1995) do not show 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 requires more non-work travel on the part of workers, who in the era of the one-worker, two-adult household could off-load non-work activities on the homemaker. Third, mobility and the near universal presence of a car for each licensed driver has changed the ability to perform non-work 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 budget. The twenty-four hours in a day, along with constraints associated with daily maintenance activities (work, sleep, eating, etc.), provide an

upper limit on the possible amount of travel. While the potential for induced demand may be large, it is not unlimited. We approach this question, using the Nationwide Personal Transportation Survey (NPTS) and Federal Highway Administration (FHWA) data to measure changes and activity patterns by individual, controlling for network changes in each state. We use 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 develop 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 control 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 adopt 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 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 pose a set of 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 1990 individuals. 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 and areas of future research conclude the paper.

2. DATA

The database used in this analysis comes from the 1990/91 and 1995/96 Nationwide Personal Transportation Surveys (NPTS). These telephone interview surveys collected data on household demographics, income, vehicle availability, location and all trips made on the survey day. The survey for the 1990 NPTS 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. The 1990 NPTS data created difficulties deterring the origin and destination of trips. We assumed that all tripmakers begin and end their day at home. Due to some improbably high shopping times, we also excluded travelers with a daily shopping time greater than 420 minutes. All other assumptions are uniform across both the datasets.

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 were reported. The activity duration data is obtained by subtracting the destination time of a particular trip from the origin time of the next trip for the same individual. All the activity durations and travel times for an individual add up to the daily time budget of 1440 minutes. The activity duration for the final trip of an individual is obtained by subtracting the destination time of that particular trip from the origin time of the tripmaker’s first trip and

then adding 1440 minutes. Only those tripmakers whose daily time budget is equal to 1440 minutes have been considered for the study.

The highway data used in the formulation consists of roadway and state characteristics by state for the years 1990 and 1995. The data for vehicle miles traveled (VMT) and lane miles have been obtained from the Highway Statistics series published by the Federal Highway Administration for each roadway type (arterials, collectors and interstates) by urban and rural region. We also use data on the population, per capita income and cost per energy unit (million BTUs) of gasoline by state for all the 50 states for the years 1990 and 1995.

3. 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. The comparison of the results between 1990 and 1995 is shown by sex and work status in Table 1. To illustrate, the first row shows that the average female non-worker spent 1172 minutes at home, 42 minutes at shop, 166 minutes at other, and 60 minutes of travel per day.

The time spent at home decreased for non-workers, 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 recession in 1990 and 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, while increasing for male and female non-workers. Similarly, the time spent at other declined for workers while increasing for non-workers. Both are consistent with a strengthening economy in 1995, as workers choose to work more and non-workers 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.

	HOME			WORK			SHOP			OTHER			TRAVEL	
FEMALE														
Non-Worker														
1995	1172	(186)	*				42	(64)	*	166	(170)	*	60	(44)
1990	1220	(209)					35	(70)		127	(172)		58	(61)
Worker														
1995	944	(226)	*	313	(249)	*	25	(49)	*	93	(132)	*	65	(44)
1990	928	(357)		284	(357)		30	(69)		132	(191)		65	(64)
MALE														
Non-Worker														
1995	1171	(200)	*				30	(55)		177	(184)	*	62	(46)
1990	1222	(211)					29	(60)		130	(183)		59	(65)
Worker														
1995	900	(233)		365	(262)	*	15	(37)	*	90	(136)	*	70	(48)
1990	903	(360)		338	(367)		20	(59)		110	(189)		69	(71)

Note: * Denotes significance at 95% level by difference of means test between 1995 and 1990 results. Standard Deviations are in parenthesis

Table 1: Time Use Comparisons for 1990 and 1995 Data

To test whether these respective activity durations and travel times for the years 1990 and 1995 differ for each of the categories, a difference of means (t-test) is performed. 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).

4. HYPOTHESES

The time spent traveling is the price of pursuing an activity or good. Thus, individuals balance time at and travel to activities to maximize 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 1440 minutes as shown in Figure 1. The downward sloping time budget line, also acts as a fixed demand function. With an increase in supply (highway capacity) from S1 to S2, under a constrained demand function, the travel times T_{S1} reduce to T_{S2} due to higher speeds, leading to increase in Act_{S1} to Act_{S2}, time spent at activities. Since, satisfaction from pursuing activities increases, individuals maximize utility (U). Thus, highway expansion is expected to reduce total time traveling and induce more time spent at non-travel activities.

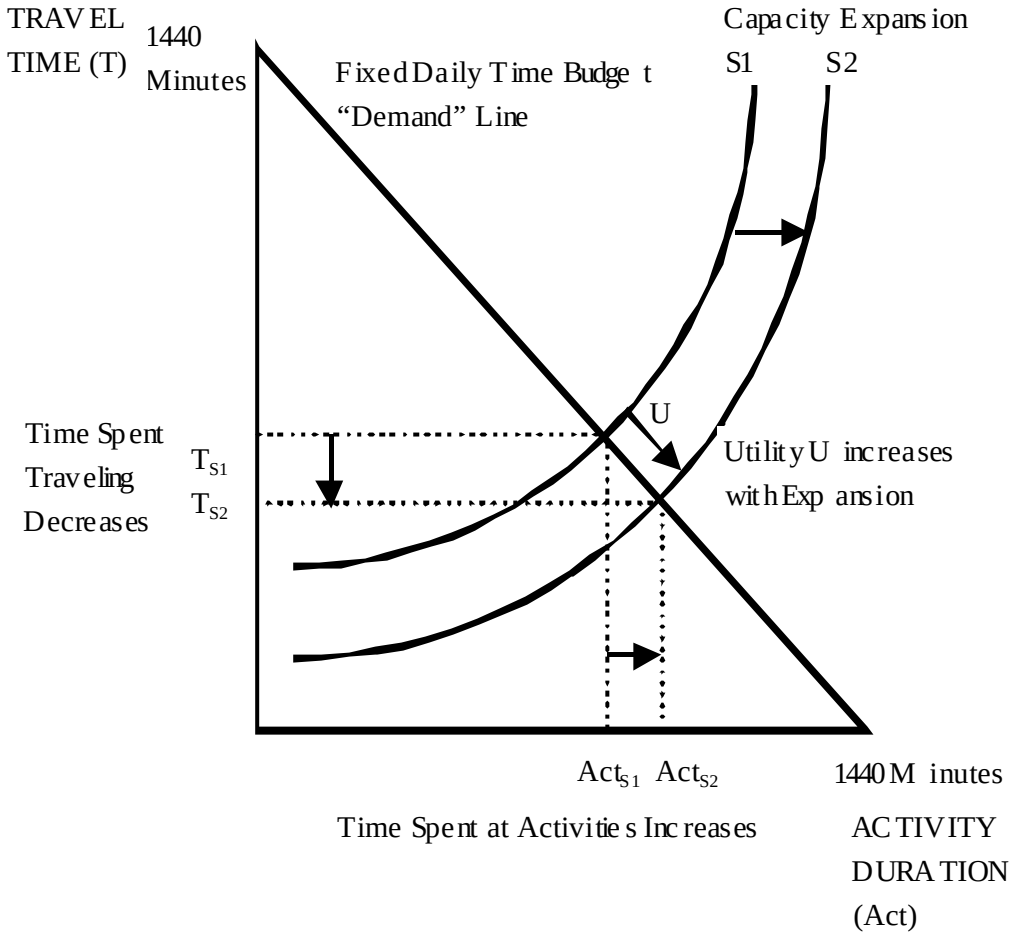

Figure 1: Daily Travel and Activity Time Production Function

Due to diverse activity and travel patterns by work status as evident from the travel time and activity duration analysis for the 1990 and 1995 travel data, we evaluate separate models for workers and non-workers. The total travel time to work and the time spent at work are zero for non workers, while they form a significant part of the daily time budget for a worker class, hence non-workers will use this time for travel or spending at other activities.

4.1 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 will go down, as drivers attain higher speeds and reliability, which enable individuals to travel longer distances in the same amount of time. Since work travel is something workers would prefer to avoid, we expect that every additional unit of highway capacity will decrease work trip travel times. With increased capacity and faster speeds, the time spent at work will decrease due to reduced peak spreading. Thus, workers will be able to arrive at their work place later in the morning and will leave earlier, closer to the peak, in the evening, no longer needing to escape the brunt of traffic congestion.

Travel 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. Most highway capacity expansion in faster growing suburban neighborhoods generates a faster network, enabling retailers to attain economies of scale with larger and fewer stores. So instead of many small stores, there are more new “big box” retail stores, which vend 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 also achieve economies of scale.

Travel to other, as with travel to work and 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. Since the nature of "other" activities for workers tends to be pleasure and entertainment oriented, the time spent at these activities will increase with highway capacity.

Since travel to home is the flip side of travel to work, it 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 for 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 hence they are “constrained” activities while home and other are pleasure maximizing “unconstrained” activities.

4.2 Non-Workers

In addition to the obvious difference regarding time spent at work, the major difference between the travel pattern of workers and non-workers is that non-workers spend more time at other activities (enabled by avoiding 300 minutes a day of work). This provides non-workers more time and flexibility to take additional trips than workers. The qualitative meaning of some activities differs for non-workers. In contrast to workers, for non-workers shopping is a much more recreational or "unconstrained" activity. On the other hand, other activities may be less discretionary for non-workers, 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 more of a “constrained” activity. Time savings in transportation may relax the peak spreading for other activities for non-workers as it did for work activities for workers.

As capacity increases, non-workers are expected to pursue more shopping related activities. Hence, the destination travel times for home and shop tend to increase with increasing capacity, while the travel time to other decreases due to travel time savings associated with attaining higher speeds. As with workers, time spent at home is a pleasure maximizing “unconstrained” activity and hence due to highway expansion the time spent at home is expected to increase.

5. 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 engage in a two-stage procedure whereby we first estimate a model of 1990 individuals, and then apply that model to 1995 individuals. This enables 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:

$$T_{90_i} = f\ (\text{A, D, G, H, L, M, S, W}) \quad (1)$$

Subject to:

$$\left(\sum_{i=1}^{8} T_{90_i}\right) = 1440 \quad (2)$$

where:

T_{90_i}	Time spent at activity "i"
i	Index of activities (travel 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

Dummy variables (0,1) have been employed for each of the characteristics. The variables are entered linearly into the model. The final model for T_{90_i} is estimated using Zellner's seemingly unrelated regression subjected to the daily time budget constraint of 1440 minutes. Seemingly unrelated regression estimation models (SURE) use asymptotically efficient, feasible generalized least squares estimation (Greene, 1997). The daily budget constraint makes the co-variance matrix of residual errors singular, which cannot be determined directly by SURE, so we drop one equation and estimate the other 7 equations simultaneously. The final dropped equation can then be calculated using the mathematical constraint equation, since 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 Table A1.

The equations for T_{90_i} for 1990 obtained from the first stage are 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 use $\hat{T}_{90i}$ to estimate a difference model of change in travel behavior between the 1995 individuals reported (or computed) 1995 activity times and their best estimate of 1990

behavior. We evaluate two different models (one for workers, one for non-workers) in the form given below

$$\Delta T_i = f\ (\Delta\ C/C_{90}\ ,\ \Delta\ F/F_{90}\ ,\ \Delta\ I/I_{90}\ ,\ \Delta\ P/P_{90}\ ,\ D_{95},\ G_{95},\ L_{95}) \quad (3)$$

Subject to:

$$\sum_{i=1}^{8}\ \Delta T_i = 0 \quad (4)$$

where:

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

'i' Index of activities

Δ C Difference in lane miles for all roadway types between 1995 and 1990

C_{90} Sum of lane miles for all roadway type in 1990

Δ F Difference in state average Fuel prices between 1995 and 1990

F_{90} State average Fuel price 1990

Δ I, Difference in state average per capita Income between 1995 and 1990

I_{90} State level per capita Income in 1990

Δ P, Difference in state Population between 1995 and 1990

P_{90} State Population in 1990

D_{95} Local population Density estimates in 1995

G_{95} Individual's sex in 1995

L_{95} Family Lifecycle characteristics in 1995

Since all the eight activities for each of years 1990 and 1995 are constrained by the individual daily time budget of 1440 minutes, their differences sum to zero minutes. A simultaneous seemingly unrelated regression estimation (SURE) is run on the above system of equations considering the ΔT_i (for each of eight activities (six for non-workers)) as dependent variables. Again, all variables are entered linearly. Since the system of equations forms a singular error variance matrix, one of the equations is dropped and a SURE model is run on 7 equations for workers (5 equations for non-workers) and the final dropped equation is obtained from the mathematical constraint. The full results are shown in Tables A2 for Workers and A3 for Non-Workers.

6. RESULTS

A summary of the final SURE results has been displayed in Table 2, which shows the elasticity of travel times and activity durations with respect to lane miles of capacity. The elasticity (η) of an independent variable ('*x*') with respect to its dependent variable ('*y*') is given by

$$\eta = \frac{dy/y}{dx/x} \quad (5)$$

To illustrate Table 2, 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. While the numbers may appear small, a one percent 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 3 are consistent with the underlying hypotheses for both workers and non-workers. The difference between worker and non-worker models is primarily due to the presence of an extra 300 minutes for non-workers to pursue more additional activities. It is found that non-workers, when given a faster network, prefer shopping while workers pursue other activities. This is due to the qualitative shift in behavior between shop and other for workers and non-workers which yields such travel and activity behavioral patterns. Thus it is important to model each category separately to determine its respective affect. Also, it is observed that with capacity expansion, individuals pursue more "unconstrained" activities (home and other for workers, home and shop for non-workers), which results in increasing their utility subject to a fixed time budget.

	Workers		Non-Workers	
Dependent variable:				
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	-	-
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	-	-
Shop	-3.44E-02 *	-.767	2.54E-02 *	1.19
Other	2.72E-03	.349	-2.83E-02 *	-3.95

Note: * Denotes Significance of the variable at 95% Level

Table 2: Elasticity of Time With Respect To Capacity

7. CONCLUSIONS

The research brings to fore how the travel times and activity durations are affected by increasing highway capacity using a simultaneous estimation difference model approach. It is observed that increases in highway capacity bring about small but 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. Non-workers choose to use the faster network both for activities at home and for shopping. Also, 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 stable. Furthermore, the effect on workers and non-workers are different. 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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Independent Variables	WORKERS								NON-WORKERS					
	TRAVEL TO				TIME AT				TRAVEL TO			TIME AT		
	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
POPULATION DENSITY														
(Persons per Square Mile)														
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
1000-1999	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
2000-2999	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
3000-3999	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
4000-4999	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
5000-7499	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
7500-9999	-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
10000-49999	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
50000+	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 $5000	-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
$5000-$9999	-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
$10000-$14999	-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
$15000-$19999	-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
$20000-$24999	-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
$25000-$29999	-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
$30000-$34999	-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
$35000-$39999	-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
$40000-$44999	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

$45000-$49999	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
$50000-$54999	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
$55000-$59999	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
$60000-$64999	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
$65000-$69999	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
$70000-$74999	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
$75000-$79999	-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
$80000+	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
LIFE-CYCLE														
(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	1023.01	41.81	82.25	134.38	55.96	10.77	33.67	1103.21	118.11	118.27

Table A1: Coefficients from Estimated Model of 1990 Time Use Behavior.

Independent Variables	TRAVEL TO HOME COEFF	t	WORK COEFF	t	SHOP COEFF	t	OTHER COEFF	t	TIME AT HOME COEFF	t	WORK COEFF	t	SHOP COEFF	t	OTHER COEFF
% 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
GASPRICES	-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
LIFE CYCLE															
(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
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
1000-1999	-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
3000-3999	-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
5000-7499	-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

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

Independent Variables	HOME COEFF	t	TRAVEL TO SHOP COEFF	t	OTHER COEFF	t	HOME COEFF	t	TIME AT SHOP COEFF	t	OTHER COEFF
% 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
GASPRICES	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
LIFE CYCLE											
(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
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
1000-1999	1.39	1.43	-1.91	-2.69	-0.71	-0.54	-50.09	-5.48	39.74	13.46	11.58
3000-3999	-5.20	-5.75	0.92	1.39	5.09	4.15	-60.48	-7.08	32.82	11.90	26.85
5000-7499	0.66	0.79	-0.23	-0.38	-0.76	-0.66	-40.22	-5.06	28.89	11.24	11.66
7500-9999	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

Table A3: Model for Change in Time Use Between 1990 and 1995 for Non-Workers