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Activity, Travel, and the Allocation of Time

David Levinson and Ajay Kumar

This paper analyzes 1968 and 1987-88 metropolitan Washington, DC household travel surveys to understand the daily allocation of time among different activities of individuals classified by work status and gender. The increase in female labor force participation rates has produced an increase in overall time spent at work per person. The increase in work trips and the simultaneous increase in non-work trips has resulted in less time spent at home. People are substituting money for time spent at home, buying household services outside the home. The group of individuals who work at home is analyzed separately to obtain an understanding of this growing segment.

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Significant socioeconomic changes have taken place in the past few decades, with far-reaching implications for travel behavior. In particular, since the end of World War II the participation rates for women and for men in the American labor force have steadily converged: male rates have declined somewhat, from 89 percent in 1948 to 78 percent in 1987, while in the same period rates for married women have increased from 20 percent to 60 percent (Schor 1991). The overall increase in the number of workers has meant higher per capita income and greater geographic mobility, but less disposable time, more travel, and more traffic congestion. Inevitably, to get the most out of every day, individuals try to substitute money for time. Facilitated by advances in technology and the emergence of new services and various labor saving devices, this substitution of money for time has implied complex adjustment patterns among travel and activities.

The study of these patterns of human activity has engaged researchers across disciplines. Recent work by transportation engineers and modelers includes the introduction of trip chaining, activity sequencing, and combined time-of-day and route choice into demand forecasting procedures (Clarke et al. 1981; Kitamura 1985; Recker, McNally, and Root 1989). Unfortunately, there has been less empirical work analyzing the long-term stability of activity patterns and their placement in a broader economic context. Transportation researchers have noted that, over time, nonwork trips have been increasing to over one-half the total number of trips by adults (Gordon, Kumar, and Richardson 1988; Pisarski 1992). Pioneering work quantifying the use of time has been conducted by Szalai (1972) internationally, Robinson (1977) in the United States, and Michelson (1985) in Canada. Meanwhile, sociologists have examined the impact of rising female participation in the labor force on the quality of life and changing roles of time at work and leisure (de Grazia 1962; Schor 1991); planners have studied the allocation of time by activity and by location, for demographic and socioeconomic classes (Chapin and Hightower 1965, Chapin 1968, 1974)¹; and economists have developed a theory of

the allocation of time proposing that individuals or households combine time and market goods to produce "commodities" (Becker 1965).

This study of activity patterns analyzed household travel surveys from the Washington, DC metropolitan region over a twenty-year period (1968–1988). The purpose of the research is to learn more about trends in activity patterns, in order to improve the theoretical basis of travel forecasts as well as to explain the significant rise in travel over the past twenty years (Levinson and Kumar 1994a). In addition, better understanding of behavior as related to work status will give insight into the changes in travel patterns associated with the rise in at-home work. The household data collected by one agency in a consistent fashion over twenty years provide an excellent opportunity to analyze the changes in activity patterns and evaluate the implications of substitutability for travel behavior.

With the increase in the number of working women, travel for work activities has risen proportionately. However, the concomitant increase in household income and the necessity to purchase elsewhere the substitutes for activities previously performed at home have produced a disproportionate rise in trips to other, nonwork, activities. Within the total daily time limit of 1440 minutes, continuous tradeoffs among activities and between household members enable adaptation to changes in technology and socioeconomic characteristics. For example, one tradeoff that is converging, but has not yet arrived at an equal balance, occurs between the roles played by each gender in work and nonwork activities. The data used in the study show that, overall, daily trips per adult have increased by one fourth, from 3.1 to 3.9, over the twenty-year period, resulting in growth of traffic volumes faster than that of the population. However, an implication of our analysis is that, with rates for female labor force participation near saturation, the disproportionate rate of growth for traffic volume should be nearing its end.

We observe two manifestations of complex adjustment patterns: a significant increase in the linking of work and nonwork trips; and a marked shift in the peak for nonwork trips over the twenty-year study period to coincide with the afternoon peak of work trips. This latter travel pattern reinforces the finding of an increase in trip chaining, where workers combine work and nonwork activities on their commute home, to accommodate various needs.

The article examines the connections among demographic and socioeconomic characteristics, the allocation of time, and the results for travel demand. The next section discusses the theory of "Rational Allocators," who as individuals and collectively as house-

hold members decide on time-money tradeoffs to strike a balance between increasing income and dwindling discretionary time. A brief review of national income trends is presented. There follows a review of the household travel survey data used in this study. Next is an examination of the changes from 1968 to 1988 in time allocation, trip frequency, and number of activities by gender and work status (nonworker, outside the home worker, at-home worker). Regressions are performed to quantify the factors affecting time allocation in 1988 for home, shopping, and other activities. The paper concludes by discussing the influence of changing technology, which should facilitate working at home at least some of the time, on time allocation and travel demand.

The Rational Allocator

A central argument of this paper is that the changes in time allocation decisions due to rising female participation in the labor force and rising per capita income over the past twenty years can be understood in Simon's (1955) framework of bounded rationality. Boundedly rational decisionmaking seeks an acceptable solution rather than an optimal one. Constrained by imperfect information about the product to be gained, individuals and households decide, on the basis of financial and temporal considerations, what to do, when and where to undertake the activity, and which family member will perform the activity. An analogy can be drawn between what Chinitz (1991) referred to as "Locators" (households, firms, and individuals), who shape urban spatial patterns in an environment of constrained land, and individual or household "Allocators," who shape temporal activity patterns within the confines of the day or week. The Allocators spend a budget of time and money to produce household commodities that maximize the economist's "utility function" (Becker 1965), or the biologist's "fitness function." While the effective household money budget increases as more household members work, an Allocator's discretionary time shrinks. Thus, the recent reports of a rise in nonwork trips, with their focus on travel patterns, tell only part of the story.

Two interrelated factors have given fresh force to substitutability: an increase in the rate of female participation in the labor force has made time a scarce commodity for a household; and the resulting increase in per capita and household income has made it possible to substitute money for time and to pursue more expensive activities (e.g., health clubs and outside entertainment). Technological advances that made possible various labor-saving devices have further fueled this process of substitution. Porter (1990) has de-

scribed the de-integration of services from households: "Many households can afford to hire someone to perform services they once performed themselves. The need for convenience and time saving is also forcing choices to allow someone else to perform many services. For example, single parents and dual-career families buy services they are no longer able to perform." Functions that had traditionally been internal to the household (e.g., child-rearing and cooking) have since the 1968 survey been more and more frequently purchased outside the home (e.g., at day care centers and restaurants).

The increase in nonwork trips can thus be seen as a complex set of adjustments, among different activities and among household members, in response to changes in both the female share of the work force and household income. The growth in nonwork trips over the past few decades is not a case of more of the same, but rather of different behavior patterns. This distinction is essential for understanding the emerging travel patterns and their implications for the future.

National Income Trends

Because of data limitations, this study was not able to evaluate directly the effect of income on individual activity decisions. Table 1, developed from the Economic Report of the President (1990), shows broad national trends for income per worker by gender, per household, and per capita, in 1988 dollars for the years 1970 and 1988. In constant dollars, income per full-time year-round worker, and per male worker has declined, but it has increased for females, and more females are employed. Thus, family income has increased by 6.5%, and per capita income has increased by 28%. Considering other phenomena such as rising geographic mobility, the increasing quality of goods and services, and increasing square footage of the average single-family home, it seems clear that as a group, Americans have become wealthier.

Region of Study

The authors selected metropolitan Washington, DC as a case study because of their familiarity with the region and because of the region's dynamic nature. Data for metropolitan Washington and Montgomery County, Maryland show large changes over the twenty years, 1968-1988: (a) population in the region increased from 3.0 million to 3.9 million persons (30 percent growth); (b) at-place employment increased from 1.5 million to 2.8 million jobs (85 percent growth); (c) from 1970 to 1990, the average household size dropped from 3.34 to 2.67; (d) vehicle registrations (including passenger cars, vans, and light trucks) rose by 118 percent; (e) autos per household increased

from 1.6 to 2.0, while autos per person increased from 0.48 to 0.73 during this period; (f) road capacity as measured in lane miles of state roads in the county increased by only 13 percent (from 1,062 to 1,199 miles); (g) annual vehicle miles of travel in the county increased by 133 percent (from 1.6 to 3.8 billion miles) (Levinson and Kumar 1994b).

Data

The principal data source for this study consists of the detailed household travel surveys conducted by the Metropolitan Washington Council of Governments (MWCOG) for 1968 and 1987-88.² The 1968 survey consists of a sample of over 23,000 households, making 150,000 trips; the 1987-88 sample contains 7,400 households and 55,000 trips. Each household was assigned a specific 24-hour "travel day," and data were collected on all trips made by members of that household on that day. For this study, only adults aged 18-65 were considered. A trip was defined as one-way travel from one address to another. The locations of the origin and destination of each trip were reported, along with the specific times the trip started and ended. Activity duration was computed by subtracting the arrival time on one trip from the departure time of the next trip. The time at home at the end of the day was calculated from the final arrival time and the initial departure time. The MWCOG data also reported trip purpose at both origin and destination end, making it possible to identify trips more specifically by accounting for trip chaining (which is defined as travel to a nonwork sojourn on the way to/from work activity). Table 2 shows the breakdown by gender and work status and the sample size for each of the two surveys.

The travel questions in the 1968 MWCOG survey were similar to those in 1987/88, permitting a direct comparison. Besides trip data, the survey collected information about certain household and personal characteristics (e.g., age, sex, vehicle ownership, household size). However, because the definition of traffic zones in the Washington metropolitan region changed over the 20-year period, a direct, detailed, spatially specific comparison was precluded. This paper examines travel and activity durations and activity frequencies and sequences. The authors are aware that the 1968 survey explicitly excluded nonmotorized nonwork trips, and so the reporting of workers' mid-day trips is problematic. We thus expect a somewhat lower nonwork trip frequency for workers in the 1968 survey than if such trips had been reported. For the same reason, the actual time at work should be higher and the actual time at other activities slightly lower than is reported for 1968. While this limitation is disappoint-

TABLE 1. National income and labor force participation

Year	Income by Category (1988 dollars)					Labor Force Participation Rates	
	Workers (Year-Round, Full-Time) Male	Workers (Year-Round, Full-Time) Female	per Worker	per Family	per Capita	Male	Female
1970	28,002	16,586	24,100	30,084	9,679	80.1%	41.6%
1988	27,342	18,545	23,559	32,191	14,116	76.2%	56.6%

Source: *Economic Report of the President* (1990), Tables C-27, C-30, C-36.

TABLE 2. Gender and work status statistics for the study sample: 1968 and 1988

	Year	Work outside home		Work at Home		Nonworkers		Total
		Male	Female	Male	Female	Male	Female	
Sample size	1968	16,085	8,283	673	174	3,188	8,555	36,958
	1988	4356	3,660	104	434	639	1157	10,350
Percentage of Sample	1968	44%	22%	2%	0%	9%	23%	100%
	1988	42%	35%	1%	4%	6%	11%	100%

ing, we believe the data are still very rich and worth analyzing.

Changes in Activity Duration and Frequency: 1968–1988

To examine the complex adjustments and the differential division of labor between men and women over the twenty-year study period, three parameters are identified: duration, frequency, and frequency distribution. Table 3 shows *Activity Duration* over the course of the day for persons between the ages of 18 and 65, cross-classified by work status (worker outside home, worker at home, and nonworker) and gender for each of four destination activities (home, work, shop, and other, including serve passenger, school, personal business, recreation, eating out, etc.), for 1968 and 1988. Table 4 shows average *Activity Frequency* (the average number of times an activity is pursued during a day) for the same stratification classes as defined above. By the definitions used here, a worker who goes to work and then goes home is listed with one work destination activity and one home destination activity. In analysis of trip frequency, trips with either end at work traditionally are defined as work trips, and trips with neither end at work as nonwork. Home-based work trips are a third definition, covering only trips with one end at home and one end at work. For our purposes, the number of work trips (as opposed to work activities) is twice the number of work-end destinations. Table 5 shows the *Activity Frequency Distribution*, the percentage of individuals making 0, 1, 2, and 3+ trips for each activity, in the three work classes, for 1968 and for 1988. The following sections discuss each

of the three travel parameters for the different activity types: Work, Home, Shop, Other, and Travel.

Work

This section examines the broad changes between 1968 and 1988 in time spent at work, which are due primarily to the growth in female participation in the labor force. The data here are not accurate enough to study detailed trends, such as might be found in a study of weekly employment hours per worker (Schor 1991). The change over time in work trip frequency at both household and individual level is of particular concern in transportation modeling because of its focus on travel demand forecasting. In a study of trip generation rates in the Delaware Valley (Philadelphia) Region between 1960 and 1988, Walker and Peng (1992) found home-based work trip rates to be stable when controlling for household size (as a result of compensating changes in household size and labor-force participation rates), but nonwork trip rates were temporally unstable, even after controlling for income, automobile ownership, and household size. Purvis (1995) reports a slight increase in work trips per household between 1965 and 1990 for the San Francisco area, but an overall decrease in daily nonwork trips. Table 3 shows that male and female workers each spent about 20 minutes less time at the workplace in 1988 than they did in 1968. The additional 70 minutes of working time for women, overall, is clearly a result of their increasing participation in the labor force. Tables 4 and 5 show that over the study period, the number of trips with work as the destination has risen for both genders.

TABLE 3. Mean activity durations per day, in minutes, for 1968 and 1988, adults 18–65

ActivityYear	Work outside home				Work at home				Nonworkers				All persons				Total	Households			
	Male		Female		Male		Female		Male		Female		Male		Female			Mean	Std. Dev.	Mean	Std. Dev.
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.					
Home 1968	820	196	865	187	1178	220	1245	187	1132	246	1225	178	886	240	1033	255	961	260	2114	1394	
1988	799	215	823	211	1163	299	1205	265	1104	323	1132	306	844	256	924	283	885	274	1808	1073	
	***		***				*		***		***		***		***		***		***		
Work 1968	486	183	459	160	0		0		0		0		396	251	243	256	321	265	538	415	
1988	466	204	441	189	0		0		0		0		400	246	311	254	354	253	563	431	
	***		***		N/A		N/A		N/A		N/A				***		***		***		
Shop 1968	7	23	10	32	19	44	45	71	24	64	50	88	10	34	30	60	19	49	39	87	
1988	10	57	15	55	43	116	48	99	34	107	55	142	14	68	26	88	20	78	41	129	
	***		***		*				**				***		***		***		***		
Other 1968	43	98	28	75	172	191	95	164	210	223	98	148	72	140	63	117	66	130	162	365	
1988	64	135	67	136	166	193	126	188	216	244	170	199	82	161	90	161	86	161	202	401	
	***		***				***				***		***		***		***		***		
Travel 1968	85	51	79	49	70	60	55	42	75	65	67	53	76	53	72	50	72	53	146	113	
1988	101	125	93	106	67	106	62	155	86	166	83	130	100	131	89	117	95	123	173	200	
	***		***				***		***		***		***		***		***		***		
Total 1968	1440		1440		1440		1440		1440		1440		1440		1440		1440		2999	1726	
1988	1440		1440		1440		1440		1440		1440		1440		1440		1440		2787	1494	

Note: *Difference of Means statistically significant at 0.10 probability level
 **Difference of Means statistically significant at 0.05 probability level
 ***Difference of Means statistically significant at 0.01 probability level
 (See note 4.)
 Numbers in bold indicate differences > 10 percent.

TABLE 4. Mean activity frequencies for 1968 and 1988, adults 18–65

ActivityYear	Work outside home				Work at home				Nonworkers				All persons				Total	Households			
	Male		Female		Male		Female		Male		Female		Male		Female			Mean	Std. Dev.	Mean	Std. Dev.
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.					
Home 1968	1.38	0.62	1.29	0.56	1.24	0.62	1.33	0.65	1.46	0.85	1.47	0.87	1.39	0.65	1.37	0.71	1.38	0.68	2.85	2.18	
1988	1.33	0.60	1.34	0.61	1.60	0.77	1.57	0.83	1.50	0.78	1.57	0.85	1.36	0.63	1.42	0.70	1.39	0.67	2.75	1.96	
	***		***		***		***				***								***		
Work 1968	1.00	0.46	1.00	0.37	0.00		0.00		0.00		0.00		0.83	0.57	0.51	0.56	0.68	0.59	1.15	0.91	
1988	1.31	0.91	1.21	0.72	0.00		0.00		0.00		0.00		1.14	1.03	0.85	0.81	0.99	0.94	1.57	1.44	
	***		***		N/A		N/A		N/A		N/A		***		***		***		***		
Shop 1968	0.19	0.49	0.21	0.52	0.36	0.66	0.69	0.69	0.50	0.91	0.87	0.97	0.24	0.57	0.52	0.83	0.38	0.72	0.78	1.36	
1988	0.22	0.56	0.31	0.63	0.75	0.97	0.89	1.02	0.59	0.99	0.88	1.09	0.29	0.66	0.49	0.83	0.39	0.76	0.78	1.26	
	***		***		***		***		***		***		***		***		***		***		
Other 1968	0.48	1.13	0.39	0.77	1.30	1.47	0.88	1.05	1.23	1.58	1.08	1.40	0.65	1.24	0.71	1.09	0.69	1.17	1.64	2.58	
1988	0.86	1.28	1.00	1.29	1.76	1.46	1.69	1.54	1.78	1.45	1.91	1.71	1.00	1.34	1.25	1.46	1.12	1.41	2.35	2.81	
	***		***		***		***		***		***		***		***		***		***		
Travel 1968	3.05	1.83	2.89	1.54	2.90	1.96	2.84	1.71	3.19	2.41	3.42	2.32	3.11	1.90	3.11	1.89	3.13	1.90	6.42	5.30	
1988	3.72	2.08	3.86	2.03	4.11	2.22	4.15	2.34	3.87	2.17	4.36	2.59	3.79	2.10	3.71	2.21	3.89	2.16	7.45	5.42	
	***		***		***		***		***		***		***		***		***		***		

Note: *Difference of Means statistically significant at 0.10 probability level
 **Difference of Means statistically significant at 0.05 probability level
 ***Difference of Means statistically significant at 0.01 probability level
 (See note 4.)
 Numbers in bold indicate differences > 10 percent.

TABLE 5. Activity frequency distribution: percent of persons with 0 to 3+ activities per day, in 1968 and 1988, by work status, adults 18-65

Activity	Work Status	1968				1988			
		0	1	2	3+	0	1	2	3+
Home	Work outside home	0%	71%	25%	5%	0%	73%	24%	3%
	Work at home	0	82	15	4	0	64	29	7
	Nonworker	0	68	22	10	0	65	29	6
Work	Work outside home	8	92	0	0	6	72	16	6
	Work at home	100	0	0	0	93	5	1	1
	Nonworker	100	0	0	0	99	1	0	0
Shop	Work outside home	84	14	2	1	79	16	3	1
	Work at home	66	29	4	1	48	34	12	6
	Nonworker	46	38	11	5	52	28	12	7
Other	Work outside home	79	13	4	3	60	25	10	5
	Work at home	34	43	14	9	36	38	16	11
	Nonworker	46	36	12	7	35	34	17	14

Note: Percentages may not add to 100% because of rounding.

Home

This section examines the hypothesis that, with increases in household income and in female labor force participation rates, less time is spent on activities at home, and the additional income is used to buy the same activities outside the home, in 1988 as compared to 1968. The change is expected to be more marked for women. Table 3 shows that in 1988 working men spent about 20 minutes less and working women spent about 40 minutes less at home than they had in 1968. While this loss of time at home appears small (less than five percent), its total impact is more pronounced. With the growth in the work force's share of women, a 40-minute decrease in time at home for working women became an average loss of more than 100 minutes of time at home for all women. Moreover, considering that some minimum time at home is necessary for basic human needs such as sleeping, cleaning, dressing, and eating, the decrease actually represents a much higher percentage of the available discretionary time. The average daily activity frequency (number of trips with home as a destination) and frequency distribution (percentage of individuals making multiple trips to home) of workers and nonworkers is not very different between 1968 and 1988 (first row in tables 3, 4, and 5). However, over the period, both male and female at-home workers spent less time at home, and by 1988 twice the number than in 1968 made multiple trips to home.

Shopping

It is generally supposed that with a rise in per capita income, the average person will spend more time

shopping and make more shopping trips. Further, with suburban shopping malls ubiquitous, one might expect that people are now more likely to shop as the need arises, in contrast to former times, when one would wait until a long list had accumulated to go shopping downtown. However, an interesting point emerges from an analysis of shopping activity duration (row 3 in table 3); while workers and nonworkers of both genders spent more time shopping in 1988 than in 1968, on average the time devoted to shopping in 1988 has remained the same as in 1968 for both individuals and households. These points may appear self-contradictory: classified by work status, people spend more time shopping, while, on aggregate, shopping time remains the same for 1968 and 1988. The explanation, once again, is the increase in the rate of female labor force participation and a decline in female nonworkers over the period. In 1968, working women shopped only 10 minutes per day, while nonworking women shopped 50 minutes. Thus, over the years, although in each category shopping activity duration as well as frequency has increased, on the whole, the quantity of shopping activity has remained the same for individuals and for households. In the process, though women still shop more than men do, men have partly taken over that task. Although there are statistically significant differences due to the large sample size, the overall stability in individual and in household time dedicated to daily shopping shows that it is an obligatory activity performed at the household level, rather than a discretionary activity that can easily be put off in the face of mounting peak-period congestion.

The convergence in gender roles clearly stands out from the change in shopping activity duration and frequency for persons working at home. While shopping activity duration for females working at home has increased by about five percent (from 45 to 48 minutes), the corresponding time for men has more than doubled (from 19 to 43 minutes). An interesting finding is that persons who work at home have the highest rates of shopping trips per person, 0.75 for males who work at home versus 0.59 for nonworking males and 0.22 for males working outside the home. Similarly, females who work at home have a shopping trip rate (0.89) higher than that for those working outside the home (0.31), but it is almost the same as that for nonworkers (0.88). At-home workers may assume more household chores if they have working spouses, and be more similar to nonworkers in this respect. In addition, nonwork activities (shopping and other) may substitute for workplace social contacts. Alternatively, this higher level of shopping trips may be a natural consequence of home-based business. Each business shopping need must be satisfied as it arises in order to maintain productivity, rather than waiting, as is often the case for household needs, until a shopping list builds up.

Other

Activities in the "other" category include school, serve passenger, personal trips for business or recreation, eating out, visiting friends. A breakdown of these categories is shown in table 6; it should be noted, however, that the surveys were not sufficient to provide additional detail. The nature of "other" is rather broad, so that while the duration for each kind of activity (personal business, visiting, etc.) may remain unchanged, the frequency of each component may change. School trips are a small share of this category (less than 5 percent), as the data is reported only for adults in the working age group. However, over this period the activity of serve passenger (pick-up or drop-off) has more than tripled for workers, the rate per person rising from 0.07 to 0.24. As with shopping, it is generally believed that individuals and households whose incomes rise will spend more time in the activities listed here as "other." Quantifying the rise of this nonwork travel has become more important, because developing effective traffic mitigation policies and environmental enforcement standards to regulate it is difficult.

Analyses of tables 3, 4, and 5 reveal the following: (a) men, for each category, but not overall, spend more time in the activities designated "other" than do women, but the difference has been declining over the years; (b) time spent at other activities has increased

TABLE 6. Breakdown of other activities

Activity	Year	Mean Frequency	Mean Duration
Pick-up/Drop-off	1968	0.01	2
	1988	0.27	6
School	1968	0.04	10
	1988	0.08	14
Unspecified	1968	0.55	55
	1988	0.76	64
Total	1968	0.67	66
	1988	1.12	86

by almost 40 to 50 percent for both working and nonworking men and women; (c) workers, because they have limited discretionary time, spend less time per other activity than do nonworkers, and make about half as many trips; (d) over the twenty years the time spent per activity has shortened; (e) the share of workers making at least one trip to other activities rose from 21 percent to 40 percent over the period; for nonworkers the rise was from 54 percent to 65 percent. For at-home workers, however, this number was flat, declining only from 66 percent to 64 percent.

In short, unlike shopping, "other" activities show an increase from 1968 to 1988 for both genders, for workers and nonworkers, and at both the individual and household levels. As discussed earlier, the increase in trips for other activities over the twenty-year study period does not represent more of the same, but rather a change in the nature of activities pursued. A number of activities performed at home in 1968 were pursued outside the home by 1988, and most of such trips get categorized as "other" trips. Parenthetically, this suggests that future data collection efforts should perhaps be directed towards weekend and off-peak travel, to obtain information about nonwork trips.

Travel

As activities paid for outside the home replaced a number of activities traditionally performed at home, inevitably more trips were made.³ However, travel did not increase proportionally to the increase in the number of activities, primarily because trip linking increased. Table 3 shows an increase in daily travel time for working men of 26 minutes (from 85 to 101 minutes), and for working women of 14 minutes (from 79 to 93 minutes). These data do not support the "Travel Time Budget Hypothesis," discussed by Zahavi (1974) and others (Zahavi and Ryan 1980; Zahavi and Talvittie 1980; Chumak and Braaksma 1981), which proposes that individuals spend a fixed amount of time per day (just over one hour) in transportation,

and make all budget allocation adjustment on non-travel times. Other researchers (Prendergast and Williams 1981; Tanner 1981) have disputed the underlying theory of a travel time budget, echoing Becker's argument that tradeoffs are made between travel time, other time, and expenditures for the full gamut of activities depending on relative price and income changes and the valuation of time. In fact, the data presented in this paper show that average time spent in travel per person per day has increased from 1968 to 1988 by about 14 minutes for workers and 11 minutes for nonworkers. But before the notion of a travel time budget, or at least tendency, is dismissed entirely, it should be noted that national data compiled by the authors (Levinson and Kumar 1995a) shows that between 1954 and 1990, time spent traveling by the average American adult remains unchanged.

In metropolitan Washington, suburbanization trends for both households and firms have maintained essentially constant commuting times at about 30 minutes each way (Levinson and Kumar, 1994b). The persistent stability in travel times for work trips is shown by the fact that it exists despite large demographic and economic shifts, and in association with much greater traffic volume relative to network capacity. In other words, the well-documented increase in travel and congestion is due primarily to more workers being on the road and more nonwork trips being made per person, rather than to trips of longer duration.

Factors Affecting Activity Duration

The determinants of time spent in travel or activities have been studied extensively (Allaman, Tardiff, and Dunbar 1982; Schor 1991). Here we examine the factors affecting time spent at home, at shopping, and at other activities in 1988. This is not offered as a comprehensive predictive or forecasting model, which would be significantly more sophisticated in structure. The independent variables (demographics, mobility, dwelling type, and work status) were tested to help quantify the effects they have on predicting the activity durations of adults for home, shopping, and other activities. Unfortunately, however, no income variable was available with the 1987/88 Household Travel Survey. Also, no regression was performed to analyze time at work, as the workday is largely fixed and depends primarily on whether one is a full-time or part-time worker. Time in travel is principally a function of spatial and network variables rather than demographics. Table 7 presents the independent variables and the results of the ordinary least squares regressions.

The results for the regression to predict time spent at home came out largely as expected. Mobility (whether the individual is a licensed driver and the

number of vehicles in the household) is negatively correlated with time spent at home, as is having a job outside the home. Having children or being the spouse (generally female) of the head of household is correlated with time at home, as is working at home. Surprisingly, gender does not have a statistically significant effect. Owning a single family home, which is taken as a surrogate for both life-cycle stage and income, is also correlated with time at home. Those with children spend more time at home; they tend to be older, which increases the likelihood that their income level will enable them to buy a house, in contrast to the stereotypical single "twenty-something" living in an apartment.

The other two regressions, explaining time spent shopping and at other activities, are much weaker in explanatory value, because while an individual is home almost every day for a significant period, shopping and other activities are much less regular, particularly from day to day. The regression to predict time spent shopping supports the finding that weekday shopping is largely obligatory at the household level. Number of children, mobility, and dwelling unit type are not statistically significant. The results for gender came out as expected: males shop less, the usually female spouses of the household head shop more. In addition, nonhome workers shop less than nonworkers or at-home workers do. The last regression, to estimate duration of other activities, is more difficult to discern. Workers spend less time at "other" activities; parents spend more, due to pick-up and drop-off trips. Mobility is positively associated with time at "other" activities. Being male and being the spouse of a household head are negatively associated. Being male is probably correlated with being a worker in this respect: while men of each work category spend more time in other activities, more women are in the non-worker category, and hence women are associated with spending time at "other" activities, which is consistent with the overall results.

Implications of Changes in Activity Patterns

With increases in activities pursued outside home and in travel time, it is instructive to analyze the changes in travel behavior to accommodate complex travel patterns. Two trends are identified in this research: an increase in trip linking (or chaining), and a shift in the distributional pattern for travel time of day.

Trip Chaining

This section, following the lead of earlier research (Levinson and Kumar 1995b) evaluates changes in the amount of trip chaining between 1968 and 1988 as a

TABLE 7. Factors affecting time spent at activities: results of OLS regressions

Independent Variables	Dependent Variables: Time Spent at		
	Home	Shop	Other
Male [0, 1]	-5.9 (-1.0)	-4.3 (-2.3)**	-24.1 (-6.8)***
Married to the head of the household [0, 1]	48.7 (7.6)***	5.7 (2.8)***	-40.9 (-10.3)***
Number of children less than 16 years old [N]	9.2 (3.4)***	0.5 (0.6)	6.0 (3.6)***
Work outside the home [0, 1]	-262.9 (-44.2)***	-30.8 (-16.1)***	-62.9 (-17.0)***
Work at home [0, 1]	37.6 (8.5)***	0.1 (0.04)	-44.9 (-6.3)***
Lives in single family home [0, 1]	10.5 (1.7)*	-0.1 (-0.06)	-1.5 (-0.4)
Licensed driver [0, 1]	-9.1 (-2.5)**	1.6 (1.4)	-2.1 (0.9)
Number of vehicles in the household [N]	-4.0 (-2.9)***	-0.0 (-.04)	3.9 (4.5)***
Constant [1]	1056.0 (113.1)***	41.8 (13.9)***	100.7 (17.3)***
R-squared	0.23	0.04	0.04
F-Statistic	421.90	51.70	50.25
(Significance F)	(0.0)	(0.0)	(0.0)
N	11079	11079	11079

Note: *statistically significant at 0.10 probability level

**statistically significant at 0.05 probability level

***statistically significant at 0.01 probability level

Number in parentheses indicates t-statistic.

manifestation of the changes in activity durations. Here, a trip chain during the morning peak period is defined as a connected sequence of trips with home as the origin and work as the ultimate destination, with stops for nonwork activities along the way. Thus, on a morning trip from home to work in which the worker first stopped at a day care center to drop off children, the trip chain would consist of two trips: from home to drop-off at the day care center and from the day care center to the place of work. Similarly, during the afternoon peak period, the trip chain consists of the workplace as the origin and home as the ultimate destination, with stops on the way.

In 1988, 85 percent of home-to-work trips were unlinked. The balance, 15 percent of the trips, involved stopping on the way for nonwork purposes, either once (12.4 percent) or twice (2.2 percent). No more than two stops were reported during the morning work trip. A much smaller percentage of trips were unlinked work-to-home trips during the afternoon peak period (69 percent). The remaining 31 percent involved one stop (21.1 percent), two stops (6.7 percent), or three or more stops (3.1 percent). In sharp contrast to 1988, in 1968 only 1.5 percent of home-to-

work trips were linked (excluding pick-up of carpool passengers). On the work-to-home trip, 9 percent of trips were linked in 1968, of which shopping constituted 3.5 percent.

Trip Peaking

Numerous models have attempted to relate departure time and congestion (Hendrickson and Planck 1984; Alfa 1986; Ben-Akiva, Da Palma, and Kanaroglou 1986; Arnott, de Palma, and Lindsey 1990; Mahmassani and Stephan 1991; Allen 1992; Hatcher and Mahmassani 1992; Loudon, Ruiter, and Schlappi 1992). Few, if any, have analyzed the temporal stability of departure time choice in the broader context of activity patterns. Figures 1 and 2 display the changes in time-of-day distribution for all work and all nonwork trips, respectively, by auto. (All nonwork trips are added together for convenience of analysis). Trips by transit constituted less than 5 percent of all trips during both 1968 and 1988, and were performed primarily during the peak periods. Because of the change in the nature of transit brought about by the introduction of Metrorail, only the diurnal curves for auto are shown.

In figure 1, the peaking pattern of daily home-based work trips shows that work trips were much more sharply peaked in the peak hours of 7:00–8:00 a.m. and 4:00–5:00 p.m. in 1968 than in those hours in 1988. Over 42 percent of trips to work were made in the peak hour in 1968, compared to only 35 percent in 1988. Two factors explain this: congestion and complexity. Congestion increased over the past twenty years in most corridors; only a fraction of commuters with the opportunity to commute at different times have chosen to do so. Complexity is introduced in the schedules of working parents as they alternate child-rearing and homemaking responsibilities with work, resulting in linking work with nonwork (pick-up/drop-off, shopping) activities. Complexity is further manifested by the spreading out of work-trip departure times; in metropolitan DC, the growth of flex-time in the federal government as well as the increased flexibility of office jobs—in contradistinction to manufacturing jobs—has facilitated this trend. Off-peak commuting was spread throughout more of the day in 1988, probably as a result of the rise in part-time work as compared with 1968.

Figure 2 shows the time-of-day distribution for all nonwork activities (shopping, serve passenger, school, etc.) for all household members, not just adults. Consistent with the finding of increased trip chaining, more nonwork trips took place in the morning and afternoon peak periods in 1988 than in 1968. The peak hour for nonwork trips moved two hours earlier, from 7:00–8:00 p.m. in 1968 to 5:00–6:00 p.m. in 1988. These changes, required by the increased complexity of households' daily routines, produce a variety of activity sequences and are accompanied by the prevalence of multi-vehicle households. In 1968, many nonwork auto errands waited until the primary worker returned home with the household car.

Conclusion

This paper provides evidence about changing activity patterns over a twenty-year period by examining the constraints imposed by an activity time budget. With the rise in female participation in the labor force over this period, the time spent at work by the average adult has increased; thus households have more income but less nonwork time in which to spend it. Rational allocation of time and money replaces some nonwork activities' consumption of time with expenditures of money (day care, eating-out, recreation). The overall effects are less time spent at home, more trips, and more congestion. Mobility has become ubiquitous; in 1988 vehicle ownership approached one per licensed driver. A 25 percent increase in trips per person over the study period is traced to the increase

in female participation in the labor force and the consequent shift of household activities to outside the home. With male and female rates of participation in the labor force now nearly equal, the number of trips is not expected to grow at the same rate in the future, and a better balance between population growth and trips can be expected.

Chaining trips became more common during the study period, as individuals tried to accomplish more activities in less time and avoid adding trips. The peak also spread; with rising mobility, nonwork trips are undertaken earlier in the day, often on the journey to or from work. Distinctions between gender roles remain, though not as strong in 1988 as in 1968. Overall, we conclude that weekday shopping is obligatory rather than discretionary, as revealed by the constancy of household and individual shopping durations despite rising congestion and shrinking discretionary time. Time spent outside the home increased between 1968 and 1988 for both workers and nonworkers. Interestingly, nonworkers make more trips than workers do, but spend less time in travel because their trips are shorter.

How transferable are the findings of this study of metropolitan DC to other cities in the country? While a specific answer is difficult without detailed data on other cities, the available evidence suggests that individual behavior does not differ much across the country (Levinson and Kumar 1994c). The increased female participation in the labor force and the rise in per capita and household income are observed in most areas of the country, though to different degrees. Therefore the tendency to rationalize activity patterns in the manner that we have observed in metropolitan Washington is expected to prevail elsewhere, though the magnitude of the change may vary.

In anticipation of its future importance to travel, the behavior of individuals who work at home was explicitly examined in this research. Individuals who work at home spend more time at home than nonworkers do. However, though they thus spend less time outside the home, they make more (albeit shorter) trips. The typical at-home worker also travels a half-hour less per day than the typical worker does. Several factors suggest that work at home, telecommuting, and teleshopping may be on the verge of wide-spread adoption. The technology is coming into place with the long-awaited advent of videophones, and of the "information superhighway," that is, broadband two-way communications facilitated by the recent consolidations in the telecommunications and entertainment industries. Some predict an imminent trend of "nesting" or "cocooning," as an aging population spends more time at home (Popcorn 1991).

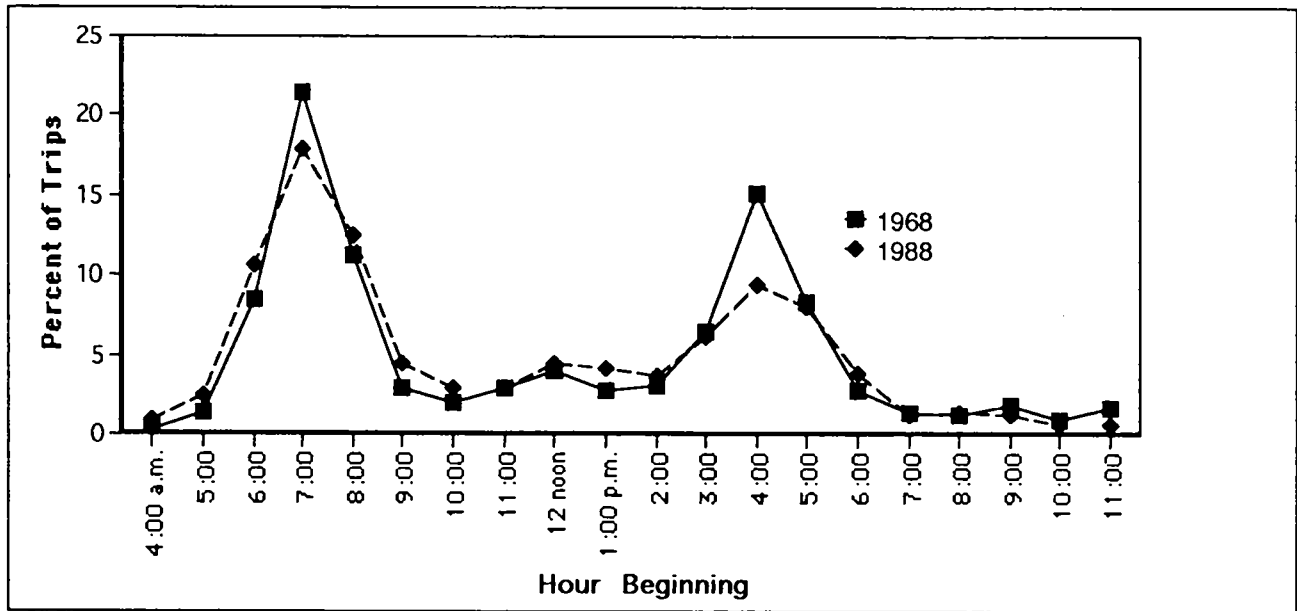


FIGURE 1. Distribution of work trips by auto, by time of day, 1968-1988

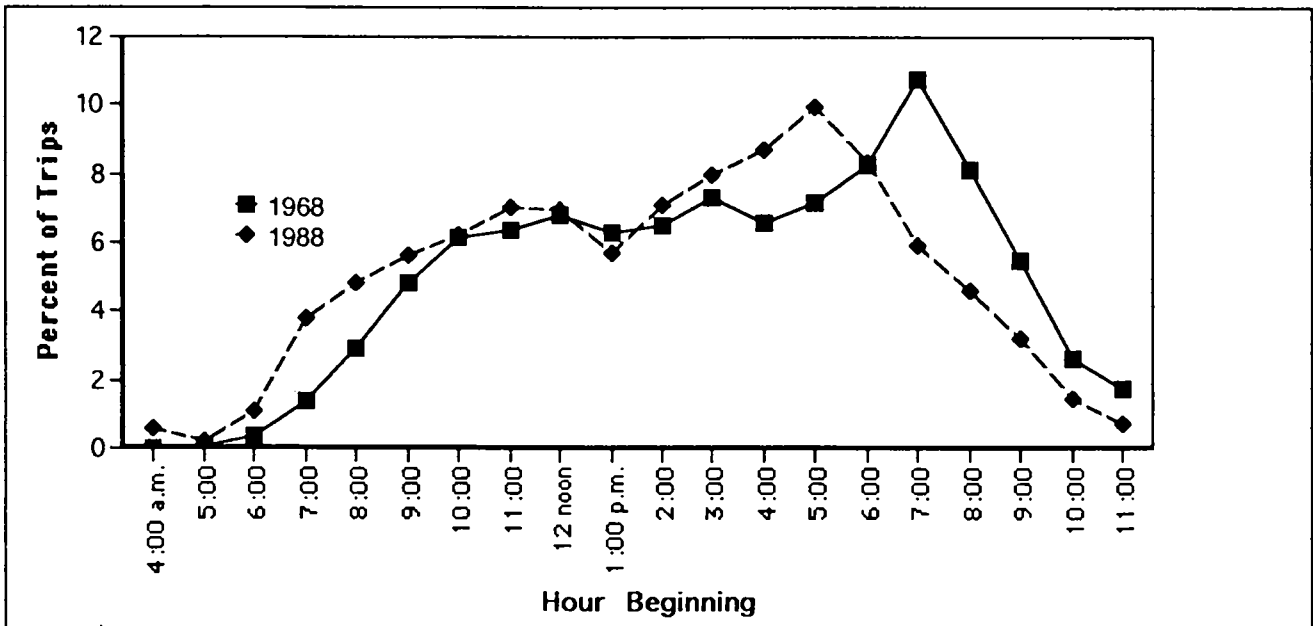


FIGURE 2. Distribution of nonwork trips by auto, by time of day, 1968-1988

Perhaps more significantly, there has been a decline in the size of the average business and a rise in networks of small businesses (Peters 1992). One possibility is that government policies can be changed to favor this sector. Whether or not work at home increases significantly will largely be a function of tech-

nological and social factors, but government policies also could help or hinder the trend. Nationally, subsidization of transportation, either auto or transit, clearly encourages more travel and less telecommuting. Locally, zoning that prohibits small businesses in residential neighborhoods is also likely to discourage

work at home, since one person working at home may need to add a worker or two before being able to open a formal office or store. Homes with offices need to be larger, and additions to existing homes can be aided or hindered by local codes. On the other hand, Mokhtarian has documented a large number of government agency programs to encourage telecommuting, either several days a week or essentially full-time (Mokhtarian 1991). Similarly, trip reduction ordinances can give credit for telecommuting; however, the rise in nonwork trips tends to vitiate the effect of these ordinances.

If the current at-home workers are typical of future trends (and if the changes over time are small compared with those that occur between work-status categories), less time per person will be spent in travel; however, commutes may get longer when they are not made daily. Household tasks such as child care and meal preparation may be more likely to be done at home if one household member is working at home; but as a substitute is sought for the interpersonal contact now received at work, more shopping and other activities may be undertaken outside the home. In this respect, at-home workers are more similar to today's nonworkers than to those who work outside home. Work at home may be viewed as the last wave of suburbanization: Where once homes and workplaces were located together or near each other in towns and cities, first the residences moved to the suburbs, then the stores did, and more recently the offices have. A consolidation of the workplace and the home will see the pattern come full circle, as the job-to-worker ratio again becomes one at the local level. Lower transportation costs are likely to be associated with increasingly suburban and exurban telecommuting households. The saving of time and money may enable other, yet unimagined, opportunities and substitutions.

AUTHORS' NOTES

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NOTES

1. In the late 1960s and early 1970s, Chapin (1974) undertook research on human activity patterns, recording what people do over the course of a day and a week. The surveys examined three aspects of household activity systems: (1) a time budget, (2) spatial patterns, and (3) some of the variables that are likely to alter activity patterns in time and space. An activity survey, such as those conducted by Chapin, may have a much more comprehensive classification scheme than is employed in this study; Chapin used 40 categories, detailing activities that are performed while at home (such as sleeping, eating, watching television).
 2. The weaknesses of household travel surveys are well known; in particular, short trips, walk trips, and trips for discretionary purposes are often not recorded.
 3. Because activities are more specific to the individual than are trip decisions, trip generation models should be activity-based. Such models should account for the fact that while gender roles were once significantly different, over recent time they have been converging as more women have entered the labor force. It also should be recognized that work trip rates are likely soon to reach a saturation level.
 4. The asterisks in table 3 present the results of a difference of means test to compare activity durations statistically between 1968 and 1988. The null hypothesis tested was that there is no difference in activity durations between the 1968 and the 1988 sample populations. The results show that, broadly, activity durations have changed, even after controlling for gender and work status, which indicates that more activities are occurring outside the home. This statistically significant change in the expected direction supports the hypothesis of money/time tradeoffs and is an indication of rising mobility and household income. (Details of the difference of means test are available from the author.)
- The asterisks in table 4 present the results of a difference of means test to compare mean activity frequency between 1968 and 1988. Again, the null hypothesis tested was that there is no difference between the populations from 1968 and from 1988. Again, we conclude that activity frequencies have increased by a statistically significant amount.

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