Transportation 14: 3–20 (1987)

ERRATUM, previously published in Transportation Vol. 13:2.

An examination of the determinants of day-to-day variability in individuals' urban travel behavior

ERIC I. PAS[1] & FRANK S. KOPPELMAN[2]

[1]*Civil and Environmental Engineering, Duke University, Durham, NC 27706;* [2]*Civil Engineering and Transportation, Northwestern University, Evanston, IL 60201, USA*

Abstract. Day-to-day variability in individuals' travel behavior (intrapersonal variability) has been recognized in conceptual discussions, yet the analysis and modeling of urban travel are typically based on a single day record of each individual's travel. This paper develops and examines hypotheses regarding the determinants of intrapersonal variability in urban travel behavior.

Two general hypotheses are formulated to describe the effects of motivations for travel and related behavior and of travel and related constraints on intrapersonal variability in weekday urban travel behavior. Specific hypotheses concerning the effect of various sociodemographic characteristics on intrapersonal variability are derived from these general hypotheses. These specific hypotheses are tested empirically in the context of daily trip frequency using a five-day record of travel in Reading, England.

The empirical results support the two general hypotheses. First, individuals who have fewer economic and role-related constraints have higher levels of intrapersonal variability in their daily trip frequency. Second, individuals who fulfil personal and household needs that do not require daily participation in out-of-home activities have higher levels of intrapersonal variability in their daily trip frequency.

1. Introduction

The analysis and modeling of urban travel behavior is typically undertaken using data for a single day for each individual or household in the sample, although it is generally accepted that individual or household travel behavior varies from day-to-day. An understanding of the day-to-day variability in person travel behavior is important to the design of transportation services as such variability affects daily peaking characteristics. Bonsall *et al.* (1984) observed hourly, daily, and monthly variations in traffic flows and pointed out that, in particular, the variation in daily peak profiles is not well understood. They discuss the importance of understanding day-to-day variability in traveler behavior in the design and assessment of traffic management schemes.

Daily variability in travel behavior may also influence the analysis of travel behavior. Pas (1986) shows that because of day-to-day variability in individuals' travel behavior, the use of multiday data in the estimation of linear regression trip generation models can be cost effective.

* copies of the corrected version of the paper are available from the author.

Most models and analyses of urban travel behavior focus on trying to explain variations in the travel behavior of different individuals (or households) in terms of the characteristics of those individuals and their environments. This component of variability in travel behavior we refer to as *interpersonal variability.* On the other hand, the travel behavior of a given individual varies from day-to-day. This component of variability in travel behavior we refer to as *intrapersonal variability.* Intrapersonal variability in urban travel behavior has received little attention in the literature, primarily because most data sets used for analyzing and modeling urban travel comprise information for just a single day for each sampled individual or household and thus preclude examination of intrapersonal variability.

Previous analyses of intrapersonal variability have yielded mixed results. Burnett (1977) and Golledge (1970) explain variability in shopping behavior and location choice as arising from a learning process. Marble & Bowlby (1968) found sample households to exhibit a considerable level of spatial stability in shopping behavior over a thirty-day period, while Shapcott & Steadman (1978) report finding a great deal of 'routinization' of weekday behavior in terms of the amounts of time spent on particular activities each day. Huff & Hanson (1985) conclude that individuals' travel-activity patterns are characterized by both repetition and variability. Bonsall *et al.* (1984) analyze data collected in license plate matching surveys and find evidence of substantial day-to-day variability in individual travel behavior.

This paper reports the results of an initial exploration of the factors affecting intrapersonal variability in weekday urban travel and related behavior. Two general hypotheses are formulated regarding the factors affecting intrapersonal variability in weekday urban travel and related behavior. These general hypotheses are used to develop a set of detailed hypotheses regarding differences in the intrapersonal variability of various sociodemographic groups. We test the specific hypotheses in the context of intrapersonal variability in daily trip frequency.

The remainder of this paper is organized as follows. In Section 2 we formulate the general and specific hypotheses examined in this study. In Section 3 we present the research design, including a description of the data set and the formulation of the statistical test used in this research. In Section 4, we present the results of empirical analyses of intrapersonal variability in trip frequency rates. In Section 5 we discuss the results of the empirical analyses and draw conclusions.

2. Behavioral hypotheses

Urban travel and related behavior is generally considered to be related to

desires which motivate this behavior, and the constraints within which this behavior takes places (Mitchell & Rapkin, 1954; Oi & Shuldiner, 1962; Chapin, 1968, 1974, 1978; Reichman, 1976; Heggie, 1978; Burnett & Hanson, 1979). Recent research has emphasized the constraints affecting travel behavior while earlier research focused on the motivations for travel. The concepts of motivations and constraints underlie many theories regarding the effect of various explanatory factors on the average daily travel behavior of individuals and households.

In this paper we argue that motivations and constraints affect not only average travel and related behavior but they also affect day-to-day variability in individual travel and related behavior. For example, employed people generally are required to make daily work trips, but employment restricts other trip making as it usually requires an individual to be at a particular place during a major portion of each weekday. Thus, employed people have less freedom than not employed people to undertake travel patterns that vary widely from day to day. We, therefore, expect employed people to have lower levels of intrapersonal variability on weekdays than their not employed counterparts.

Below, we formulate two general hypotheses regarding the effect of motivations and constraints on intrapersonal variability in urban travel and related behavior. We then derive a set of specific hypotheses which are amenable to empirical investigation.

2.1 General behavioral hypotheses

The demand for travel has long been recognized as a derived demand which is motivated by the need or desire for activity participation at spatially separated locations. These needs and desires are satisfied within the constraints which limit the travel opportunities of the individual or household. Thus, variation in individual daily travel behavior may result from variation in the needs and desires which the individual attempts to satisfy and be affected by the travel resources and time constraints which limit the individual's freedom to vary behavior from day-to-day.

Some needs and desires for activity participation require satisfaction less frequently than each day. For example, in societies where home refrigeration is commonly available, grocery shopping is typically not undertaken each day. Also, many recreational activities such as movie going and sports participation are undertaken on a weekly or less frequent basis. These considerations lead to the following general hypothesis.

Hypothesis GI: Individuals whose travel motivations include individual and household needs and desires that do not require daily travel will have higher

levels of intrapersonal variability than those persons who fulfill needs and desires that arise each day.

The constraints that affect intrapersonal variability in travel and related behavior fall into two distinct classes. First, there are constraints that arise because an individual's role(s) require him/her to be at specific places at particular times, typically to interact with other persons. These constraints, referred to as "coupling constraints" by Hagerstrand (1970, 1973), reduce the individual's 'flexibility' (Herz, 1983). For example, the members of a household typically eat together and this activity requires them to be at a given place at a specific time. For another example, workers generally spend pre-specified hours at their work place to interact with co-workers, suppliers, and customers. Second, there are constraints that are related to the resources that an individual has available for engaging in travel and related behavior. For example, an individual not having access to an automobile is constrained in his/her ability to participate in discretionary out of home activities.

We expect that those individuals more subject to coupling and resource constraints will have lower levels of intrapersonal variability in their travel and related behavior when compared with individuals who are relatively free of such constraints. This belief is described by the following hypothesis.

Hypothesis G2: Intrapersonal variability in travel and related behavior is inversely related to time restrictions which result from coupling constraints and to travel related resource constraints.

2.2 Specific hypotheses

Specific hypotheses regarding the impact of a variety of sociodemographic characteristics on the level of intrapersonal variability in travel and related behavior are derived from the two general behavioral hypotheses formulated above.

2.2.1 Employment status

We expect employment status to have considerable impact on intrapersonal variability because being employed substantially limits an individual's ability to vary his/her behavior from day to day. Consideration of work-related coupling constraints leads to the following hypothesis.

Hypothesis S1: Employed persons have substantially lower levels of intrapersonal variability than not employed persons.

2.2.2 *Social status*

Sociological research studies show that persons in higher social classes are more active and diverse in their participation in social and community organizations and leisure activities than those in lower social class positions (Reisman, 1954). Hodge & Treiman (1968) state that the positive association between membership in voluntary organizations and socioeconomic status is one of the best documented relationships in the sociological literature. In part, these findings can be explained by the fact that "...high status represents a convergence of many kinds of interests arising in part from higher education, more and varied contacts, and contacts arising from the demands of the occupational role" (Axelrod, 1956). Because most social and leisure activities are undertaken on an infrequent basis, we expect that higher social class individuals will exhibit more day-to-day variability than lower social class individuals.

Social class is commonly measured by occupational status, income and education. Thus, we formulate the following hypothesis.

Hypothesis S2: Intrapersonal variability in travel and related behavior is positively related to the occupational status of the household's head, the household's income, and the individual's level of education.

2.2.3 *Household roles*

Certain roles performed by individuals require them to be in specific places at particular times. Therefore, we hypothesize that those individuals more subject to household role-related coupling constraints have lower levels of intrapersonal variability in their daily travel and related behavior. On the other hand, some household roles require the individual to perform out-of-home activities on some days of the week. Thus, we expect individuals who fulfil such roles to have higher levels of variability in their daily travel and related behavior. The hypothesized effects of particular household role-related factors on intrapersonal variability are discussed below.

Marital status. Married people have less freedom to vary their travel behavior from day to day in comparison with single people, because they are subject to more household-related coupling constraints. Thus, we formulate the following hypothesis.

Hypothesis S3: Married people have lower levels of intrapersonal variability than single people.

Gender. As a result of traditional gender-related roles, women typically per-

form household maintenance tasks. These tasks, such as grocery shopping, are not necessarily performed each day. Our expectation concerning the effect of gender-related roles on intrapersonal variability is described by the following hypothesis.

Hypothesis S4: Women have higher levels of intrapersonal variability in their daily travel behavior than men.

We expect the effect of gender on intrapersonal variability to be somewhat different for single and married people because single people must undertake all household roles, independent of gender, while married people may specialize their role along traditional gender-based lines. Therefore, we expect gender has less effect on the intrapersonal variability of single people than of married people, and we investigate the effect of gender-related roles on intrapersonal variability separately for single and married people.

Presence of children. The presence of children in the household is expected to have two different impacts on intrapersonal variability in the travel and related behavior of the adult members of the household. First, adults living in households with children are likely to be subject to more household-related coupling constraints. On the other hand, we expect that the presence of children in the household will increase the likelihood of adult members undertaking irregular maintenance tasks to satisfy the children's needs. Because of these opposite effects, we formulate the following hypothesis.

Hypothesis S5: The presence of children in the household has little observable effect on intrapersonal variability in travel and related behavior.

However, because of socialized gender-linked roles, we expect that the presence of children in the household will have more impact on the travel and related behavior of females than males. Thus, we investigate the effect of the presence of children on intrapersonal variability separately for males and females.

2.2.4 Resource-related constraints

Those individuals having considerable travel and related resources are more able to vary their day-to-day travel and related behavior than those individuals having limited travel and related resources. Thus, we expect those individuals possessing higher levels of travel and related resources to have higher levels of intrapersonal variability in their travel and related behavior.

Car availability. Individuals having a car available to them have more ability

to vary their travel patterns from day to day. Thus, we formulate the following hypothesis.

Hypothesis S6: Individuals having access to an automobile have higher levels of intrapersonal variability in their travel and related behavior.

Income. Money is a resource that enables people to participate in out-of-home activities, particularly leisure-related activities. Furthermore, income is an indicator of social status, and we have noted earlier that people of high social status are more likely, than those of lower social status, to participate in both social and leisure activities. These considerations result in the formulation of the following hypothesis.

Hypothesis S7: Those individuals with higher income have higher levels of intrapersonal variability in their daily travel and related behavior.

3. Research design

In this section, we describe the data set used to examine the detailed hypotheses formulated above, the measure to characterize intrapersonal variability in trip frequency, and we outline the statistical procedure used to test the various hypotheses. Empirical examination of the specific hypotheses is used to infer confirmation or rejection of the general behavioral hypotheses, because the latter cannot be examined directly.

3.1 Data

The data used in this study were collected during the Reading Activity Diary Survey between January and March 1973 (Shapcott, 1978). The data were collected with a personal interview, a respondent-completed diary, and a short questionnaire. Respondents were asked to record each change of activity (both in and out of home), over a seven day period. Thus, the data include movements by all travel modes. The activity-based information was recoded into travel-activity information for the purposes of this related research. The recoding procedures were validated using the data collected in the Reading Travel Survey of 1971 (Downes & Wroot, 1974). The empirical results reported in this paper are based on a sample of 145 persons from the Reading Activity Diary Survey data set. For each person, the data used here are the daily trip frequency for five consecutive weekdays and individual and household sociodemographic characteristics.

3.2 Measure of intrapersonal variability in trip frequency

The examination of day-to-day variability in individual travel is, of necessity, based on some pre-selected measures of travel and travel related behavior. In this paper we investigate differences in intrapersonal variability in terms of daily trip generation rates. We measure intrapersonal variability for a given segment of the population by the mean intrapersonal variance in daily trip generation rates. This measure is defined as:

$$\bar{V} = \frac{1}{N} \sum_{i=1}^{N} \left[\frac{1}{N_D - 1} \sum_{j=1}^{N_D} (t_{ij} - \bar{t}_i)^2 \right] \tag{1}$$

where $\bar{V}$ = mean intrapersonal variance in trip generation rates for the given population segment,
t_{ij} = number of trips made by individual i on day j,
$\bar{t}_i$ = mean daily number of trips made by individual i,
N_D = number of days in the recording period, and
N = number of individuals in the population segment.

This measure is equivalent to the intrapersonal component of variance in the crossed-error model of Fuller & Battese (1974). A large value of the mean intrapersonal variance indicates a segment whose members have high levels of day-to-day variability in their daily trip generation rates.

3.3 Statistical test

We wish to test the null hypothesis that the mean intrapersonal variances [equation 1] in two population segments are equal. Define e_{ij} as the deviation of the number of trips made by individual i on day j from the mean number of trips made by individual i (i.e. $e_{ij} = t_{ij} - \bar{t}_i$). For each group we assume that the e_{ij} are independent and identically normally distributed with mean zero. The sum of the squared deviations in a group, normalized by the variance, is therefore chi-square distributed. Thus, the ratio of the sums of squared deviations in two groups, each normalized by the variance and the respective degrees of freedom, has the F distribution.

Under the null hypothesis, the group variances are equal; hence, the ratio of the mean intrapersonal variances [equation 1] in two population segments has the F distribution with $N_p (N_D - 1)$, $N_q (N_D - 1)$ degrees of freedom (where N_p and N_q are the segment sizes). Therefore, we can test the null hypothesis that the intrapersonal variances in two segments are equal by forming the ratio

of the mean intrapersonal variances in the segments, and comparing this ratio to the appropriate F value.

4. Empirical results

In this section we report the results of the empirical investigations of the hypotheses formulated in Section 2. We employ the travel-activity data set derived from the Reading Activity Diary Survey of 1973 to examine intrapersonal variability in daily trip generation rates.

The mean and standard deviation in daily trip generation rates, as well as the decomposition of the variance into interpersonal and intrapersonal variance, are reported in Table 1. These results are reported for the overall sample, as well as for the employed and not employed segments separately. The results reported in Table 1 show that intrapersonal variability comprises a substantial proportion of the total variability in daily trip generation rates, in the overall sample as well as in the employed and not employed segments. These results also show that intrapersonal variability is much larger in the not employed segment than in the employed segment. Below, we test the specific hypotheses, concerning differences in intrapersonal variability, which were formulated in Section 2.2.

4.1 Effect of employment status

Employment status is expected to have a major effect on intrapersonal variability in travel and related behavior. Furthermore, employment status is highly correlated with other sociodemographic variables examined in this study.

Table 1. Mean and variance in daily trip generation rates.

Group (Size)	Mean Daily Trip Rate (Std. Dev.)	Components of variance		
		Interpersonal variance	Intrapersonal variance	Interpersonal var. / Total Var.
Overall Sample (145)	3.58 (2.09)	1.95	2.44	0.44
Employed Segment (96)	3.93 (1.98)	1.88	2.03	0.48
Not Employed Segment (49)	2.88 (2.16)	1.29	3.38	0.28

Thus, we first test whether employed people have lower levels of intrapersonal variability than not employed people (Hypothesis S1), and then hypotheses S2 to S7 are examined in the employed and not employed groups separately.

The mean intrapersonal variances and segment sizes for the employed and not employed segments are given in Table 1. The test statistic, 1.67, exceeds the critical value of the F distribution with 196 and 384 degrees of freedom at the .01 level. Therefore, we reject the null hypothesis that the mean level of intrapersonal variability is the same for employed and not employed people. Below, we examine differences in intrapersonal variability between particular subsegments of the employed and not employed groups.

4.2 Employed segment

Table 2 displays the results of the analyses of differences in intrapersonal variability in daily trip frequency for specific sub-segments of the employed group, corresponding to the hypotheses formulated earlier. Table 2 reports the size of each sub-segment, the mean intrapersonal variance in daily trip frequency in each sub-segment, the variance ratio, the degrees of freedom, and the probability that the null hypothesis (of equal mean intrapersonal variances in the subsegments) should not be rejected.

The results in Table 2 show that within the employed group, social class (occupational status, household income, and education level) and resource availability (household income and car availability) generally do not have statistically significant effects on the level of intrapersonal variability in daily trip frequency. A major exception being the difference between the highest and lowest occupational status groups. Similarly, the results in Table 2 show that marital status does not have a statistically significant effect on the level of intrapersonal variability in daily trip frequency. Although the null hypothesis of equal mean levels of intrapersonal variability is not rejected in these cases, the results reported in Table 2 are consistent with the hypotheses formulated earlier. For example, single people are more variable in their daily trip frequency than married people (Hypothesis S3), and intrapersonal variability increases with the occupational status of the household head (Hypothesis S2).

The results reported in Table 2 also show that within the employed group, household role-related variables have statistically significant effects on intrapersonal variability in daily trip frequency. That is, as hypothesized, married females are found to have significantly higher levels of intrapersonal variability than married males (Hypothesis S4), even when both are employed.

In Section 2, we hypothesized that the presence of children in the household has two opposite effects on intrapersonal variability in travel and related behavior, and that therefore we did not expect to find differences in intrapersonal

variability between those people with and without children in the household (Hypothesis S5). However, the results in Table 2 show that within the employed group, married females with children have significantly higher levels of intrapersonal variability than married females without children. On the other hand, no significant difference is found in intrapersonal variability between employed married males with and without children. These results indicate that the presence of children in the household has more impact on the travel behavior of females than males, as expected.

Table 2. Intrapersonal variability in daily trip generation – Employed persons.

Explanatory factor (specific hypothesis)	Segment (sample size)*	Mean intrapersonal variance**	Variance ratio (D.O.F.)***	Prob.****
Occupational Status of Household Head (S2)	Professional (11)	2.836	1.38 (44,256)	–
	Skilled (64)	2.048		
	Skilled (64)	2.048	1.35 (256,72)	–
	Unskilled (18)	1.522		
	Professional (11)	2.836	1.86 (44,72)	≤.01
	Unskilled (18)	1.522		
Household Income (S2, S7)	Low (32)	2.163	1.03 (128,172)	–
	High (43)	2.095		
Education Level (S2)	Low (54)	1.844	1.26 (152,216)	≤.10
	High (38)	2.321		
Car Availability (S6)	Yes (59)	2.019	1.02 (148,236)	–
	No (37)	2.051		

Table 2. Continued.

Explanatory factor (specific hypothesis)	Segment (sample size)*	Mean intrapersonal variance**	Variance ratio (D.O.F.)***	Prob.****
Marital Status (S3)	Single (13)	2.423	1.23 (52,324)	-
	Married (81)	1.977		
Gender (Conditional on Marital Status) (S4)	Single Male (6)	2.167	1.22 (28,24)	-
	Single Female (7)	2.643		
	Married Male (45)	1.789	1.24 (144,180)	≤ .10
	Married Female (36)	2.214		
Presence of Children (Conditional on Marital Status & Gender (S5)	Married Male Without Children (24)	1.950	1.22 (96,84)	-
	Married Male With Children (21)	1.600		
	Married Female Without Children (22)	1.545	2.11 (56,88)	≤ .01
	Married Female With Children (14)	3.264		

* The employed segment of the sample used in this study has 96 members. However, because of missing data on some variables, the sample size used in some analysis is less than 96.

** The mean intrapersonal variance in trip generation rates for members of any population segment is defined in Equation 1.

*** The ratio of the mean intrapersonal variances in the two segments. This statistic has the F-distribution with the degrees of freedom shown in parenthesis.

**** The probability that the null hypothesis, that the two groups have the same intrapersonal variance in trip generation rates, should not be rejected. (Reported only if the probability is ≤ .10).

4.3 Not employed segment

Table 3 displays the results of the intrapersonal variability analyses for the not employed group, analogous to those discussed above for the employed group. The not employed group is almost all female, thus certain comparisons are not made. The results reported in Table 3 show that among the not employed group, social class and the availability of travel and related resources have sig-

Table 3. Intrapersonal variability in daily trip generation: Not employed persons.

Explanatory factor (specific hypothesis)	Segment (sample size)*	Mean intrapersonal variance**	Variance ratio (D.O.F.)***	Prob.****
Occupational Status of Household Head (S2)	Professional (3)	5.033	1.38 (12,128)	-
	Skilled (32)	3.641		
	Skilled (32)	3.641	2.17 (128,36)	≤.01
	Unskilled (9)	1.678		
	Professional (3)	5.033	3.00 (12,36)	≤.01
	Unskilled (9)	1.678		
Household Income (S2, S7)	Low (30)	2.483	2.23 (52,120)	≤.01
	High (13)	5.546		
Educational Level (S2)	Low (34)	2.779	1.88 (52,136)	≤.01
	High (13)	5.223		
Car Availability (S6)	Yes (23)	4.570	1.96 (92,104)	≤.01
	No (26)	2.327		

Table 3. Continued.

Explanatory factor (specific hypothesis)	Segment (sample size)*	Mean intrapersonal variance**	Variance ratio (D.O.F.)***	Prob.****
Marital Status (S3)	Single (4)	2.250	1.57 (164,16)	–
	Married (41)	3.527		
Presence of Children (Conditional on Marital Status & Gender) (S5)	Married Female Without Children (20)	3.225	1.31 (72,80)	–
	Married Female With Children (18)	4.222		

* The not employed segment of the sample used in this study has 49 members. However, because of missing data on some variables, the sample size used in some analysis is less than 49.

** The mean intrapersonal variance in trip generation rates for members of any population segment is defined in Equation 1.

*** The ratio of the mean intrapersonal variances in the two segments. This statistic has the F-distribution with the degrees of freedom shown in parentheses.

**** The probability that the null hypothesis, that the two groups have the same intrapersonal variance in trip generation rates, should not be rejected. (Reported only if the probability is $\leq .10$).

nificant impacts on intrapersonal variability in daily trip generation rates. For example, those not employed people who have access to an automobile have significantly higher levels of intrapersonal variability than those who do not have access to an automobile, as hypothesized (Hypothesis S6). Similar results are obtained for household income (Hypotheses S2 and S7) and occupational status of household head and educational level (Hypothesis S2). The results in Table 3 also show that while there are substantial differences in intrapersonal variability between individuals with different household roles, none of these differences is statistically significant.

5. Discussion and conclusions

The empirical results reported above support the two general behavioral hypotheses formulated earlier. First, the empirical results reported in this paper support the hypothesis that those individuals who are more likely to fulfil in-

frequent individual and household needs and desires have higher levels of day-to-day intrapersonal variability in their travel behavior than those persons whose roles require daily activity participation and related travel. Second, the results are consistent with the hypothesis that those people having fewer household- and employment-related coupling constraints have more day-to-day intrapersonal variability in their urban travel and related behavior. The empirical results for the not employed group also support the hypothesis that those individuals having more travel-related resources available to them have a higher level of intrapersonal variability in their travel and related behavior in comparison with those people who have limited travel-related resources available to them.

The empirical investigations of the specific hypotheses provide some interesting observations. First, we find that, as expected, employed people have much lower levels of intrapersonal variability in trip frequency in comparison with those people who are not employed outside the home. Second, we note that social class and the availability of travel and related resources are very important factors with respect to differences in intrapersonal variability among sub-groups of the not employed segment; however, these factors are less important within the employed segment. On the other hand, household role related variables are somewhat more important in the case of the employed segment.

Third, the empirical results reported above indicate that employed married females have substantially higher levels of intrapersonal variability in trip frequency than employed married males. On the other hand, we find little difference in intrapersonal variability between employed single males and females. Furthermore, the empirical analyses show that the presence of children in the household has considerably more impact on the behavior of females than males. These results tend to support the belief that socialized gender-linked roles have substantial effects on travel and related behavior. This conclusion about the importance of gender-linked roles is derived in the context of Reading, England in 1973. It is possible that socialized gender-linked roles are less important in other countries now. Thus, it is important that the results reported in this paper be verified with more current data collected in different social/cultural environments.

This research indicates that there is substantial intrapersonal variability in daily trip generation rates, and that there are large and meaningful differences in the level of intrapersonal variability between population groups. Intrapersonal variability limits the potential of conventional models to explain daily travel behavior, because differences in individual characteristics cannot explain that portion of the total variability which we term intrapersonal variability. Thus, models developed to describe trip generation for populations or population segments which have high levels of intrapersonal variability will appear to have poor goodness of fit measures. Recognition of the magnitude of in-

trapersonal variability, and differences in intrapersonal variability across population groups, may provide aid in the assessment of model goodness of fit results.

A similar issue arises in the case of models of different measures of travel and related behavior. For example, Pas & Koppelman (1984b) report that a marginal automobile ownership choice model having a relatively limited specification appears to outperform a conditional mode choice model in predicting behavior both in the model estimation context as well as in model transfer situations. Clearly, the lower level of day-to-day variability in automobile ownership than in mode choice is an important determinant of this difference in performance. The relationship between intrapersonal variability and the ability of models to describe individual behavior is discussed elsewhere (Pas, 1985).

The results reported in this paper show evidence of high levels of intrapersonal variability in daily trip-generation rates, relative to the levels of interpersonal variability in this variable. A number of factors should be considered in assessing this result. First, we have examined intrapersonal variability in total daily trip generation rates. Clearly, day-to-day variability in trip generation rates for some trip purposes will be considerably higher than intrapersonal variability for total daily trip generation rates. A more detailed study of variability by trip purpose would be helpful in identifying those travel components which are more or less variable and would establish a clearer identification of the characteristics of individuals which influence levels of variability.

Second, the data employed in this research may be biased in ways that affect day-to-day variability. Bonsall *et al.* (1984) report that survey data appear to lead to under-estimates of day-to-day variability relative to estimates based on field observations. However, Golob & Meurs (1986) find that respondents report fewer trips in later days of a multiday survey. Such a bias in response would tend to increase the average level of intrapersonal variability in trip generation rates. On the other hand, the analyses conducted by Barnard (1986) indicate that responses to an activity diary survey provide more complete travel information than responses to a traditional home interview survey.

Overall, we conclude that there are high levels of intrapersonal variability in daily travel behavior, that such variability differs across population groups in a manner which is consistent with the tenets of activity theory and that further investigation is likely to identify even stronger patterns of variability differences than those reported here.

Acknowledgements

The research reported in this paper was supported in part by the Geography and Regional Science Division of the National Science Foundation through

grants SES-8112494 and SES-8112495 for "Collaborative Research on the Spatial-Temporal Characteristics of Person Travel Behavior." The data used in this research was kindly supplied by J. Andrew Slack of Ball State University with permission from the SSRC Data Archive at the University of Essex. James H. Dunlop, graduate research assistant in the Civil and Environmental Engineering Department at Duke University, provided data analysis support and Jo Ann Scott prepared the manuscript. We appreciate their assistance. The comments of referees on an earlier version of this paper are also much appreciated.

References

Axelrod, M., "Urban Structure and Social Participation," *American Sociological Review,* Vol. 21, 1956, pp 13–18.

Barnard, P.O., "Use of an Activity Diary Survey to Examine Travel and Activity Reporting in a Home Interview Survey," *Transportation,* 1986.

Bonsall, P., F, Montgomery and C. Jones, "Deriving the Constancy of Traffic Flow Composition from Vehicle Registration Data," *Traffic Engineering and Control,* Vol. 25, No. 7/8, 1984, pp 386–391.

Burnett, K. P., "Tests of a Linear Learning Model of Destination Choice: Application to Shopping Travel by Heterogeneous Population Groups, *Geographiska Annaler, Series B,* Vol. 59, 1977, pp 95–108.

Burnett, K.P. and S. Hanson, "Rationale for an Alternative Mathematical Approach to Movement as Complex Human Behavior," *Transportation Research Record,* 723, 1979, pp 11–24.

Chapin, F.S., Jr., "Activity Systems and Urban Structure: A Working Schema," *Journal of the American Institute of Planners,* 1968, pp 11–18.

Chapin, F.S., Jr., *Human Activity Patterns in the City: Things People Do in Time and in Space,* Wiley, New York, 1974.

Chapin, F.S., Jr., "Human Time Allocation in the City," *in Human Activity and Time Geography,* T. Carlstein, D. Parkes and N. Thrift (eds.), Wiley and Sons, New York, 1978.

Downes, J. D. and R. Wroot, 1971 Repeat Survey of Travel in the Reading Area, Department of the Environment, TRRL SR 43 UC, Crowthorne, England, 1974.

Fuller, W. A. and G. E. Battese, "Estimation of Linear Models with Crossed-Error Structure," *Journal of Econometrics,* Vol. 2, 1974, pp 67–78.

Golledge, R., "Some Equilibrium Models of Consumer Behavior," *Economic Geography,* Vol. 46, 1970, pp 417–424.

Golob, T. F. and H. Meurs, "Biases in Response Over Time in a Seven-Day Travel Diary," *Transportation,* 1986.

Hagerstrand, T., "What About People in Regional Science?" *Papers and Proceedings of the Regional Science Association,* Vol. 24, 1970, pp 7–24.

Hagerstrand, T., *The Impact of Transport on the Quality of Life,* Fifth International Symposium on Theory and Practice in Tansport Economics, Greece, October 1973.

Heggie, I.G., "Putting Behavior into Behavioral Models of Travel Choice," *Journal of Operational Research Society,* 29, 1978, pp 541–550.

Herz, R., "Stability, Variability, and Flexibility in Every Day Behavior," in *Recent Advances in Travel Demand Analysis,* Carpenter, S. and P. Jones (eds.) Gower Publishing Company, Aldershot, England, 1983, pp 385–400.

Hodge, R.W. and D.J. Treiman, "Social Participation and Social Status," *American Sociological Review,* Vol. 33, No. 5, 1968, pp 722–739.

Huff, J. O. and S. Hanson, "Repetition and Variability in Urban Travel," Manuscript in Publication Review, 1985.

Marble, D.F. and S.R. Bowlby, "Shopping Alternatives and Recurrent Travel Patterns," in *Geographic Studies of Urban Transportation and Network Analysis,* F.E. Horton (ed.), Northwestern University Press, Evanston, IL., 1968.

Mitchell, R.B. and J.C. Rapkin, *Urban Traffic: A Function of Land Use,* Columbia University Press, New York, 1954.

Oi, W.Y. and P.W. Shuldiner, *An Analysis of Urban Travel Demands,* Northwestern University Press, Evanston, Illinois, 1962.

Pas, E. I., "Are We Too Severe in Assessing the Goodness-of-Fit of Travel Demand Models?" Manuscript in review, 1985.

Pas, E.I., "Multiday Samples, Parameter Estimation Precision and Data Collection Costs for Least Squares Regression Trip Generation Models," *Environment and Planning A,* to appear, 1986.

Pas, E.I. and F.S. Koppelman, "Comparative Analysis of the Transferability of Disaggregate Automobile Ownership and Mode Choice Models," *Transportation Research Record,* 1984, pp 40–48.

Reichman, S., "Travel Adjustments and Lifestyles – A Behavioral Approach" in *Behavioral Travel Demand Models,* Stopher, P.R. and A.H. Meyburg (eds.), Lexington Books, Lexington, Massachusetts, 1976, pp 143–152.

Reisman, L., "Class, Leisure and Social Participation," *American Sociological Review,* Vol. 19, no. 1, 1954, pp 76–84.

Shapcott, M., "Comparison of the Use of Time in Reading, England with Time Use in Other Countries," Transactions of the Martin Centre for Architectural and Urban Studies, Vol. 3, 1978, pp 231–257.

Shapcott, M. and P. Steadman, "Rythms of Urban Activity," *in Human Activity and Time Geography,* T. Carlstein, D. Parkes and N. Thrift (eds.), Wiley and Sons, New York, 1978.