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Travel Regularities and Their Interpretations: A Discussion Paper

JANUSZ SUPERNAK

ABSTRACT

The regularities in travel behavior analyses are examined in this paper. Reasons are investigated for different interpretations of travel regularities caused by (1) differences in basic assumptions, model specification, and selection of analysis unit; (2) differences in selection and evaluation of empirical material; and (3) differences in data used. Criteria for evaluation of meaningfulness and applicability of travel regularities are proposed. Travel-time budget analyses and studies of travel behavior of homogeneous groups of persons are compared as alternative approaches to investigate

differences in travel regularities and diversity of their interpretations.

Detecting regularities and establishing relationships in any analyzed phenomenon, process, or behavior is always an important and interesting part of any research effort. Discovering regularities is normally a first sign of understanding the analyzed problem. Often these regularities have useful applications. In human travel behavior, regularities confirmed by several studies from different metropolitan areas can constitute a basis for geographically transferable models and can be used in travel demand forecasts and policy analyses.

In travel behavior analysis, as in other fields of research, there are several ways to analyze different regularities and many ways to interpret them. This diversity in travel regularities and their interpretations does not necessarily mean that any one version must be wrong. However, in many cases where the research conclusions are divergent, it is natural to ask why. What methodological differences are responsible for different regularities? Are these regularities meaningful, consistent, or useful in practical applications? Although the final judgment about quality of different regularities and respective research approaches will never be fully objective, evaluation using these criteria would be in order.

There are several reasons potentially responsible for different interpretations of regularities in travel behavior analyses: (a) conceptual differences (different approaches, analysis units, unit stratifications, model specifications, and so forth); (b) differences in selection, presentation, evaluation, and interpretation of empirical findings; and (c) overall quality of the data used (i.e., its completeness, adequacy, accuracy, compatibility).

An attempt is made to address some of the issues in this paper. The content, form, and scope of this paper were prompted by the comments of Zahavi (1) printed with the author's article "Travel-Time Budget: A Critique" published in Transportation Research Record 879 (2). At that time there was no opportunity to respond in an author's closing statement. However, because Zahavi raised many important issues, both on the subject of travel-time budgets and on the broader questions of interpreting differences among researchers' analyses of data, many of his comments and other works (1,3) are used as the basis for this paper. Over several years, Zahavi has contributed many innovative ideas in the study of travel budgets, but possibly just as significant are the important methodological issues that have been generated by his research. Today it may be neither important nor appropriate to debate the validity or nonvalidity of the concept of travel-time budgets. Although this article is not intended as a response to the late Zahavi's comments on travel-time budgets, it does refer to them in an effort to illustrate the issues and questions he raised in the field of travel behavior analysis.

ANALYSIS OF HUMAN TRAVEL BEHAVIOR: CONCEPTUAL DIFFERENCES

Background

The concept of stability of a travel-time budget is well-known to a majority of researchers in the field and does not need to be introduced in detail in this paper. A good summary of Zahavi's work is given elsewhere: "Analysis of Zahavi's work on the subject revealed the evolution of the concept, from an overall average daily travel time for vehicles, to average values per traveler systematically influenced by socioeconomic factors, to a final relationship with the average speed of the transportation system" (4). This last version is given in a report by Zahavi: "The mean daily TT-budget per travel is an inverse function of speed, decreasing as speed increases, to an asymptote of about 1.1 hours per day" (3,p.IV). Full details of the concept are given in several reports (3,5,6).

The author's critique of travel-time concepts in general (not specifically Zahavi's work) presented in TRR 879 (2) (a) questioned the meaningfulness and applicability of travel-time concepts; (b) postu-

lated some methodological improvements in travel-time budget studies; (c) found trip rates of homogeneous groups of persons more stable than the respective travel budgets; and (d) revealed regularities in several travel characteristics of these groups, with a potential for geographic transferability of outside-the-home activity budgets of homogeneous groups of persons. Details are given in that paper (2).

Regularities: Behavior of an Individual or a Group?

Any regularity in travel behavior refers to either the entire population (of persons or travelers) or to some clearly specified subgroups of the population. In any disaggregate approach where, for example, individual *i* is used as the analysis unit, the implied assumptions should be that the results can be generalized over a larger group of persons represented by individual *i*. Also, whichever period is used as an analyzed time duration (e.g., a day), the behavior expressed by such characteristics as trip rates, travel-time budget, and so forth, should not be expected to be identical each and every day. For example, a travel-time budget of 60 min means that the average daily travel time of an average representative of an analyzed group (*G*) is 1 hr.

Averaging travel characteristics in order to generalize the travel behavior of the population under study encounters some problems represented by the following questions: Because the human population is heterogeneous, should the average behavior of the entire population or rather its more homogeneous subpopulations be described? What is the geographic and temporal stability of travel characteristics if it is known that the population structure is subject to significant changes in both space and time? How will changes in the population structure influence the validity of certain transportation policies that may apply differently to different population subgroups?

Heterogeneity of the Population and Importance of its Proper Stratification

It is interesting to note that, for any heterogeneous population under study (human population is certainly just this with respect to outside-the-home activities and travel patterns), meaningful regularities can be found only after meaningful, crucial variations are found. For example, more is known about dogs than about mammals as a whole, and more about bulldogs than about dogs as a whole. The differences among biological species were the reasons for stratifying them into more homogeneous groups whose average physical outlooks, behaviors, and so forth, could already be found to be quite regular. Any analysis based on an average traveler (i.e., a person who just happened to travel during the survey day by motorized modes) fails to recognize crucial variations within heterogeneous groups; thus by averaging over unidentifiable units, the analysis fails to discover really meaningful regularities.

Acknowledging an existence of a high heterogeneity of the population (persons or travelers) with respect to its travel behavior (employed husbands versus housewives, or groups between the ages of 20 to 30 versus 70 to 80) implies certain methodological consequences. If travel behavior is predominantly differentiated by age and employment status, these variables should be the primary candidates for consideration in any analysis of travel patterns. They should also be a basis for meaningful stratifi-

cation of a heterogeneous population into more homogeneous subpopulations.

Why should the analyst care about a proper stratification of the population in any study of travel behavior? The reasons are as follows:

1. The analyst wants to identify groups of distinctly different travel behaviors that could be caused by differences in objective needs for traveling, options available, and travel constraints;
2. The analyst wants to assure a proper representation of each group while designing, for example, cross-sectional or longitudinal surveys of travel behavior;
3. The analyst would like to capture dynamic changes in representations of each group, and their consequences on the population treated as a whole; and
4. The analyst is interested in identifying differences among groups in reaction to relevant outside changes, both natural (e.g., the changing energy situation) and imposed (policies).

What criteria should be followed for a proper stratification of the population due to an analyzed issue? Theoretically, the desired criterion could be formulated as a formal minimization of the within-group variance for each group. In analyses of trip rates it could be formally done by stratifying groups due to their number of daily trips: those with zero, one, two, and so on. Thus the within-group variance would be zero, and the total variation would be explained by the between-group variance. However, this grouping would be quite useless because the groups could not be identified.

Therefore, a much more complicated formula is required: stratification into homogeneous groups has to result from some kind of multivariate analysis. This should reduce the within-group variance to the extent possible, and result in a relatively small number of homogeneous groups that are relevant to the analyzed issue, easy to identify, and whose populations will be relatively easy to predict.

An excellent guide for creating homogeneous groups can be found in two reports (7,8). It has to be noted that any arbitrary stratifications, one-dimensional or multidimensional, may appear ineffective or even totally irrelevant, and that "segmentation along an irrelevant dimension will result in inaccurate prediction results" (8).

The Significance of Homogeneity of Groups of Persons

The importance of homogeneity of groups of similar travel behavior can be demonstrated by at least two points.

1. Homogeneous groups should have smaller variability than the population as a whole; this can reduce the desired size of the travel survey if a stratified sampling scheme is chosen.
2. Homogeneity of the groups should reduce the divergence of results between different survey techniques (e.g., more units and shorter observation time versus fewer units and longer observation time for travel behavior). This may be crucial in justifying, for example, a 1-day transportation survey procedure from which judgments about an average daily behavior are made.

Homogeneity of the groups does not denote even distributions. Quite often coefficients of variance of observations of either trip rates or travel bud-

gets will still remain relatively high. There are some reasons for this:

1. Including zeros to represent nontravelers and low numbers for nonvehicular trips increases the tail part of data and results in higher variances;
2. A short observation period (normally 1 day) is responsible for a large number of zero observations if travel is regular but sporadic [a simple numerical example in a previous paper (2) shows that coefficient of variance can drop dramatically if the observation period increases]; and
3. The coefficient of variance is not always an absolute measure of variability in data.

Transferability of Travel Characteristics

Is transferability the primary criterion for the evaluation of meaningfulness and applicability of regularities? Some authors appear to suggest that the answer to this question is yes. Zahavi writes that "the primary test for different approaches is whether or not the model is transferable in both space between cities and in time in one city" (1).

Note that the transferability criterion is a demanding one and clearly it is quite risky. If models are expected to be fully transferable in both space and time, then any single empirical test that proves against transferability could jeopardize the final conclusions, even if all previous tests supported the notion of transferability.

The problem of transferability appears to be more complex than the preceding quote from Zahavi (1) might suggest. First, it is clear that some travel characteristics should not be expected to be spatially transferable. For example, average daily travel times to and from work vary widely among cities because of their different distributions of residential areas and work places, and differences in sizes, shapes, types of industry, transportation infrastructures, and so forth. Thus it would be unreasonable to expect the obligatory part of travel-time budget (T^{obl}) to be transferable. The overall travel-time budget (T) could be transferable, but this would impose a regulatory role on the discretionary part of the travel-time budget (T^{disc}) because $T = T^{obl} + T^{disc}$, a notion that was questioned in a previous paper (2). Second, it is not clear whether the spatial transferability is a prerequisite for the temporal transferability: some authors disagree with this notion. On the other hand, the existence of geographic transferability in some characteristics may not imply meaningfulness of this single regularity. This issue will be discussed in more detail later in the paper.

Therefore, the following criteria for evaluating the meaningfulness of regularities can be proposed:

1. The subsets of the population to which regularities are applicable should be clearly specified,
2. Regularities should be adaptable for another urban environment [an absolute transferability (e.g., trip rate $N_i = \text{const}$) may be possible but is not strictly required],
3. Regularity should provide a logical and consistent explanation (at least signs of relationships should always be the same),
4. Regularity should properly illustrate major trends observed in analyzed phenomenon or behavior, and
5. Regularity (or set of regularities) should be easily applicable.

Problem of Partial Regularities

The concept of stability of the travel-time budget per traveler (TT/TR) is examined. In order to reliably estimate the amount of traveling in the system [total travel time (T) or distance (D) in this concept], it is not enough to confirm transferability of the daily travel time per traveler (TT/TR) or the relationship TT/TR as a function of speed V ,

$$TT/TR = b + (a/V) \quad (a, b = \text{constants}) \quad (1)$$

In order to obtain the estimation of T , at least two more relationships have to be transferable: (a) percentage of traveling households (β^{HH}) as a function of household characteristics, and (b) average number of travelers per household (TR/HH) as a function of household characteristics. Thus

$$T = (L/HS) \cdot \beta^{HH} \cdot (TR/HH) \cdot (TT/TR) \quad (2)$$

where L is the population size and HS is the average household size.

Thus the concept of stability of the travel-time budget requires simultaneous transferability of regularities in all three characteristics: TT/TR , β^{HH} , and TR/HH . [In the entire UMOT interaction process (3), stability of the daily household expenditure on travel (M) as a share (C) of household income (I) has to be assumed, i.e., $M = C(I/HH)$.] The temporal stability of the travel-time budget per traveler (TT/TR), even if fully confirmed, will be useless if at least one of the other relationships previously mentioned appears nontransferable. It is worth noting that these relationships are virtually ignored in the travel-time budget literature, even though they deserve the same attention as does the TT/TR relationship.

Analysis Unit Controversy: Person Versus Household

The analysis units used in the stability of the activity budget concept versus the travel-time budget concept are examined. In the first case, the unit is an average representative of homogeneous group i , whereas in the second case it is a motorized traveler that is representative of an average traveling household H . Averaging over unidentified household members has one important disadvantage: it ignores the high heterogeneity of the family.

The household versus person (or traveler) controversy was commented on in some works (2,9,10). Here, only the main points are presented to explain why an individual level of data aggregation was chosen for the analysis made in a previous paper (2).

1. An individual is the only true travel decision maker; travel choices of an average household member (or traveler) have virtually no interpretation.

2. A reasonably small number of homogeneous groups (categories) can be created only at the individual level. Applying the unit "an average representative of a homogeneous group of households" is virtually impossible or at least impractical; it would require hundreds of different types of households, and yet a vast majority of these units will have to remain highly heterogeneous.

3. References to a person's household environment can be introduced at this level if needed. The need can be disclosed by performing a multivariate analysis of significance of the variables. In some cases household-oriented variables can be individualized [e.g., car availability (11)]. Household

references can take the form of a hybrid approach (12), but the bottom line is that effective stratifications of the population need not follow a person's family affiliations (2,7,13). A family (in a transportation sense) is one of the most heterogeneous sets of three, four, or five persons one can think of (9).

4. The effect of household size is not unobservable at the person level of data aggregation. Moreover, the individual approach addresses another important issue: it identifies the person who constitutes the additional family member. The daily travel time per person drops sharply with family size not because of any magic power of the household size variable, but because family members number 1 and number 5 are, as a rule, very different people (e.g., employed father versus his preschool child). In a person approach family members will belong to different homogeneous groups and possess different travel characteristics. If multivariate analysis reveals that the household-size variable is needed at the person level, it can be introduced into the model (e.g., by distinguishing housewives from families with children from housewives without children). Finally, the interactions and trade-offs among family members are difficult to describe at any level, even at the family level. On the other hand, some effect of these trade-offs can be observed at the person level (i.e., employed husbands spend less time on family shopping than their non-employed wives).

Controversy: Person Versus Traveler

The discussion about the analysis unit in travel budget studies is well documented in the literature (1,2,4,14). The majority of researchers base their calculations on all persons, independently of whether they traveled or not during the survey day.

If the concept of traveler is applied, then an arbitrary 1-day observation period will become the reference point. Theoretically, however, any time period can be chosen to define the traveler. Travel surveys today are not necessarily based on 1-day data: the observation period can be 1 month, 1 week, 2 days, 1 day, or peak period. For each of these periods both the definition of traveler and the percentage of nontravelers will be different. Over longer periods of time virtually everyone becomes a traveler.

There are several consequences of this choice of the analysis unit.

1. The concept of traveler has no clear reference to the frequency of traveling; it treats someone traveling every day in the same way as someone traveling once a week (if he happened to travel during the survey day).

2. The consequence of 1 is that regularities per traveler may contradict those of per person, with a potential for confusion and misinterpretation of resulting relationships. This point can be illustrated by a (simplified) numerical example. Three groups of American television watchers are investigated: group A consists of people who regularly watch daily news and practically nothing else. Group B watches only "60 Minutes," a popular weekly news magazine program. Group C watches only main sport events such as the Super Bowl in football and final play-offs in basketball. These results are summarized in Table 1. Which group watches more television: A, B, or C? Group C watches the most on a daily basis if they watch (the importance of "if" is crucial). The order is reversed if how much time the representatives of

TABLE 1 Example of Television Watching Time Budgets for Groups A, B, and C

	Television Watching Time Budget (hr)		
	Group A	Group B	Group C
Yearly per person	183.0	52.0	12.0
Daily per watcher ^a	0.5	1.0	3.0

^aWatcher (similar to the definition of traveler) is the person who watches television during a given day.

these groups devote to watching television over longer periods of time (e.g., a year) is analyzed.

3. Ignoring nonmotorized travel appears to be a more serious problem than indicated by Zahavi (1): "It should be noted at this stage that walking, as a mode, was found to be a small proportion of travel in Baltimore; walking comprised only 3-12 percent of the total travel time of the above travelers belonging to high- and low-income households, respectively. As for distance, the proportions were only 1-5 percent, respectively." First, these proportions are much higher in other cities and, especially, in city centers. Second, the concept of motorized modes also excludes cycling, an important way of traveling in several countries in Europe and Asia. For example, Brog and Erl (15) report that the importance of bicycle as a mode of travel in West Germany is growing. Finally, the decision to exclude nonmotorized modes is difficult to accept on conceptual grounds. The time spent on traveling by nonmotorized modes has to be taken, as in the case of travel by motorized modes, from the total budget of disposable time. If the proportion of nonmotorized modes is indeed only marginal, why not include these trips into travel-budget considerations? Gunn (14) warns that "it is dangerous to assume that trends and relationships based on travel by mechanized modes alone can be given any general behavioral interpretation."

By using regularities that are valid "per homogeneous group of persons," the analyst can (a) easily generalize this regularity over any longer period of time, (b) capture temporal trade-offs many persons make for their activities (e.g., to do more traveling during one day in order to have more time left for within-home activities the next day), and (c) substitute a series of partial regularities to illustrate travel behavior (e.g., TT/TR , β^{HH} , and TR/HH) by a single regularity per person.

DIFFERENCES IN INTERPRETATIONS OF EMPIRICAL FINDINGS

Examples of Regularities

To illustrate some points mentioned previously, some examples of regularities discussed by Zahavi (1) and Supernak (2) are examined in more detail. Figures 1-3 and Table 2 (2) represent a sample of regularities relating to behavior of homogeneous groups of persons, whereas Figures 4-9 and Table 3 represent a sample of regularities referring to the travel-time budget concept.

The interpretation of results shown in Figures 1-9 and Tables 2 and 3 will be made according to the proposed criteria for evaluation of the meaningfulness of regularities (see section on transferability).

Regularities: Application for Specific Population Groups

Regularities presented in Figures 1-3 (2) apply to clearly specified segments (categories) of the population. All regularities appear to be category specific; differences between categories in all characteristics analyzed are significant, thus supporting the relevance of the stratification of the population into eight groups due to age, employment status, and automobile availability. Regularities presented in Figure 4 (1) also apply to a specific population subgroup: average traveler representative of traveling household H.

In either approach a major problem is the ability to predict the representation of either (a) population of a given person category or (b) the population of travelers. In the first case, prediction of person categories is based on projection of age and employment, as well as on the forecast of the automobile availability made separately for employed and nonemployed persons. The desired level of automobile availability was found to depend primarily on population density (11).

The ability to predict population of travelers depends on the consistency of the relationships shown in Figures 5 and 6.

Adaptability of Regularities into Another Urban Environment

The adaptability of regularities into another urban environment was tested for trip rates within Baltimore and for traveler trip rates between Baltimore

TABLE 2 Basic Travel Characteristics of Person Categories 1-8 in Baltimore (2)

No.	Category Description	α_i (%)	$\gamma_i^{\text{nontrav}}$ (%)	β_i^{walk} (%)	N_i		T_i (min)		t_i (min)	
					Mean	SD	Mean	SD	Mean	SD
1	Person < 18 years old	18.1	14.8	48.8	2.98	2.10	51.6	36.9	17.3	10.9
2	Employed, 18-65 years old, car never available	9.1	9.9	26.7	2.50	1.72	62.7	42.6	25.1	17.8
3	Employed, 18-65 years old, car sometimes available	13.5	6.3	8.5	3.17	1.91	63.8	38.8	20.1	13.5
4	Employed, 18-65 years old, car always available	18.5	4.3	4.8	3.48	2.00	69.8	38.1	20.0	12.8
5	Nonemployed, 18-65 years old, car never available	17.4	50.6	51.2	1.33	1.73	22.8	35.9	16.7	16.5
6	Nonemployed, 18-65 years old, car sometimes available	6.8	25.2	16.5	2.55	2.22	40.6	38.9	15.9	10.8
7	Nonemployed, 18-65 years old, car always available	6.4	18.1	4.7	2.99	2.36	44.1	37.2	14.8	10.4
8	Persons > 65 years old	10.3	35.2	27.2	1.48	1.65	22.8	34.8	15.4	16.3
Entire population		100.0	20.5	22.4	2.59	2.10	48.3	41.8	18.7	14.3

Note: α_i = percentage in the sample, $\gamma_i^{\text{nontrav}}$ = percentage of nontravelers (nontraveler = person making no trip during the survey day), β_i^{walk} = percentage of walking trips, N_i = daily trip rate, T_i = time spent on traveling during the day, and t_i = average trip duration.

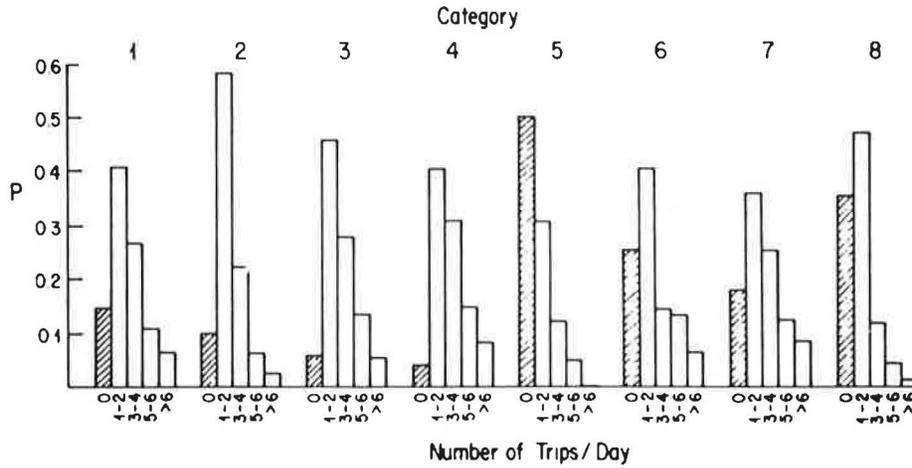


FIGURE 1 Trip frequency distributions for person categories 1-8 in Baltimore (2).

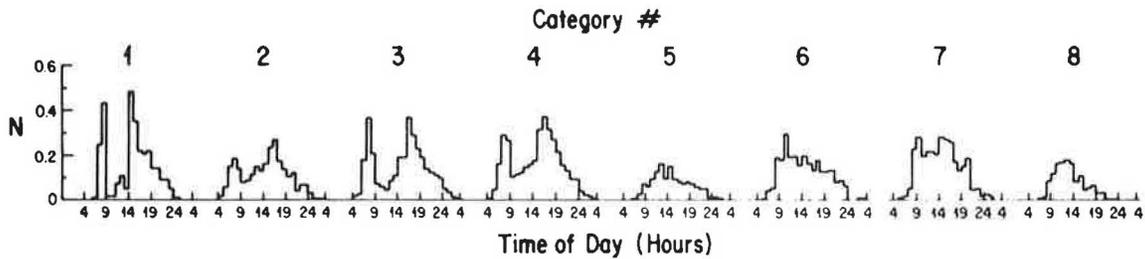


FIGURE 2 Hourly trip histograms for person categories 1-8 in Baltimore (2).

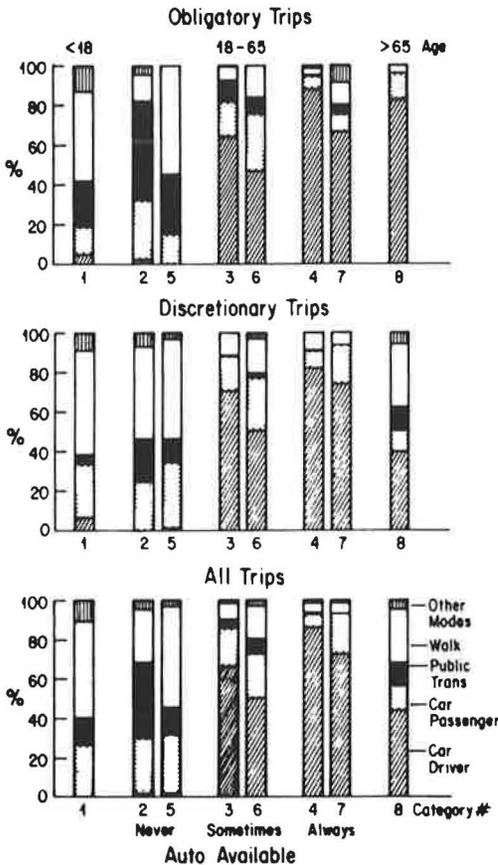


FIGURE 3 Basic modal splits for person categories 1-8 in Baltimore (2).

and Minneapolis with reasonable success. Trip rates appeared to be geographically more stable than respective travel-time budgets for person categories. The claim of any universal geographic transferability of mobility characteristics of homogeneous groups of persons ($N_i = \text{const}$) can not be made yet, and it is not likely to occur. The condition of adaptability of regularity will be satisfied if the relationship $N_i = f(\text{city characteristics})$ appears consistent and transferable. More compatible data sets are needed to perform the necessary tests.

As for the concept of travel-time budget, Figures 4-6 (1) provide satisfactory evidence of stability and transferability of all three relationships crucial to the success of the concept (see Equation 3 presented later): (a) regularity of travel-time budgets per motorized traveler distribution (Figure 4); (b) regularity of relationship explaining the percentage of traveling household (Figure 5); and (c) regularity of relationship explaining the percentage of travelers per household (Figure 6). Four cities,

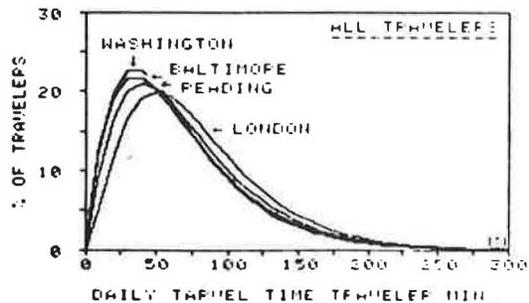


FIGURE 4 Travel time per traveler distribution: all travelers in four cities (1).

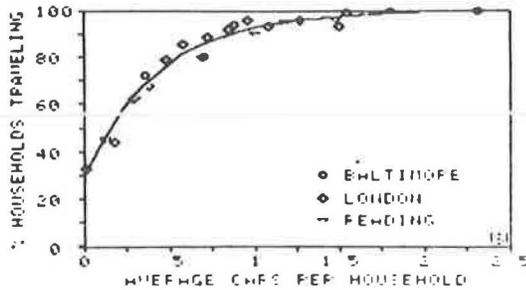


FIGURE 5 Percentage of households traveling versus cars per household (1).

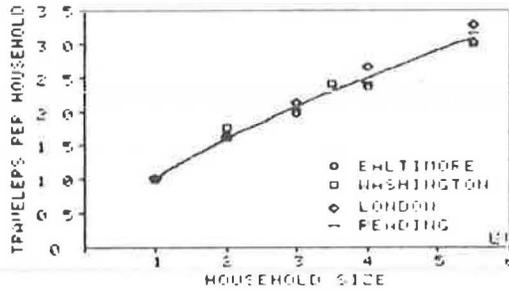


FIGURE 6 Travelers per household versus household size (1).

Baltimore and Washington, D.C., in the United States and London and Reading in the United Kingdom, were selected for these transferability tests. Travel-time frequency distributions appear to be "transferable among the four cities when accounting for travel speed" (1) (see Figure 4).

The ability to generalize findings shown in Figure 4 over a larger number of cities from several countries around the world can be tested by analyzing data provided in several papers (2,3,16). If daily travel-time means were to be ranked in increasing order, the picture would look like Figure 7. Four cities analyzed by Zahavi (1) happened to be "neighbors" in this large spectrum of different results. Conclusions about transferability of the travel-time frequency will have to be questioned if some other cities were selected for this comparison (e.g., No. 1, 3, 11, and 14).

The relationship presented in Figure 5 also creates some problems when generalized over populations in other cities. In many cities around the world there are more carless households than those with cars. It is not likely that in these countries only one-third of carless households will travel by motorized modes during an average 24-hr period, considering that a vast majority of carless households

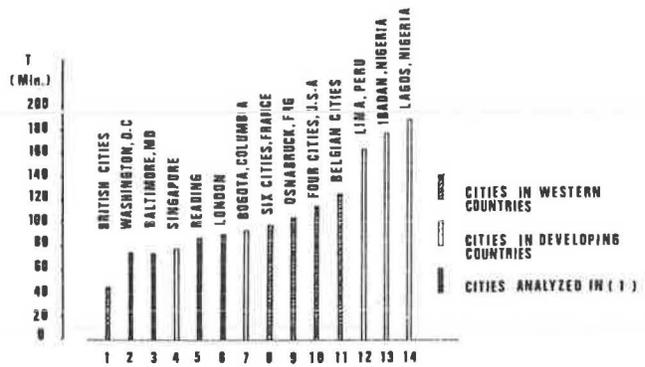


FIGURE 7 Mean daily travel times for selected locations.

has at least one employed member who has to work every working day.

The relationship shown in Figure 6 explains the number of travelers per traveling household by household size. Figure 1 shows that there are significant differences in percentages of nontravelers among different household members. Therefore, the number of employed family members and the number of students should be seen as a primary explanatory variable to estimate the number of travelers per household. In Table 3 a sample of results of the relationship $Trav/HH = a + b_1 (HH \text{ size}) + b_2 (\text{cars}/HH)$ is presented for American and West German cities. The results appear nontransferable and inconsistent.

Consistency of Regularities

The regularities in travel behavior should be logical (i.e., signs of relationships should be as expected and consistent). For example, Figures 1-3 show that if the percentage of employed persons increases, there is more travel in general, by car, and during rush hours, as expected. More of these regularities are presented elsewhere (10,11). One of them is the increasing role of the automobile in areas of low population density.

Another example verifies the postulated inverse relationship between daily travel time per traveler and speed. The best relationships for distance per traveler versus door-to-door speed for Munich, West Germany, were found by Zahavi (3,p.138) as follows:

$$\text{Dist/Traveler} = -7.184 + 1.738 (\text{Speed}), \text{ for carless households} \quad (3)$$

$$\text{Dist/Traveler} = -0.739 + 1.173 (\text{Speed}), \text{ for car owning households} \quad (4)$$

For north and south corridors of Washington these relationships are, respectively, as follows (5,p.35):

$$\text{Dist/Traveler} = 1.841 - 1.002 (\text{Speed}) \quad (5)$$

$$\text{Dist/Traveler} = -1.639 + 1.277 (\text{Speed}) \quad (6)$$

TABLE 3 Travelers per Household by Household Size and Car Ownership

City	Year	a	b ₁	b ₂
Washington, DC	1955	0.917	0.192 (3.23)	0.471 (3.79)
Washington, DC	1968	0.643	0.231 (4.50)	0.503 (7.62)
Twin Cities	1958	0.024	0.325 (5.28)	0.870 (5.74)
Nurenborg	1975	0.205	0.547 (14.06)	0.275 (3.67)

The relationships cited do not appear consistent. The values of coefficient estimates vary dramatically, and even the signs of the relationships are divergent. For example, Equations 3, 4, and 6 indicate that if speed increases, daily travel time per traveler increases, too (which is contrary to the postulated form of the relationship given by Equation 1) whereas Equation 5 would support the opposite conclusion.

Regularities: Ability to Capture Major Trends

Any regularity should properly illustrate major trends in the analyzed issue. This is a condition for a satisfactory forecasting ability of any model that is based on this regularity. For example, in several countries (including the United States), two trends have had a profound effect on the situation on the highways: (a) increasing female participation in the labor force and (b) process of suburbanization.

Figures 1-3 show the results of the first trend. There is more travel in general, by car, and during rush hours as a result of an increase in female employment. Also, it can be shown (11) that the trend of the population moving into the suburbs consistently causes an increasing need for higher automobile availability and, consequently, an increase in automobile use. The person category approach also appears convenient to illustrate major demographic trends such as the increasing percentage of older people in the population.

Figure 6, on the other hand, can illustrate the effect of shrinking household size on the number of travelers in a household, but cannot capture the effect of increasing female participation in the labor force.

Applicability of Regularities

Both approaches discussed here--the one based on homogeneous categories of persons and the one based on average traveler--are easily applicable and require a limited amount of basic data. Both approaches directly refer to several modeling stages such as automobile ownership and availability, trip and travel generation, and modal split.

The advantage of the person category approach is its consistency in using the same analysis unit through all modeling stages (11,12).

Regularities: Alternative Interpretations

It is not uncommon that different researchers can make different interpretations of the same regularity. For example, Figure 8 (1) can be interpreted to mean that "travelers at higher speed spend less daily time for more travel distance" (1). Alternative interpretations could be that (a) longer travel distances, even in the aggregate, are normally traversed with higher door-to-door speeds (by using expressways more often or by increasing the fast in-vehicle time part of travel by public transportation), and, more importantly, that (b) travelers and their characteristics may be seen as irrelevant here because the relationship illustrates the operation of the transportation system rather than traveler behavior.

Figure 9 (1) can be treated as an illustration of consistency of regularity. An alternative interpretation could be that stratification by income appears irrelevant. It can be argued that six distributions for six income groups are in fact equivalent

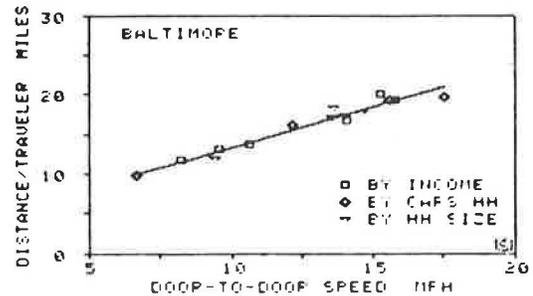


FIGURE 8 Distance per traveler versus speed (1).

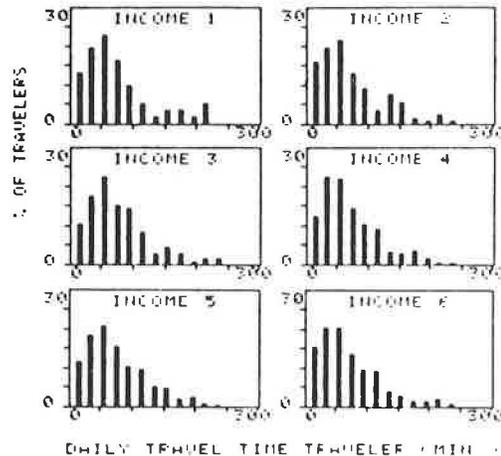


FIGURE 9 Travel time per traveler distributions by household income (1).

to a single distribution for the entire population. Thus Figure 9 can be treated as an example of an irrelevant stratification. Similarly, stratification by income, car ownership, and household size appears to be irrelevant for the distance per traveler relationship (Figure 8). If an irrelevant variable is left in the forecast model, it can lead to a wrong prediction because the true explanatory variables are more likely to be outside the model.

Consequences of Differences in Interpretations of Travel Regularities

Analysis of regularities is often associated with a testing of some more general concepts and theories. Specific interpretations of these regularities influence these concepts and may lead to conclusions that are different than those of other researchers and that are sometimes counterintuitive. Often the validity of a given interpretation can be tested by applying some boundary conditions. Sometimes a common sense, overall understanding of the field and experience can be quite useful evaluation tools, as well.

A quote from Zahavi et al. (5, pp.78-79) is a good example: "Exercises carried out with the UMOF travel process produced some results which appeared to be counterintuitive at first sight. For example, the scenario which provides a free transit system resulted in an increase in travel distance by both transit and private modes." This counterintuitive finding was recently criticized by Downes and Emerson (17). It could be interesting to analyze to what extent did the methodological issues discussed in this paper contribute to this result.

DATA INFLUENCE ON REGULARITIES AND THEIR INTERPRETATIONS

The discussion about different interpretations of travel regularities has yet another dimension. If the overall quality of data is bad, the entire verification of the empirical findings becomes virtually impossible or meaningless. The analyst would not know what was responsible for the lack of regularities: an irregular original, a poor model, or just poor data.

Data Quality: What Requirements?

There is an obvious interdependence among the design of the data-collection process, the gathering of data, the data analysis, and the presentation of results. All can contribute to the overall quality of the data and to the validity of the interpretation.

There are several elements useful for evaluation of data quality. The data sets should be accurate, complete, representative, flexible for different uses, and compatible. Data quality issues have been covered by several recent publications (18), and it will not be discussed here. Rather, the data compatibility issue, which is crucial for the validity of transferability tests, will be discussed.

Data Compatibility: A Fundamental Requirement

In order to be compatible, data sets have to be consistent in the following elements: subject subsystem records, object subsystem records, and travel process records.

Subject subsystem refers to an individual as a potential traveler and his relevant characteristics. The most common problems with data records about travelers are (a) completeness of the record (all persons, not only travelers, and all relevant personal characteristics), (b) flexibility of the record (avoiding prestratification according to age groups, for example), and (c) subjective versus objective perception, biases, errors, and so forth.

The object subsystem should cover all land use characteristics and transportation infrastructure records. Uniform network coding, compatible ways to introduce parameters of a given transportation system, and uniform records of land use patterns (residential densities) are samples of data problems associated with the object subsystem.

Trip records have to be given special attention. All modes, including walking, biking, and so forth, should be recorded. Clear definition of the trip, distinction between intracity and intercity travel, definition of the shortest trips, and so on should be made compatible. Work-day travel and weekend travel should be separated. Uniform, or at least compatible, definitions of trip purposes should be made. These problems are only some examples of potential discrepancies.

Consequences of Data Adjustments

The problem of data noncompatibility in travel demand analyses is both serious and common. A comparative analysis of trip patterns in Baltimore and the Twin Cities (2) is a typical example of difficulties with data compatibility. Data sets from these cities differed significantly because of both the records of traveler characteristics (e.g., different age brackets) and trip records (e.g., different definitions of the shortest trips). Also, data records had

to be checked for errors (e.g., whether a trip-chaining pattern was logical). Therefore, careful and systematic data adjustment had to be made to assure compatibility of both sets. Only after this process was finished could the results from Baltimore and the Twin Cities be compared at all.

One of the consequences of data adjustment is that the results based on the processed data should vary from the results based on raw data. The need for data adjustment was the reason why, for example, results of the Twin Cities travel-time budgets presented by Supernak (2) varied from some previous results cited by Zahavi (1).

FINAL REFLECTION

Final recommendations are not offered in this paper because it is intended as a discussion paper. Examples of alternative approaches, different results, and diversified interpretations of travel regularities have been presented. Also, insight into the reasons why these differences do happen was provided. Differences in interpretations of results do not necessarily prove anyone wrong; instead they illustrate a healthy diversity of research approaches, assumptions, and conclusions. Different views are often helpful for better understanding the analyzed field. It is hoped that this paper will stimulate some more thoughts and discussion. It is often through this process that progress in any field is made.

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The views expressed in this paper are solely those of the author.

Changes in Regional Travel Characteristics in the San Francisco Bay Area: 1960-1981

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ABSTRACT

The results of updating a travel survey in the nine-county San Francisco Bay Area are reported. The trip-making characteristics from the 1965 home-interview survey are compared with those from the 1981 telephone survey. The comparison is complemented with work trip modal shares from 1960, 1970, and 1980 census journey-to-work data. The observed changes in travel habits are traced to changes in demographic and economic characteristics in the region. Household trip rates are summarized by trip purpose, mode of travel, household size, automobile ownership, income, and housing structure type. The significance of the changes in trip rates is assessed intuitively and verified by simple statistical tests. The comparative analysis indicates that the total household

trip rates are stable over long periods of time. However, there are significant shifts in the frequency of trip making by trip purpose: Households make fewer home-based shopping and personal business trips and more non-home-based trips now relative to 1965. Although some trip rates by socioeconomic stratifications are significantly different in the two surveys, the overall effect on aggregate regional rates are tempered by shifts in the distribution of households by socioeconomic stratifications. Regional transit shares for work trips were found to be on the decline between 1960 and 1970, and were constant between 1970 and 1980. For those urban counties where significant transit service improvement took place between 1970 and 1980, transit work trip shares increased significantly. Public transportation appears to be absorbing more of the nonwork trip market now relative to 1965.