Comparing Women's and Men's Morning Commute Trip Chaining in Atlanta, Georgia, by Using Instrumented Vehicle Activity Data

Hainan Li, Randall Guensler, and Jennifer Ogle, *Georgia Institute of Technology*

Differences between women's and men's morning commute trip-chaining patterns are examined by using a subset of instrumented vehicle activity observations for 10 days of morning commute journeys made by 182 drivers from 138 households in Atlanta, Georgia. Morning commute trips that involve trip chaining are longer both in distance and in duration for both men and women compared with morning commutes without trip chaining. On the basis of analysis of the Atlanta data reported, overall gender differences in the morning commute trip-chaining patterns for men and women appear to exist. Men traveled a greater distance and spent more time in the morning commute than did women. Men stopped more frequently than women, and women tended to have shorter stop durations than did men. Some of the findings contradict previous research. It is not clear whether the differences reported here are specific to Atlanta, to the households involved in the sample, or perhaps to the specific time frame in which the analyses were undertaken. A larger sampling of the instrumented vehicle data (1 year of commute travel for 250+ households in the Commute Atlanta project) is currently being prepared to further assess these differences and to examine whether gender roles may be changing, at least in Atlanta.

Empirical evidence in previous research efforts indicates that a secondary role of the commute journey is to provide an opportunity to link nonwork travel with the commute itself (*1*). Commuting trips are becoming increasingly complex as workers incorporate personal, household, and child-care activities into their trips (*2*). Since women's participation in the labor force is at an all-time high, many working women fulfill household and family responsibilities as well as their work duties. Given the gender roles in many households, women's commute patterns are potentially different from men's and may be affected by a typically greater share of household and family responsibilities. These differences in commute behavior may also vary depending on their socioeconomic and life-cycle status. This study compares men's and women's morning commute trip-chaining patterns by using a subset of instrumented vehicle activity observations.

Literature Review

Previous research (*3–6*) indicates that women are more likely than men to trip-chain on the way to and from work. On the basis of the 1990 Nationwide Personal Transportation Survey (NPTS) data, Strathman and Dueker (*5*) found that women make stops on their way to and from work or during work 42% of the time, whereas men make stops 30% of the time. Wegmann and Jang (*7*) examined the trip-chaining behavior of workers and developed nine work-related trip-chaining patterns from the 1990 NPTS data. They found that women have a higher total number of trip-chaining activities per day than men. Yet they did not find significant differences in the amount of home-to-work trip chaining of men and women.

On the basis of the 1990 NTPS data, Strathman and Dueker (*5*) found that the trip purpose "other family/personal business" is the most heavily represented in chains that are made both to work and from work. Wegmann and Jang (*7*) compared activity types pursued by men and women during morning commute trip chaining. They found that family and personal business trips and school or church trips account for 60% to 70% of the morning commute trip-chaining activities. Men and women made a comparable number of work-related business trips, shopping trips, school or church trips, and trips to visit friends or relatives. In these studies, men made significantly more other social and recreation trips compared with women, and women made significantly more other family and personal business trips compared with men.

McGuckin and Murakami (*8*) compared the trend of trip-chaining patterns noted between 1995 and 2001 by using the 1995 NPTS and 2001 National Household Travel Survey (NHTS) data. Thus research identified a robust growth in trip chaining that occurred between 1995 and 2001, nearly all in the direction of home to work. Men increased their trip chaining more than women, and a robust amount of the increase was due to stops for coffee.

On the basis of trip purpose in the 2001 NHTS data, for workers who made stops on the way to work, the most common type of trip embedded in the home-to-work chain was a serve-passenger trip (33%), followed by family or personal business (16%) and stops for a meal or coffee (14%). In families in which both parents worked on weekdays, 61.3% of the trips to drop off a child were made by women compared with 38.7% made by men.

Gender effects on trip chaining may differ across households in different life-cycle stages. Strathman et al. (*9*) determined that certain household types contributed the largest amounts of peak-period trip-chaining behavior. Single adults with young children have the highest propensity to form complex trip chains on the way to and from work, followed by single adults with school-age children, dual-income couples without children, and dual-income couples with preschoolers. Working mothers are more likely to link trips than working fathers (and they are more likely to link trips when the children are younger). On the basis of 1982 and 1985 data from France, the Netherlands, and the United States, Rosenbloom (*4*) determined that 65% of working women with children under 6 years old linked trips to work, whereas only 42% of comparable men did.

From the literature review, it appears likely that a difference exists in commute trip-chaining behavior between men and women and among different household structures. In previous studies, women were more likely to trip-chain on the way to and from work compared with men, and women made more serve-passenger trip chains compared with men. Previous research results were mostly based on household travel surveys. However, one of the problems with household travel surveys is misreporting, as revealed in previous research (*10–14*).

Advancements in Global Positioning System (GPS) technology provide a new method for multiday data collection for travel diary studies and other transportation applications. On the basis of the summary by Pendyala (*15*), GPS technologies capture travel behavior better during a long period of time and eliminate the survey fatigue problem of the multiday travel diary survey. GPS-based travel data can capture short and infrequent trips that may not be obtained in a traditional travel diary survey. Yalamanchili et al. (*16*) compared the trip-chaining indications provided by the GPS data with those provided by the recall data. Results of their study show that the GPS-based data performed in a manner superior to the recall data in capturing multistop chains in that the former captured more than twice as many multistop chains as the latter when comparisons were made in the context of a 1-day travel period. On the basis of the GPS study carried out in the California statewide household travel survey, Zmud and Wolf (*14*) found, on an aggregated level, that travel survey data underreport 27.4% of trips compared with the GPS-measured data. Especially for short-duration trips (between 0 and 10 min), 70.9% of the trips captured by GPS technology were missed in the travel survey.

GPS-Based Vehicle Activity Studies

The data used in this study were taken from the Georgia Institute of Technology Commute Atlanta project. This project instrumented approximately 487 vehicles from 268 representative households in the 13-county Atlanta metropolitan area with event data recorders (EDRs). The EDR provides an accurate itinerary of vehicle trips, including those short, intermediate, and infrequent stops that would otherwise be missed with traditional travel diary data collection methods. The network of EDR-equipped vehicles logs more than 2 million vehicle-seconds of activity each day. The research team collected second-by-second speed and position data for more than 600,000 trips during the first 10 months of the project. The Commute Atlanta research included standard household sociodemographic interviews and the collection of standard 2-day travel diaries (via computer-assisted telephone interview methods) for the participating households (*17*).

Sample Summary

Ten days' worth of morning commute journeys for 182 drivers from 138 households make up the data subset

used for the analyses presented here. To meet the research goal of this study, only the 182 drivers whose gender information was known and who work full time at a fixed location and do not share their vehicle with another household member were included in the data subset. Significantly fewer lower-income households meet all of these conditions. The household recruitment strata used in the Commute Atlanta project and the subset of these households used in the analyses reported here are provided in Table 1. The recruitment process and study refusal rates are detailed elsewhere (*17*).

For the data subset employed in the gender-based analyses reported here, the average household size is 2.86 persons. The average age of the drivers is 43. Most of the drivers have resided at their current residence location for more than 3 years, indicating a good level of familiarity with their travel areas. The respondents are divided fairly equally between men and women, with 49.5% being men. Children less than 16 years of age are present in 52 households (70 commuters) and children 5 years or younger are present in 20 households (25 commuters). The ratio of workers per household is 1.45, which is comparable with 1.37 from the U.S. census data in 2000 for the Atlanta Metropolitan Statistical Area (MSA). Household vehicle ownership of the sample is higher than the average value in the 2000 census for the Atlanta MSA (2.37 vehicles per household compared with the 1.8 vehicles per household). This difference is expected since the objective of the project is to determine effects of by-the-mile congestion pricing on commute travel behavior, and only households that own vehicles were recruited.

At least 55% of the drivers have either undergraduate or postgraduate educations, and the median household income of the sample is between $75,000 and $99,000. Household income in the sample is significantly higher than the median household income of the Atlanta MSA ($51,948 in the 2000 census) because of higher-than-expected refusals and opt-outs of lower-income households and higher-than-expected retention of upper-income households (*17*). It may also be due to the fact that the commuters with white-collar occupations usually have a higher salary and a fixed working schedule, whereas commuters with blue-collar occupations who work in shifts may have commute schedules different from the traditional morning and afternoon peak periods. Hence household incomes for the commuters identified during the morning peak periods are higher than those of the overall working population. The net result, however, is that upper-income households and more educated individuals are overrepresented in the sample when compared with census demographic profiles of the Atlanta MSA population. Conclusions regarding behavior with demographics need to be restricted to each sample stratum in which sufficient data are available (see Table 1).

The home address of each household and the work address of each worker were geocoded. The series of trips in which the first trip starts at home, the last trip ends at the workplace, and all intermediate trips are included that take place during the morning commute period (weekdays from 5:00 to 10:00 a.m.) on a given day is considered a single morning journey to work. Because drivers may or may not turn off the car's engine when they stop, stops made during the morning commute were divided into two types. Engine-off stops take place when the driver turns off the engine during the stop; such trips are captured automatically in the data stream since one data file records activities between engine-on and engine-off stops. Occasionally, drivers will turn the engine on and off without moving and generate a false trip. These false trips were screened out from the data set. Engine-on stops take place when the driver does not turn off the engine during the stop; these stops are detected by a script that examines the travel trace in detail. An engine-on stop is detected if the vehicle's position falls outside of the 75-ft buffer of the road network and the vehicle speed is less than 5 mph for a duration longer than 1 min. A manual check of the detection results was tested against a set of sample trips. The algorithm detected the stops successfully under most situations. Figure 1 shows an example of one

TABLE 1 Household Recruitment Strata

Sampling Strata	Annual Income	Household Size	Vehicles per Household	Atlanta Population (percent)	Household Sample Target No.	Households Recruited (percent)	Households Used (percent)
0	Any	Any	0	7.4	0	0 (0%)	0 (0%)
1	<$30,000	Any	1+	18.4	35–40	20 (7.46%)	4 (2.90%)
2	$30,000–$75,000	1	1+	11.3	35–40	34 (12.69%)	17 (12.32%)
3	$30,000–$75,000	2+	1	6.8	35–40	18 (6.72%)	7 (5.07%)
4	$30,000–$75,000	2	2+	10.6	35–40	38 (14.18%)	13 (9.42%)
5	$30,000–$75,000	3+	2+	13.9	35–40	34 (12.69%)	14 (10.14%)
6	$75,000+	1	1+	2.8	0	5 (1.87%)	4 (2.9%)
7	$75,000–$100,000	2+	1+	12.1	35–40	41 (15.30%)	26 (18.84%)
8	$100,000+	2+	1+	16.8	35–40	73 (27.24%)	51 (36.96%)
99	Unknown	Any	Any	na	0	5 (1.87%)	2 (1.45%)
Total				100	280	268 (100%)	138 (100%)

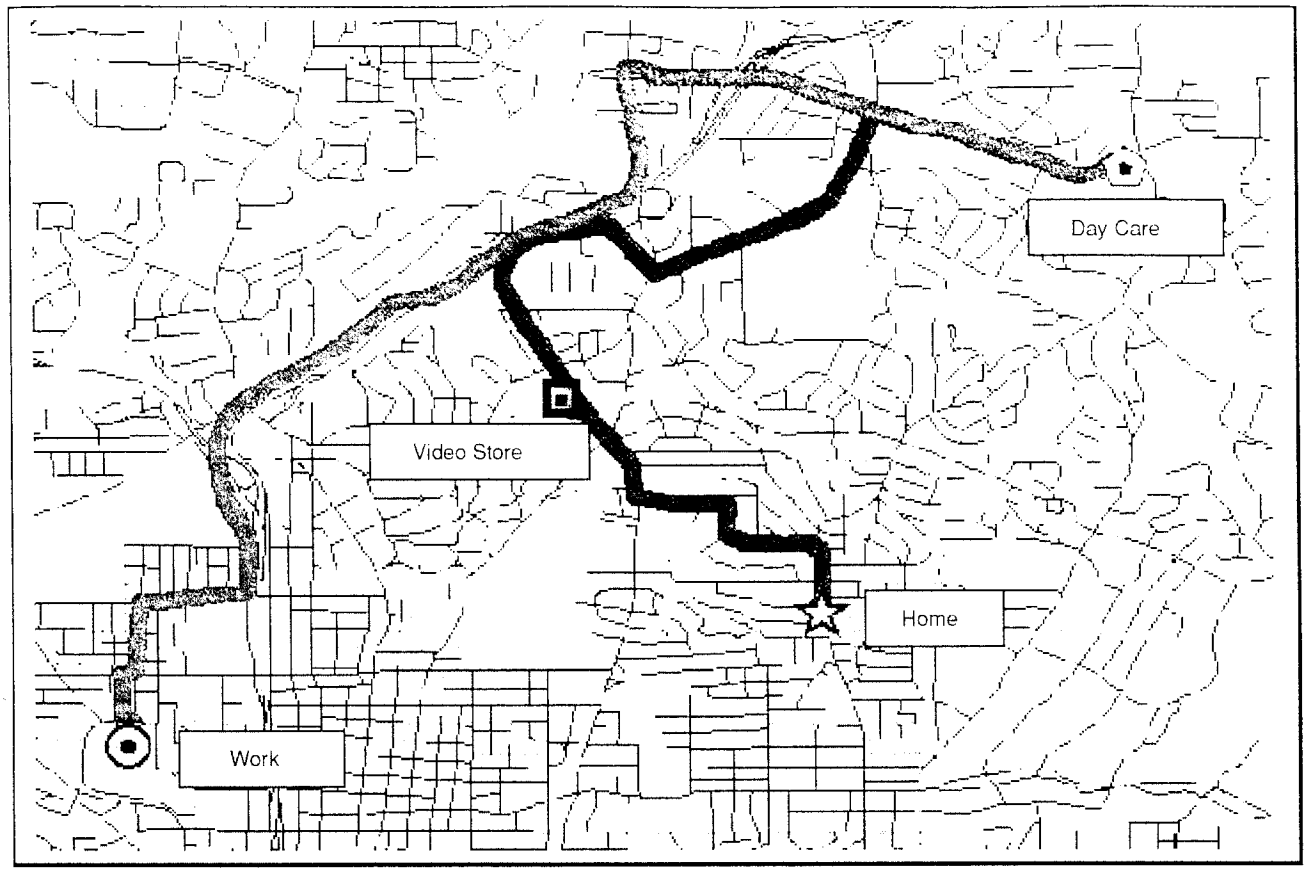

FIGURE 1 Morning commute: trip-chaining example.

engine-off stop (at a daycare center) and one engine-on stop (at a video store). Among the 1,820 commute journeys from 182 commuters during the 10-day period analyzed, a total of 722 vehicle stops were detected in the sample. Among them, 460 were engine-off stops and 262 were engine-on stops.

FINDINGS

Commute Time and Distance

Mean values of morning commute distance, travel time, and commute duration (stopping time plus travel time) of men and women in the sample are summarized in Table 2. The results of *t*-tests conducted to compare the mean values between men and women indicate that men traveled longer distances and spent more time in their morning commute than did women. This result is consistent with previous research results summarized by Sarmiento (*18*).

A previous study indicated that a large percentage of households' total travel is undertaken in conjunction with the journey to and from work and that the growth of nonwork vehicle trips made during the commute contributes to traffic congestion (*19*). Work trips with nonwork stops contribute to the vehicle miles and vehicle hours traveled in an urban area (*20*). In this study, *t*-tests of paired sample means (Table 3) indicate that for both men and women, commute journeys with trip chaining tend to be longer in distance than those with no chaining. However, trip chaining adds less distance to women's morning commutes than to men's.

TABLE 2 Gender Comparison of Average Commute Distance, Duration, and Travel Time

	Men	Women	Difference	*t*-Statistics	Significance (two-tailed)
Travel distance (miles)	16.42	14.77	1.65	3.143	0.002
Commute duration (minutes)	40.80	36.02	4.78	3.319	0.001
Travel time (minutes)	32.05	29.58	2.47	2.872	0.004

TABLE 3 Travel Distance Comparison of Commutes With and Without Trip Chaining

	With Trip Chaining	Without Trip Chaining	Difference	*t*-Statistics	Sig. (two-tailed)
Distance (miles)	18.19	16.33	−1.8618	−4.996	0.000
Distance (miles) (men)	19.56	17.18	−2.1669	−3.280	0.002
Distance (miles) (women)	16.72	15.42	−1.5568	−4.484	0.000

Stop Frequency

In the data subset, the research team detected slightly more stopping than was found in previous research. A total of 537 (30.5%) out of 1,820 morning commute journeys had one or more stops. Similarly, Hanson (*21*) found 29.4% of passenger vehicle trips having one or more stops between home and work. In a survey of 164 respondents, Mahmassani et al. (*22*) found that 24.3% of morning commute trips had one or more stops. On the basis of an empirical analysis with data from an activity survey conducted in the Boston metropolitan area and San Francisco Bay Area, Bhat and Singh (*23*) determined that 85.2% of the morning commute journeys had no stop, with the remaining 14.8% having one or more stops. Although commuting may be significantly different in Atlanta, GPS-based data collection methods may simply be more effective in capturing trip-chaining behavior.

The frequency of nonwork stops during the morning commute by gender is shown in Figure 2. Of the 1,820 commutes, 90 men made 900 commutes and 92 women made the remaining 920 commutes. Chi-square test results at the 0.05 level indicate that in the sample, men are more likely to make one or more stops than are women.

For each commuter, a stops ratio was calculated by dividing the number of commute journeys with stops by the total number of commute journeys for each driver. Among the 182 commuters, 50 never stopped, and the remaining 132 commuters (66 men and 66 women) stopped at least once during the 10-day period. Approximately one-third of the drivers stop during at least half of the commute journeys, and 5.49% of the drivers stop every day during their morning commute journey. These results indicate that making nonwork stops during the morning commute is a common phenomenon among a large percentage of commuters. The stops ratio during the morning commute grouped by gender is shown in Figure 3. Chi-square test results at the 0.05 level indicate that the men in the sample generally had a higher stop ratio than the women.

Stop Locations

In this study, stop locations were recorded in latitude and longitude format. For the 132 commuters (66 men and 66 women) who stopped at least once during the journey to work, the number of stop locations was compared across genders. If two stop locations were within 600 ft, they were considered to be the same. On average, men commuters stopped at an average of 3.05 locations compared with 2.86 for women. The *t*-test that assumes men and women have the same number of stop locations is not rejected at the 0.05 significance level.

If the stop locations are divided into two groups—routine locations, at which a commuter stopped at least twice during the 10-day commute period, and nonroutine locations, at which a commuter only stopped once during the 10-day commute period—77 out of the 132 commuters stopped at routine locations. The male commuters have an average of 0.89 routine stop locations compared with 0.92 for women. The *t*-test that assumes men and women have the same number of routine stop locations is not rejected at the 0.05 significance level.

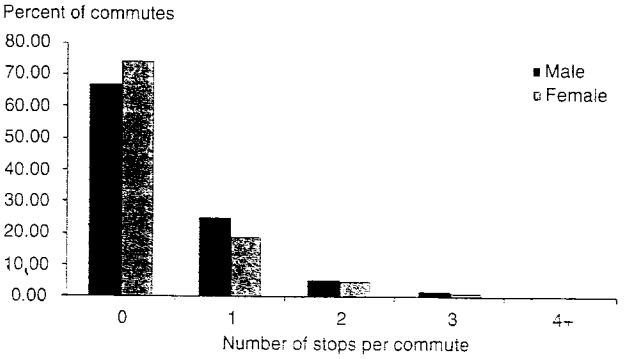

FIGURE 2 Morning commute: number of stops by gender.

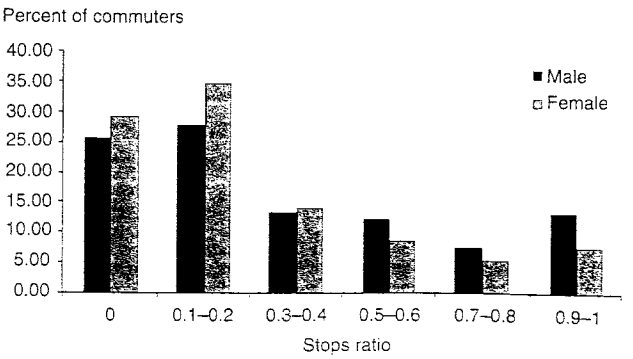

FIGURE 3 Morning commute: stops ratio by gender.

Stop Duration

Few previous studies examined trip-chaining stop durations. In this study, the median durations for engine-off stops are 315 s for women and 375 s for men. The median durations for engine-on stops are 146 s for women and 150 s for men. The stop duration distribution of men versus women is shown in Figure 4. Women tend to have shorter stop durations than men (finding significant at the 0.05 level by the chi-square test).

CONCLUSIONS

The research team conducted a cross-classification analysis of repeated behavioral data to examine the morning commute trip-chaining patterns for 182 men and women in Atlanta. This study employed a 10-day subset of on-road travel observations collected by GPS-equipped vehicles in the Commute Atlanta project.

On the basis of the sample in this study, the existence of nonwork stops during the morning commute is a common phenomenon for both men and women. Some significant gender differences in morning commute trip-chaining patterns were noted in this analysis. For example, men traveled longer distances and spent more time in their morning commute than did women. Men also made more stops and stopped for longer durations than did women in morning commutes. However, the number of stop locations did not differ significantly across genders.

Some of the research findings here contradict previous research results reported in the literature. Because the analytical results reported here are constrained to the household sample employed in the study (a higher presence of relatively affluent, car-owning households in the Atlanta commuting environment), it is not clear whether the differences identified also hold true for other sociodemographic groups and across regions. Hence, one should exercise caution in directly comparing the results in this paper with previous research results based on national travel surveys. However, it is also important to note that the Atlanta results did not rely on user-reported data but on revealed travel data collected by means of vehicle instrumentation. Hence, some of the differences may be associated with differences in underreporting of travel by men and women and the characteristics of the trips that go unreported. Additional research into the underreporting issue is currently under way in Atlanta through comparisons of instrumented vehicle data and travel diary data.

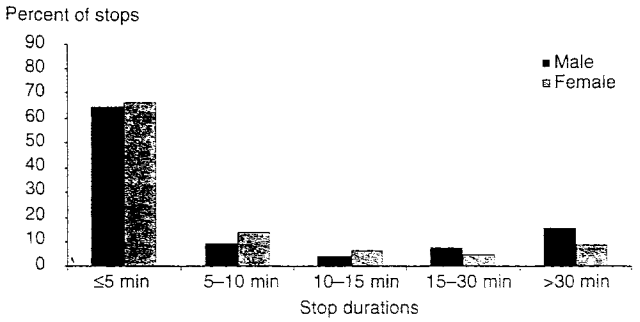

FIGURE 4 Stop duration (engine-on and engine-off stops combined) by gender.

Travel behavior of demographic groups is constrained by different circumstances. Working women, in particular, often face constraints arising from their multiple roles in the workplace and in the household. As the division of labor between men and women equalizes, corresponding changes in the division of household responsibilities should also occur. Although women continue to retain primary responsibility for housework, the gap may be narrowing over time. One important piece of information that is missing in this study is the trip purposes for trip-chaining stops. Until this information is collected in the household travel diary surveys and until the parcel-level land use database is integrated into the analysis, it will be difficult to further evaluate the division of household labor between genders with this sample. However, once the new data are available, it will be possible to examine whether the differences reported here are likely due to increased sharing of household and family responsibilities between men and women workers in the same household, at least in Atlanta.

A larger sampling of the instrumented vehicle data (1 year of commute travel for 250+ households in the Commute Atlanta project) is currently being prepared for more detailed analysis. More than 1 year's instrumented vehicle data have been collected in Atlanta. Such detailed commute data, over such a long period of time, have never been previously available to travel behavior researchers. As instrumented vehicle sampling programs become more pervasive and data are collected across multiple cities and in larger sociodemographic segments, the research community will be able to expand and improve the core body of knowledge associated with trip-chaining behavior significantly.

REFERENCES

1. Nishii, K., K. Kondo, and R. Kitamura. Empirical Analysis of Trip Chaining Behavior. In *Transportation Research Record 1203*, TRB, National Research Council, Washington, D.C., 1988, pp. 48–59.
2. Bianco, M., and C. Lawson. Trip Chaining, Childcare, and Personal Safety. In *Women's Travel Issues: Proceedings from the Second National Conference,*

October 1996, FHWA, U.S. Department of Transportation, 1997, pp. 124–142. http://www.fhwa.dot.gov/ohim/womens/wtipage.htm.

3. Rosenbloom, S. The Impact of Growing Children on Their Parents' Travel Behavior: A Comparative Analysis. In *Transportation Research Record 1135*, TRB, National Research Council, Washington, D.C., 1987, pp. 17–25.
4. Rosenbloom, S. Trip-Chain Behaviour: A Comparative and Cross-Cultural Analysis of the Travel Patterns of Working Mothers. In *Gender, Transport and Employment* (M. Grieco, L. Pickup, and R. Whipp, eds.), Gower Publishing Company, Aldershot, England, 1989.
5. Strathman, J., and K. Dueker. Understanding Trip Chaining. In *1990 NPTS Special Reports on Trip and Vehicle Attributes*, FHWA, U.S. Department of Transportation, 1995, pp. 1–27.
6. Al-Kazily, J., C. Barnes, and N. Coontz. Household Structure and Travel Behavior. In *1990 NPTS Demographic Special Reports*, FHWA, U.S. Department of Transportation, 1995.
7. Wegmann, F. J., and T. Y. Jang. Trip Linkage Patterns for Workers. *Journal of Transportation Engineering*, May-June 1998.
8. McGuckin, N., and E. Murakami. Examining Trip-Chaining Behavior: Comparison of Travel by Men and Women. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1693*, TRB, National Research Council, Washington, D.C., 1999, pp. 79–85.
9. Strathman, J. G., K. J. Dueker, and J. S. Davis. Congestion Management: Travel Behavior and the Use of Impact Fees. In *Effects of Household Structure and Selected Travel Characteristics on Trip Chaining*, Transportation Northwest (TransNow), Seattle, Wash., 1993, Vol. 1.
10. Willmot, C., and T. Adler. Item Nonresponse. In *Transport Survey Quality and Innovation* (P. Stopher and P. Jones, eds.), Elsevier, London, 2003, pp. 555–567.
11. Wolf, J., M. Loechl, M. Thompson, and C. Arce. Trip Rate Analysis in GPS-Enhanced Personal Travel Surveys. In *Transport Survey Quality and Innovation*, Elsevier, London, 2003, pp. 483–498.
12. Wolf, J., M. Oliveira, and M. Thompson. Impact of Underreporting on Mileage and Travel Time Estimates: Results from Global Positioning System–Enhanced Household Travel Survey. *In Transportation Research Record: Journal of the Transportation Research Board, No. 1854*, Transportation Research Board of the National Academies, Washington, D.C., 2003, pp. 189–198.
13. Zmud, J. P., and C. H. Arce. Item Nonresponse in Travel Surveys: Causes and Solutions. In *Transportation Research Circular E-C008: Transport Surveys: Raising the Standard*, TRB, National Research Council, Washington, D.C., 2000, pp. II-D/20–II-D/34.
14. Zmud, J., and J. Wolf. Identifying the Correlates of Trip Misreporting: Results from the California Statewide Household Travel Survey GPS Study. Presented at 10th International Conference on Travel Behavior Research, Lucerne, Aug. 10–15, 2003.
15. Pendyala, R. *Measuring Day-to-Day Variability in Travel Behavior Using GPS Data*. Final Report. FHWA, U.S. Department of Transportation, 1999.
16. Yalamanchili, L., R. M. Pendyala, N. Prabaharan, and P. Chakravarthy. Analysis of Global Positioning System–Based Data Collection Methods for Capturing Multistop Trip Chaining Behavior. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1660*, TRB, National Research Council, Washington, D.C., 1999, pp. 58–65.
17. Ogle, J., R. Guensler, and V. Elango. Commute Atlanta Value Pricing Program: Recruitment Methods and Travel Diary Response Rates. Presented at 83rd Annual Meeting of the Transportation Research Board, Washington, D.C., 2004.
18. Sarmiento, S. Household, Gender, and Travel. In *Women's Travel Issues: Proceedings from the Second National Conference*, October 1996, FHWA, U.S. Department of Transportation, 1997. http://www.fhwa.dot.gov/ohim/womens/wtipage.htm.
19. Strathman, J., and K. Dueker. Understanding Trip Chaining. In *NPTS Special Reports on Trip and Vehicle Attributes*, FHWA, U.S. Department of Transportation, 1990, pp. 1–7.
20 Mahmassani, H. Dynamics of Commuter Behaviour: Recent Research and Continuing Challenges. In *Understanding Travel Behaviour in an Era of Change* (P. Stopher and M. Lee-Gosselin, eds.), Elsevier, London, 1996, pp. 279–313.
21. Hanson, S. The Importance of the Multi-purpose Journey to Work in Urban Travel Behavior. *Transportation*, Vol. 9, 1980, pp. 229–248.
22. Mahmassani, H., G. Hatcher, and C. Caplice. Daily Variation of Trip Chaining, Scheduling, and Path Selection Behaviour of Work Commuters. In *Understanding Travel Behaviour in an Era of Change* (P. Stopher and M. Lee-Gosselin, eds.), Elsevier, London, 1996, pp. 351–379.
23. Bhat, C., and S. Singh. A Comprehensive Daily Activity-Travel Generation Model System for Workers. *Transportation Research*, Vol. 34A, 2000, pp. 1–22.