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Travel-Time Budget: A Critique

JANUSZ SUPERNAK

A critical evaluation of travel-budget concepts that stresses the travel-time budget is presented. Neither the detailed theoretical discussion nor the empirical findings from Baltimore and the Twin Cities of Minneapolis-St. Paul presented here support the concept of stability of travel-time budgets. The paper postulates some methodological improvements in travel-budget analyses that focus on the proper definition of the analysis unit. Making these improvements is seen as a prerequisite for finding meaningful regularities in travel behavior as well as for allowing comparisons of results. The alternative concept presented assumes stability of activity budgets (represented by trip rates) of homogeneous groups of persons. The proposed eight-category individual travel-demand model reveals many regularities in travel characteristics and satisfactory geographic transferability of trip rates of defined person categories.

Models that simulate social systems are often built around the assumption that certain properties of the phenomenon examined remain stable and constant for some period of time. In the past 20 years, the concept of the stability of travel expenditures of time and/or money has gained some popularity. Although this hypothesis, which is a tempting and attractive one, raises an interesting approach to the endeavor of transportation modeling, it thus far remains unproven. Recent opinions about the validity and applicability of travel budgets vary from cautious optimism (1-4) to skepticism (5-8) and leave some basic questions still unanswered.

Is the existing confusion caused by the variety of results obtained or, rather, the relative freedom of their interpretations? Is the methodology of this investigation correct? What is the proper analysis unit for travel-budget studies? Why is relative stability in very aggregated measures accompanied by high variability in disaggregated measures? Finally, is there an adequate theoretical base--and sufficient practical advantage--to support the replacement of the trip-rate concept by the expenditure-budget concepts in transportation modeling and forecasting?

In order to answer these questions, this paper attempts another critical and independent evaluation of travel-budget concepts. Four parts will be considered. First, an alternative look at previous findings is put forth. Second, a behavioral base and the importance of proper methodology for the travel-budget concept are discussed. Third, an empirical testing of travel-budget concepts for Baltimore (1977) and the Twin Cities of Minneapolis-St. Paul (1970) is explored. Finally, conclusions and recommendations are offered.

CONFLICTING EXPECTATIONS AND DIVERGENT FINDINGS

Variety of Concepts

Contrary to a clear and explicit concept of stability of trip rates, there is no uniform definition of a travel-expenditure budget. There are at least four formulations of the universal measure that are expected to remain stable:

1. Travel-time budget (1),
2. Travel-money budget (9),
3. Generalized expenditure budget (2), and
4. Household travel-distance budget (10).

Without going into details, one can easily note that these concepts are not necessarily compatible; if one is valid, another may not be. Sometimes two concepts can be compatible only under some special, but not very realistic, assumption (e.g., 1 and 4 are compatible only if speed v = constant).

Any specific travel-expenditure formulation can have a broad variety of definitions. For example, travel-money budget can be expressed as (a) total expenditure on transportation, (b) total expenditure on transportation as a fraction of total income, (c) total expenditure on transportation as a fraction of disposable income, and (d) current expenditure on transportation as a fraction of disposable income. As before, stability in one measure may automatically mean lack of stability in another. If many different measures are introduced, the chance is greater that one of them may show satisfactory consistency. Generally, the wide variety of concepts would not suggest that any specific travel-budget concept has a particularly strong theoretical background. Rather, attempts are made to support the budget formulation that best suits the empirical data.

Differences in Findings

Findings from different cities around the world can hardly support the concept of stability of travel budgets. The range of travel-time averages obtained from different cities in both Western and developing countries is very wide even at the aggregate level. For example, the average daily travel time in British cities is 46 min (11); in Washington, D.C., 73 min; but in Belgian cities, 125 min (see paper by Banjo and Brown elsewhere in this Record). The results from developing countries are also very divergent. For example, travel-time budget in Singapore amounts to 79 min; in Bogota, Colombia, 94 min; in Lima, Peru, 173 min; and in Lagos, Nigeria, 186 min (from Banjo and Brown).

It is surprising that the quantity of key importance for the entire travel-budget concept--the daily travel time of an average traveler, assumed to remain stable--is so dramatically inconsistent. It should be investigated, therefore, whether the travel-time budgets are the primary regularities in travel behavior or only reflections of some other, more meaningful regularities (e.g., stability of the respective trip rates).

Other travel-budget formulations also bring diverse results. For example, the total money expenditure for transportation in the United States and Canada has appeared to remain stable over time and amounts to 13 percent, while for the United Kingdom this percentage rose from 7.5 percent in 1956 to 13 percent in 1972 (1). Thus, the consistency of findings that relate to the second key quantity in travel-budget concepts--money spent on transportation--is likewise doubtful.

Results of travel budgets are even more confusing when presented at a more disaggregate level. The regularities found in one study often contradict the results from other studies. For example, the results from developing countries presented in Roth and Zahavi (4) show that in Singapore, and Salvador, Brazil, travel-time budgets are consistently rising with income, while in Bogota, Colombia, and Santiago, Chile, these budgets are equally consistently decreasing with income (in Bogota from 2.14 h for the lowest income to 0.94 h for the highest income).

Why does the stratification of households by income, which is seen by many researchers as meaningful, bring such confusing travel-budget findings? In order to answer this and similar questions, one should ask the following questions of an even more basic nature: Are the different travel-budget results comparable at all? Are we looking at the right thing? and Is the methodology of travel-budget analyses acceptable? The following section presents a basic discussion about the methodology of travel-budget studies and its influence on the results obtained.

TRAVEL BUDGETS: METHODOLOGICAL PREREQUISITES AND BEHAVIORAL BACKGROUND

The following elements are involved in any traveling process:

1. Subject subsystem (i.e., travelers with their relevant characteristics),
2. Object subsystem [i.e., all relevant characteristics of the urban area where travels are made (geography of the city, transportation infrastructure, etc.)], and
3. Environment [i.e., external conditions that may influence travel choices (energy situation, policies, economy, etc.)].

All of these elements should be articulated in the context of travel-budget concepts. This analysis should be done from the point of view of the representative traveler (real or potential), whose choices normally are based on logical, rational behavior rather than on the sometimes quite speculative laws of traveling used in different models.

Subject Subsystem: Discussion About Analysis Unit

A person usually decides to travel because the trip is necessary to a set of outside-the-home activities that a given person P_i has to (or wants to) participate in during the day, week, month, or year. Some of these activities will always create a regular pattern (e.g., work Monday through Friday for an employed person); others will bring only statistical regularities over longer periods of time (e.g., going out for entertainment about six times a month). Some of the activities are obligatory in nature (work, education) with, normally, strong spatial and temporal constraints; some are necessary but have very few constraints (e.g., shopping); and, finally, some others can be abandoned even for quite unimportant reasons (e.g., recreational trip if the weather is bad). Without delving into details, one can distinguish two basic groups of activities: (a) obligatory (work, education) and (b) discretionary (shopping, personal business, social, recreation, others).

Travel patterns reflect different outside-the-home activity patterns and vary from person to person. If person P_i makes n_1 home-based trips and n_2 non-home-based trips during the day, he or she can participate in a total of N outside-the-home activities (8), i.e.,

$$N = (1/2)n_1 + n_2 \qquad (1)$$

where $n_1 = 2, 4, 6, \ldots$ and $n_2 = 0, 1, 2, \ldots$. Even without any deeper analysis, one can easily notice that the population of persons is extremely heterogeneous with respect to reasons for traveling and travel itself, as is true of other characteristics one can think of, i.e., weight, height, shoe size, time spent watching television, etc.

Which unit should be taken, then, in order to compare travel budgets of inhabitants of different cities? Could it be (A) an average person who represents the entire population? Let us look for a parallel. An average Frenchman, who represents people of all ages, will certainly be much taller than his Mexican counterpart, mainly because of a much higher percentage of children in Mexico.

Should it be, then, (B) a given family category? To extend the previous analogy, even the term family height (a sum of heights of all family members) sounds ridiculous and any comparisons look unacceptable. The unit family is not normally used in travel-budget analysis [except, maybe, Tanner's family travel distance (10)], but in trip-generation models it is still the most common disaggregate unit (12).

Another proposal is (C), an average representative of a given family type, which is often used in transportation analysis. But substitution of the analogous parallel category of average family height reveals that the unit is artificial: The number of members of different ages will always be the deciding factor here. Again, any sensible analysis of height differences between the French and the Mexicans cannot be based on this analysis unit unless thousands of categories are introduced (e.g., a family with two adults and twin babies, a family with two adults and one 7-year-old boy, etc.).

Consider the next unit--(D) traveler--which is often used in travel-budget studies. Looking for another parallel, one can say that if someone goes to the cinema during a given day, he or she will do that only once that day and will spend about 2 h on that activity. This result will be, one can expect, strikingly consistent throughout the world and, of course, totally useless for explaining differences in cinema-going behavior, e.g., once a year versus once a week. In travel analysis, the above-described problem of sporadic activity is certainly less drastic (i.e., activities are much more frequent during the analyzed period), but the unit traveler is still unacceptable: Every person is a traveler sometimes (except, maybe, bed-ridden people). The traveler concept will eliminate someone who regularly travels five times a week (but not during the interview day) and also someone who does it once a week (and also did not travel during the interview day). Empirical arguments against this unit are presented later in the paper.

Another unit used (1)--(E) a traveler who is representative of a given family type--will certainly reduce coefficients of variance of observations but still leave problems discussed in (C) and (D) unsolved.

In order to reduce the heterogeneity of the data, some other, even more specified units are introduced, e.g., (F) motorized traveler (1). For example, could someone investigating American television-watching time budgets use responses referring to the ABC program only? Any travel-budget concept, to follow the original meaning of the word, should include all persons and travels made by all modes (walking is also a mode sometimes replaceable by another).

Which analysis unit, then, should be recommended for transportation analysis and, in particular, for travel-budget studies, to make any comparisons possible? Let us come back to the original example. It should be reasonable to say that a Mexican boy 8-10 years of age is X_1 centimeters tall while a French boy age 8-10 is X_2 centimeters tall. Age and sex distinctions seem to be a very natural criteria of grouping (categorization) for this comparison, but it may be erroneous to take the first sample from the Mexican countryside and the second one from Paris.

In order to make the proper categorization of analysis units for any reasonable comparison, multidimensional statistical analysis should be performed to discover the variables most significant in differentiating the population under study according to the analyzed issue. This should result, finally, in homogeneous groups of units investigated. Homogeneity, however, does not denote even distributions. Within each category there may be a high variety of observations, but the analysis method can still be acceptable if samples are random and large enough.

Relatively large coefficients of variance inside the homogeneous categories should not be treated as something abnormal or wrong in transportation analysis. Similarly, very low coefficients of variance for cinema goers from the previous example should not be treated as encouraging evidence. Even the most homogeneous subpopulation will include those making two and others six trips, and some traveling 20 and others 80 min. Even a few cases of such an irregularity in data bring relatively large coefficients of variance. Another problem deals with the duration of the transportation survey. For example, let us have 50 percent of the population making (regularly) two trips every odd day and 50 percent making two trips every even day. The results are as follows: one-day average = 1 trip/day, coefficient of variance = 100 percent; two following days average = 2 trips/2 days, coefficient of variance = 0 percent; one-day traveler average = 2 trips/day, coefficient of variance = 0 percent. One should stress that the arbitrary one-dimensional categorization does not solve the problem of comparing apples with oranges or even one kind of "orapples" with another, different kind of "orapples".

These basic prerequisities for an analysis unit seem to be well followed in many sciences (i.e., biology, agriculture, and medicine). In transportation, they seem to be somehow overlooked (at least in quite a high percentage of works), and therefore they were worth stressing by using a few, sometimes extreme, examples.

Object Subsystem: How Its Changes Should Influence Travel Budgets

The object subsystem includes both geographical reality of the given urban area and the entire transportation infrastructure in the area. Of concern here will be such characteristics as the distribution of generation and attraction points (e.g., residential areas and work places), city size, geometric shape, population density, road system, and public transit facilities and their parameters (e.g., speed or public transit headways). Further analysis will examine this subsystem in relation to the travel-budget concept. The object subsystem of any city is, like the subject subsystem just discussed, extremely heterogeneous. Different parts of any given metropolitan area will have different densities, transportation infrastructures, distribution of activity places, etc. Cities will also be highly differentiated among themselves (e.g., new California cities have very little in common with their old Pennsylvania counterparts).

To analyze the influence of these differences on the travel-time-budget concept, one should first concentrate on the key issue here: the distribution of generation and attraction points in a given subarea. This will affect both obligatory and discretionary trips, but the former are of particular concern here. Discretionary trips will follow, in most cases, rational principles of the gravity model (opportunity model): The place of the activity will be the nearest one that could fulfill a given need of person P_i satisfactorily (e.g., the nearest cinema showing this particular film).

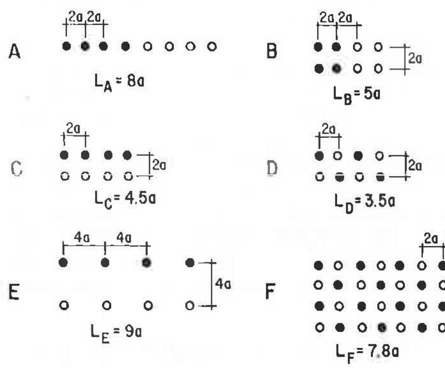
This principle is also valid for obligatory trips with the exception that the nearest activity place is also the only place (sometimes not near at all). It can be argued that one would try to find a job near the residence place or move as close as possible to the job place itself. This is, however, not always easy, feasible, or particularly desired (e.g., one might prefer to travel farther so as to live in a particularly attractive neighborhood; in families with two or more employees, which is very common today, one or more of them may have to travel relatively far to work).

An analysis follows to find out how differences in city geography can influence average distance L^{obl} and, consequently, average obligatory trip duration t^{obl}. This problem seems to be significant, since

$$t^{obl} = T^{obl}/N^{obl} \tag{2}$$

Assuming that obligatory trip rate N^{obl} = constant, which reflects one of the most stable transportation regularities (an employee travels every working day to his or her job, and traveling home

Figure 1. Distribution of employment places and labor forces and its influence on average work trip length.



for lunch does not happen often), then obligatory travel-time budget T^{obl} = constant only if t^{obl} = constant. Quite a few simplifying assumptions are made for this analysis:

1. Identical units of employment and labor force are situated in regular geometric configurations ($E_i = E_j = F_k$),
2. The proportional distribution is applied (α = 0 in the gravity model), and
3. No diagonal routing is allowed.

Six simple theoretical cases are studied (Figure 1). The respective calculated values of L are given. Keeping in mind all simplifying assumptions, one can see that

1. Change in both shape of the city and distribution of work places brings significant changes in L (cases A, B, C, and D),
2. n^2 times decrease of population and employment densities brings n times increase in L (cases C and E), and
3. Increase in city size with unchanged patterns of labor force and employment distribution brings a natural increase in work travel distance L (cases D and F).

In reality these differences will not be so drastic (e.g., in large cities the proportional distribution does not hold). The tendencies, however, are clear:

1. Because of differences between cities A and B (due to shape, size, and distribution of work trips ends), $L_A^{obl} \neq L_B^{obl}$ and $t_A^{obl} \neq t_B^{obl}$; and
2. If a city population increases and/or is redistributed toward the suburbs, L^{obl} increases and, consequently, so does t^{obl} (the latter increasing probably slower, however, because of the potential use of expressways with higher speeds).

In summary, it should be expected that t^{obl} is not stable either geographically or temporally. So, if N^{obl} is relatively stable, then $T^{obl} = N^{obl} \cdot t^{obl}$ is not. The total travel-time budget T will be as follows:

$$T = T^{obl} + T^{disc} \quad (3)$$

How probable is it that T^{disc} will be decreasing when T^{obl} is increasing in order to hold T constant? There are, basically, two possibilities for such an adjustment: (a) to reduce gradually L^{disc} and t^{disc} or (b) to reduce the number of discretionary trips. Both possibilities seem to be counterintuitive: (a) If person P_i already makes rational choices, there is not much chance to find closer attraction points (e.g., closer shops), and (b) if trips reflect his or her real needs, person P_i may find it difficult to eliminate any discretionary trips. The opposite situation seems equally improbable. Let us suppose that person P_i (or better, 1000 persons) moved to a new residence near work. Instead of t_1^{obl} = 30 min, they have now, say, t_2^{obl} = 5 min. Will they double their normal discretionary activities or will they not shop in the nearest shops to maintain t_2^{disc} = 55 min?

The above theoretical considerations can be supported by empirical evidence. Gunn (6) finds the "discretionary travel...positively correlated with mandatory travel, instead of negatively as a simple hypothesis of attempting to attain a particular 'budget' level would suggest." Banjo and Brown (see paper elsewhere in this Record), citing the travel-expenditure data from Lagos and Ibadan, Nigeria, show that unusually large times of travel for work (89 and 78 min, respectively) are accompanied by exceptionally long times for nonwork trips (111 and 113 min, respectively).

Environment of Transportation Subsystems: How Much Influence on Travel Behavior?

Remarks made in this section refer to the given (homogeneous) group of travelers (subject subsystem) and a given concrete land use and transportation reality (object subsystem). Thus, both travel needs of the group (demand) and the means to realize them (supply) are known. The question now is, What changes in travelers' behavior can be expected as a result of changes in the surrounding environment (policies, economy, energy situation, etc.)?

Travels reflect needs for outside-the-home activities that are often vital to a person's life and that of his or her family. Traveling plays a role for the outside-the-home activities just as using electricity, heat, or water does for the inside-the-home activities: Without these basic services, participation in activities would be impossible. How do we normally treat other essential needs in the context of expenditures or budgets? How many persons, for example, will decide to underheat their apartments because of the rising costs of heating? Who would, on the other hand, overheat his or her apartment only because the heat cost in his or her residential place is exceptionally low?

These are, of course, exaggerated examples, but they show that basic needs are very slightly, if ever, affected by changing environment. It would not be surprising if the heating-expenditures analysis were to show (in macroscale, at least) some interesting regularities; this, however, would be neither target budget nor constraint budget but simply a shadow of another regularity--constancy and inflexibility of basic needs. The desired apartment temperature will be the primary regularity here; heating-expenditure regularities will result from it.

The evidence that transportation needs are similarly basic can be supported by the analysis of elasticity coefficients, e.g., in the relation between changes in public transit fares and patronage. Numerous studies found transportation demand inelastic. For example, the observed percentage ridership loss on New York City subways in response to a 33 percent fare increase was only 2.4 percent [a fare elasticity of -0.09 (13)]. Fare reductions also bring a less-than-proportional change in ridership; e.g., in St. Louis, lowering fares from 45¢ to 25¢ brought only a 15 percent increase in passengers (13). Consumers' responses to price changes of other basic services or goods produce similar elasticity coefficients. Herz (14) offers empirical evidence from German cities that the environment affects travel behavior only very slightly. Similar conclusions can be supported by findings from Baltimore and the Twin Cities, which will be presented later in this paper.

The principle that basic needs will be satisfied at a similar level under any (except, maybe, catastrophic) external circumstances does not mean that some rationalization will not take place; e.g., if a new heating system is significantly cheaper than the original one, the decision to install this new system will be a rational action provided the apartment can be heated equally well. Similarly, a fuel-efficient car may have slightly reduced travel comfort but can fulfill its basic role equally well, i.e., to transport a person to his or her points of outside-the-home activities.

STABILITY OF TRAVEL EXPENDITURES: HOW STRONG ARE THE ASSUMPTIONS?

Money Expenditures: Is Amount of Travel a Regulatory Element?

Money expenditure on transportation in the United States and Canada is about 13 percent of total expenditure (1); in Britain, it rose from about 7.5 percent in 1956 to about 13 percent in 1972 (15). Statistics at more disaggregate levels would suggest that families can tolerate transportation-expenditure variations in relatively wide ranges, e.g., British families with cars spent about three times more money on transportation than families without cars (1). Even if families attempt to slow down the increase in transportation expenditures, only some elements of the total are flexible and can serve as a regulatory function. For example, a family can regulate the type of car they buy (price, fuel efficiency) but not, below strict limits, the mileage driven.

Proportions between different transportation expenditures are also important; e.g., one flight between Buffalo and Denver costs $550, which would cover about two years of bus fare expenses on travel to and from work in Buffalo (at 50¢ a ride). Assuming that the flight was not planned but absolutely necessary (e.g., a pressing family matter), would one consider walking, say, three miles to work each day in order to lower total transportation expenditures? A much more probable reaction to this unexpected expenditure would be a trade-off with an expenditure that is not so essential.

Money expenditures for travels within a city are rarely seen as dramatically high and unacceptable (even for poor people) when compared with other basic expenditures. Possibilities of different trade-offs in expenditures (inside and outside transportation) as well as local differences (e.g., in public transit fares and in the geography of the city) raise doubts about the usefulness of the travel-money-budget concept for transportation planning purposes at the city level.

Time Expenditures: Trade-Offs Between Travels and Activities

Time spent on traveling in Baltimore is about 65 min for employed persons and about 35 min for those nonemployed (see Figure 2). In the first case, it is about one-eighth of the time disposable for all inside-the-home and outside-the-home activities (8-h sleep, 8-h work); in the second case, for nonemployed persons, it amounts to about one-thirtieth of the whole disposable time. Both proportions, particularly the second one, are not very high and leave enough time for different trade-offs between (discretionary) activities and travels and between travels and activities that cause travels (e.g., saying that "we cannot stay longer at the party because it is late and we have a long way to travel"). The example of a trade-off for travel can be the following. Instead of visiting, say, three different places of discretionary activities in the neighborhood, one might prefer to travel farther (e.g., to the big mall) where all three activities can be performed at the same place.

There should be, of course, some limits in both expenditures, as Goodwin (5) suggests. Traveling, say, 2 h to and from work or spending 30 percent of the salary on travel will certainly be seen as unacceptable for an extended period of time. One should expect, however, that relatively wide ranges of time and money expenditures for travels can be seen as acceptable. Therefore, the use of fixed travel budgets as a primary regulatory device for determining the amount of travel seems a risky procedure in transportation planning.

Generalized Travel-Cost Budget: Trade-Off Between Money and Time or Increase of Both?

The concept of a generalized travel-cost budget assumes a certain trade-off between time and cost of travel. Tanner (2) says, "in practice, rich people tend to use modes that are fast but expensive (e.g., car) while poor people use modes that are slow but cheap (e.g., walking)."

Let us analyze this concept from the point of view of a homogeneous group of travelers, say, a group of employed people who always have available both a car and public transportation. If the places of work and home residence are fixed, the analyzed group of persons will have, indeed, the choice of traveling faster but more expensively (by car) or slower but less expensively (by public transit). How realistic is the situation that someone who has a free choice (i.e., car use is unrestricted, parking available, etc.) between car and public transportation will use the second mode? Results from Baltimore and Minneapolis showed that employed persons with a car always available will use public transit in only about 1 percent of the cases [see Figure 3 (16)]. If the concept of a generalized travel budget were valid, this percentage should be much higher. Clearly, the trade-off between car and public transit is not based on travel cost; the car wins here because of its other important advantages, such as convenience and flexibility.

What about the trade-off between the car and walking? In this case, the main factor is the limit of walking distance. The gasoline expenditure saved by walking short distances instead of driving will be only marginal, and all longer distances will have to be driven anyway.

Let us assume now that the analyzed group of persons change residence location and move to the suburbs. Nearly all attraction points (work, shops, banks, etc.) will now be farther away. The distances driven will be longer. Even if the speed is now higher, it will mean, generally, more traveling both in terms of money and time expenditures. Instead of a trade-off between money and time, we have here an increase of both and thus an increase in generalized travel cost. Increase of travel distance is a normal consequence of city development, particularly if new suburbs are much less dense. An exodus from city centers toward suburbs,

Figure 2. Travel characteristics for eight Baltimore person categories.

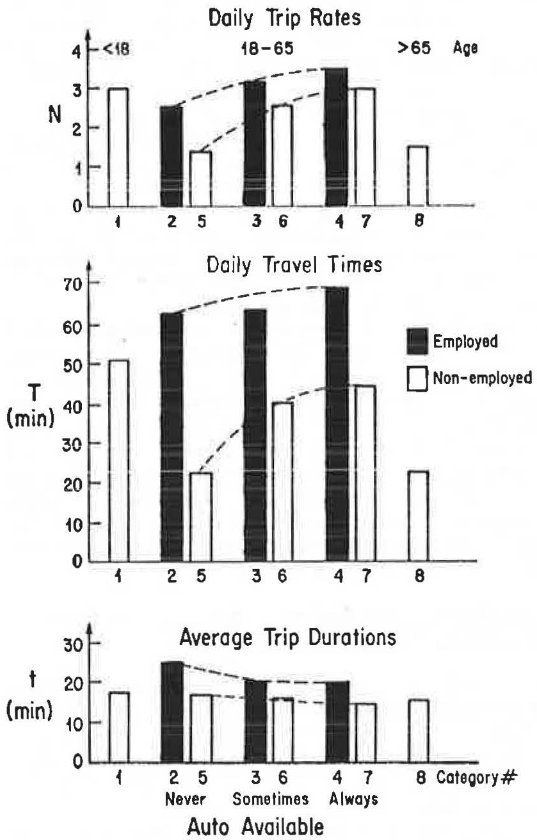
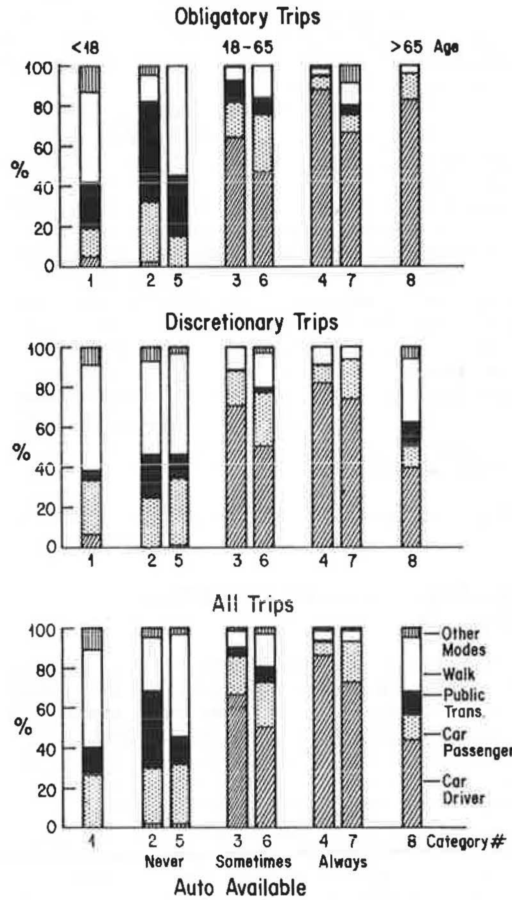


Figure 3. Basic modal splits for person categories 1-8 in Baltimore.



which is observed quite often today, is another factor that influences the increase of a generalized travel-cost budget.

Perhaps this is part of the reason why "generalized expenditure on travel (in Britain) has increased faster than real incomes" (2). Cautious optimism that generalized expenditure on travel "might remain constant over a wide range of circumstances" (2) seems still theoretically and empirically unproven.

EMPIRICAL FINDINGS FROM BALTIMORE AND TWIN CITIES

Subject Subsystem: Importance of Proper Market Segmentation

The theoretical discussion from the previous section is now followed by some empirical findings. A systematic three-stage multivariate analysis of travel behavior was done by using 1977 data from Baltimore in order to build a simple travel-demand model based on a limited number of homogeneous person categories (as opposed to household or traveler categories). Among eight originally analyzed variables (referring only to the subject system, i.e., to the person as a potential traveler)--employment status, car availability and ownership, age, sex, family status, employment type, and race--the first three variables appeared to be the most significant in describing differences in a person's travel behavior expressed by daily trip rate N, daily time spent on traveling T, and average trip duration t (see Figures 4 and 5). The car-availability variable is defined as follows. For persons possessing a driver's license, a car is always available if $Nc_i \geq Nd_i$ (where Nc_i = number of cars in the family i and Nd_i = number of drivers in the family i). A car is sometimes available if $Nc_i < Nd_i$ ($Nc_i \neq 0$). It is never available for a given person if he or she does not possess a driver's license or if $Nc_i = 0$.

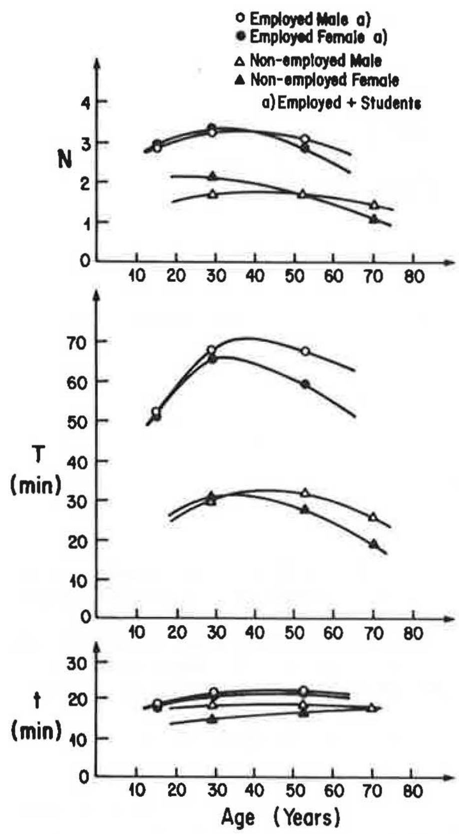
Analysis done here strongly supported a person data-aggregation level (as opposed to a household level) and revealed some interesting findings (17). For example, two variables--family status (single, family with children, family without children, etc.) and income--were not statistically significant. The first finding supports the idea that travel choices of each family member are made independently and the second shows that income duplicates the explanation of the variable of car ownership, the latter being always much stronger and more consistent (see Figure 5).

This study employed pair-wise comparisons of the means, analysis of variance, and Q-type cluster analysis. The number of categories was reduced from 100 to 40 and finally to 8. The final category description and basic travel characteristics are summarized in Table 1. Characteristics N_i, T_i, and t_i are also presented in graphic form (Figure 2). Trip frequency distributions for categories 1 through 8 are presented in Figure 6, hourly trip histograms in Figure 7, and basic modal splits in Figure 3.

Findings from the Baltimore metropolitan area can be summarized as follows:

1. There are significant differences between person categories due to all analyzed travel characteristics, i.e., trip rate N, travel budget T,

Figure 4. Trip rates, travel-time budgets, and average trip durations in relation to age, employment status, and sex: Baltimore, 1977.



average trip duration t, trip frequency distribution f, hourly trip histogram H, and basic modal split m. There is empirical evidence (Table 1 and Figures 3 and 6) that ignoring nontravelers and some transportation modes (e.g., walks) represents an undesirable simplification of any concept of travel budget.

2. The theoretical critique of the travel-time budget based on the average traveler who is representative of a given family type can now be confirmed empirically. Differences in travel-time budgets between family members are dramatic and much more significant than in trip rates N_i (range between 20 and 70 min). Any average values of T, calculated for the family as a whole, depend first of all on family size and structure.

3. The saturation effect suggested by Goodwin (5) can be observed here in both trip rates N_i and travel times T_i (Figure 2). These levels are visibly higher for employed persons (particularly in travel times T_i = 70 min) than for nonemployed persons (T_i = 40 min). The saturation effect

Figure 5. Trip rates in relation to automobile availability, income, and age: Baltimore, 1977.

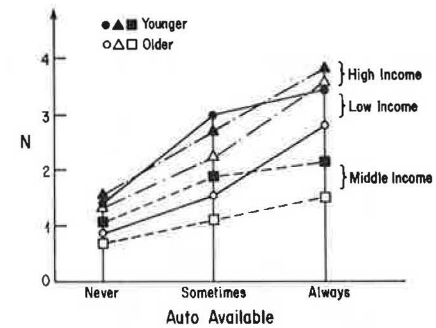


Table 1. Basic travel characteristics of person categories 1-8 in Baltimore.

No.	Category Description	α_i (%)	$\gamma_i^{nontrav}$ (%)	β_i^{walk} (%)	N_i Mean	N_i SD	T_i (min) Mean	T_i (min) SD	t_i (min) Mean	t_i (min) 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, $\gamma_i^{nontrav}$ = 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 6. Trip frequency distributions for person categories 1-8 in Baltimore.

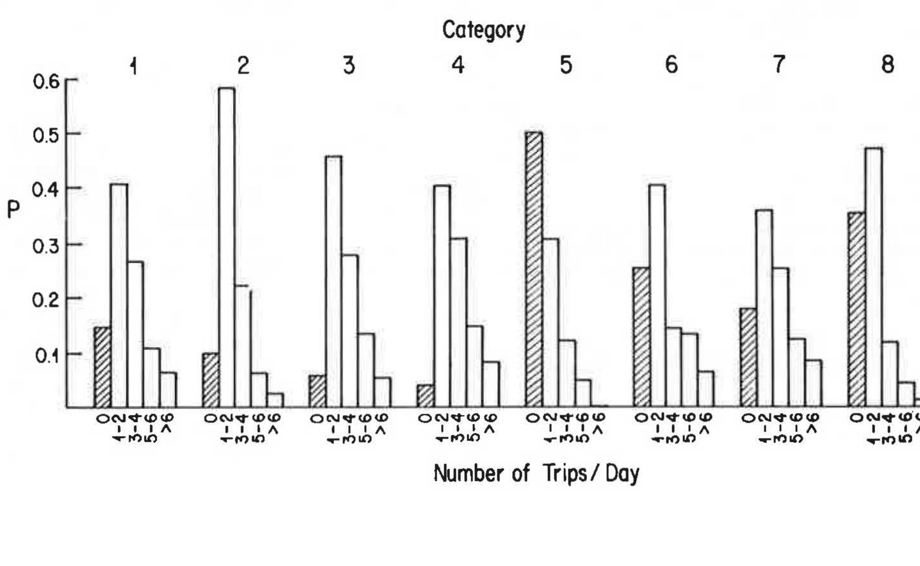


Figure 7. Hourly trip histograms for person categories 1-8 in Baltimore.

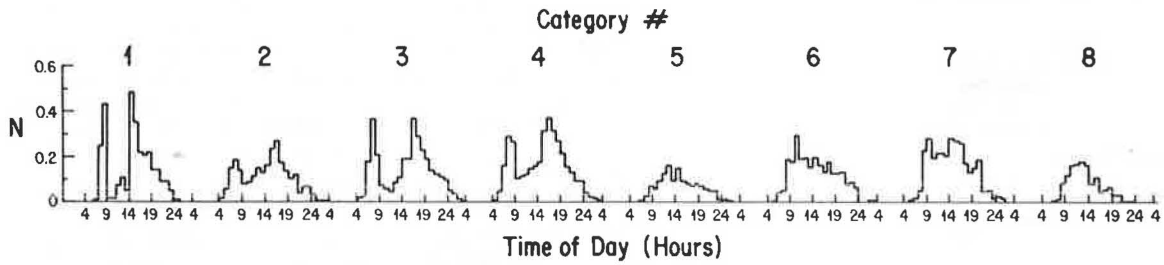
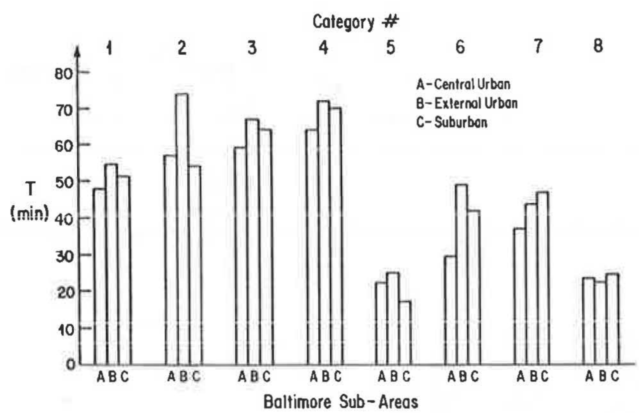


Table 2. Category percentages of α_{ij} in three Baltimore subareas.

	Percentage of α_{ij} by Category							
Baltimore Subarea	1	2	3	4	5	6	7	8
Central urban	18.3	15.9	9.6	8.9	27.4	5.9	3.8	11.1
External urban	20.5	9.3	13.5	19.3	16.8	6.9	4.3	9.4
Suburban	15.4	2.7	17.0	27.5	7.9	8.0	11.0	10.5

Figure 8. Travel-time budgets for person categories 1-8 for three Baltimore subareas.



occurs in the situation of car always available, which is agreeable with expectation.

4. Average trip durations are visibly differentiated between employed and nonemployed persons, again as expected. Nonemployed persons have discretionary activities only, most of which could be done relatively near the residence place, while employed persons must participate also in obligatory activities (work), regardless of their locations.

5. Travel-time budgets, if they exist, are very different for different categories of persons. Figure 2 shows that category 5 [with car never available (so with lowest speed)] spends significantly less time on traveling than respective categories with a higher level of car availability and, consequently, higher speed. It is contradictory to some suggestions about the relation between travel-time budget T and speed V--higher speed, therefore less traveling--which does not hold for the unit "person".

Influence of the Object Subsystem: Trip Rates (Activity) Budget Versus Travel-Time Budget

The research presented in this section attempts to answer the following three questions:

1. How do differences in area type affect category representation (how much the average person varies from area to area)?
2. Which travel characteristic, when referring to a homogeneous group of persons, is more geographically stable--trip rate N_i or travel-time budget T_i?
3. What is the influence of speed on the travel-time budget?

To make comparisons possible, the Baltimore metropolitan area was split into three zones: central, external urban, and suburban. The respective percentages of person categories α_{ij} are shown in Table 2. Categories 2, 3, and 4 (employed) and 5, 6, and 7 (nonemployed) are differentiated by car-availability level (never, sometimes, and always). As seen from Table 2, proportions $\alpha_2:\alpha_3:\alpha_4$ and $\alpha_5:\alpha_6:\alpha_7$ vary significantly among the three Baltimore subareas. The relation between car-availability level and area population density was used as a base for the person car-availability model (18).

A two-way analysis of variance was employed to check the stability of values N_i, T_i, and t_i between the three subareas (central, urban outskirts, and suburbs) of Baltimore and to find out which differences (those between person categories or those between areas) were more significant in explaining differences in these basic travel characteristics. Travel budgets for respective person categories and Baltimore subareas are shown in Figure 8. This part of the analysis yielded the following results:

1. There are important differences in category percentages α_{ij} among Baltimore subareas. Area differences in car-availability level, proportion of employed to nonemployed, and age distribution are the reasons why the units "an average person" or "average representative of a family" are not comparable between areas and cities.

2. The desired level of automobile availability depends on employment status and residence location. The need for automobile accessibility is much higher for employed persons than for nonemployed ones because important obligatory activities (work) require reliable, fast, and flexible transportation more often than discretionary activities (longer travel distance is also a factor here). The loca-

tional differences in car-availability level also agree with expectations: The level of automobile availability has to be higher in the suburbs where the need for private transportation is higher (e.g., longer trips distances), automobile exploitation is easier (no parking problems), and the use of alternative transportation modes (public transit and walking) is limited. The relation between area type (measured by population density) and desired level of automobile availability was found to be regular (Figure 9).

3. Trip rates of homogeneous categories of persons appear to be more geographically stable than respective travel-time budgets T_i, as shown in the table below, which gives the results of the analysis of variance for N_i, T_i, and t_i for Baltimore (category versus area difference):

Factor	F-Values N	T	t	$F^{0.05}$
A, categories	13.37	45.21	10.91	2.77
B, areas	2.64	6.50	2.78	3.74

This finding is in agreement with the recent results obtained by Herz (7), Gunn (6), and Banjo and Brown (paper elsewhere in this Record). In the last study, where the travel-time budgets were found to be exceptionally high (about 3 h), the authors say that, "The recent Lagos Metropolitan Area Transportation Study indicated that trip rates were similar to those recorded in Western countries."

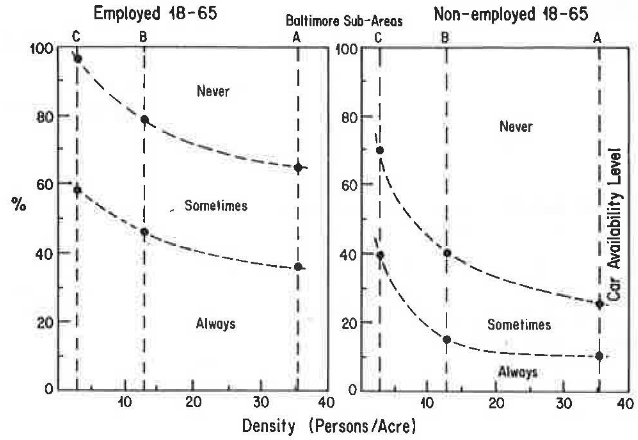
4. Differences between person categories are statistically significant for all three basic travel characteristics--trip rate N, travel time T, and average trip duration t--which supports once again a person data-aggregation level and the need for proper market segmentation of this analysis unit.

5. The suggestion that higher speed will yield less traveling does not hold (Figure 8). As Prendergast and Williams (19) found, a higher automobile availability and/or ownership level (and also higher speed) brings an increase in travel times. This effect can be seen while comparing respective person categories (e.g., category 5, car never available; and category 6, car sometimes available) as well as geographic areas (central area A, lower speed; external urban area B, higher speed). Contrary to some suggestions, speed does not appear as a primary factor here. The findings suggest that it is population characteristics (age and employment status) that dictate the need for activities and travel, while the geography of the city (distribution of attraction points) influences travel distance and desired car-availability level that, through the supply-system characteristics (e.g., speed on the road and/or in public transportation), result in travel-time expenditures.

Comparison Between Baltimore and Twin Cities: Activity Budget Versus Travel-Time Budget

Comparison of travel characteristics between Baltimore and the Twin Cities promised to be an interesting research task. First, there are significant differences in geography, size, transportation infrastructure, density, and other object system characteristics between these two metropolitan areas. Second, the Twin Cities transportation survey was done in 1970 while the Baltimore one was done in 1977; the time between 1970 and 1977 brought some important changes in the transportation surrounding environment (e.g., oil crisis, reorientation in policies, etc.). Potentially, this comparison could allow, therefore, the examination of both spatial and, to some extent, temporal stability of the basic travel characteristics N, T, and t.

Figure 9. Relation between car-availability level and residential density for employed and nonemployed persons in Baltimore.



Unfortunately, all of these characteristics had to be related to travelers only (instead of all persons) and their nonwalk trips because, in the Twin Cities, data sets for nontravelers and walk trips were not recorded. This lack of data compatibility, a common phenomenon in transportation surveys, was of course very undesirable, particularly in light of previous discussions about the analysis unit. This restriction, however, was the only way to make possible any comparison between these metropolitan areas. Two more undesirable changes in the original model concept had to be made, the lack of data compatibility again being the reason. First, category 1 had to be reformulated into young persons of age 14-24 instead of the original category of persons less than 18 years of age. Second, the recommended version of category definition based on car availability (car never, sometimes, or always available) had to be replaced by a version based on family car-ownership level (0, 1, or 2+ cars). The only advantage of the model reformulation was a chance to examine how the results obtained correspond to these travel-budget analyses that consequently employed the unit "traveler". All limitations of the model that result from excluding nontravelers, walk trips, etc., should, of course, be kept in mind while analyzing the results obtained here.

Both metropolitan areas were split into two subareas: urban and suburban. Table 3 gives travel-time expenditures per traveler in the urban and suburban areas of Baltimore and the Twin Cities. A three-way analysis of variance was employed to examine which factors--categories, cities, or areas--were mainly responsible for explaining differences in trip rates N, daily travel times T, and average trip duration t. The results of this analysis are presented in Table 4.

An attempt also was made to calculate transferability errors for N, T, and t characteristics between Baltimore and Minneapolis. For example, trip rates for Minneapolis were calculated as follows:

$$N^{MINN}_{calc} = \sum_{i=1}^{8} \alpha^{MINN}_{i,\,surv} \cdot N^{BALT}_{i,\,surv} \quad (4)$$

where α_i is the percentage of category i. A similar procedure was applied to calculate respective values of T and t.

The respective transferability errors were calculated as follows:

1. Without category split, where respective

Table 3. Travel-time expenditures in Baltimore and Twin Cities for person categories 1-8 (travelers and nonwalk trips only).

City	Area	Travel-Time Expenditures by Category (min) 1	2	3	4	5	6	7	8
Baltimore	Urban	74.1	74.1	74.0	70.0	72.1	64.4	56.8	58.4
	Suburban	63.0	57.5	68.8	67.7	35.0	58.6	56.6	53.6
Minneapolis	Urban	54.7	57.5	59.0	59.8	46.7	51.6	53.1	45.9
	Suburban	57.8	62.5	65.4	68.8	57.6	48.5	52.1	49.6

Table 4. Results of analysis of variance of main tripmaking attributes for three factors (travelers and vehicular trips only).

Characteristic	Factor	F-Statistic	F-Critical at 0.05 Level
Daily trip rate ($N^{trav, veh}$)	Category	6.79	3.79
	City	4.90	5.59
	Area	2.05	5.59
Daily travel time ($T^{trav, veh}$)	Category	2.52	3.79
	City	7.16	5.59
	Area	1.72	5.59
Avg trip duration ($t^{trav, veh}$)	Category	19.11	3.79
	City	45.67	5.59
	Area	6.59	5.59

survey values were directly borrowed from Baltimore to the Twin Cities:

$$\text{Error 1} = (N_{surv}^{BALT} - N_{surv}^{MINN})/N_{surv}^{MINN} \quad (5)$$

2. With category split, where the calculated and survey values from the Twin Cities were compared:

$$\text{Error 2} = (N_{calc}^{MINN} - N_{surv}^{MINN})/N_{surv}^{MINN} \quad (6)$$

The results of this transferability check are given in Table 5.

This part of the analysis yielded the following results:

1. Differences in travel times T between areas and categories are flattened by the change of analysis unit from person to traveler, as expected. Travel times T_i for employed travelers are now only slightly higher than travel times for their nonemployed counterparts (Table 3). The important differences in the percentage of nontravelers between employed and nonemployed persons remain unexplained while using traveler as an analysis unit. Therefore, results presented in Table 4 are much less valuable than findings from the in-text table that showed analysis of variance and should be treated with caution.

2. Differences in travel times (per traveler) between cities and areas (urban and suburban) are not consistent. In Baltimore, the urban travel times are higher than their suburban counterparts, while in the Twin Cities the opposite result occurred.

3. The regularity suggested in Zahavi (1), i.e., lower speed, therefore higher travel time, does not appear to hold even for the analysis unit "traveler". Differences in T between categories (2, 3, and 4 and 5, 6, and 7) and areas (urban and suburban) are not consistent: In Baltimore, suburban residents (higher speed) travel less, but in the Twin Cities the opposite regularity appeared. Representatives of category 4 (higher speed) in three of four analyzed cases travel longer than their category 2 counterparts (lower speed), which is again contradictory to the suggestion made in Zahavi (1). This, again, questions the primary importance of speed influence on travel budgets.

4. The analysis of variance (Table 4) suggests that trip rates N (even if related to travelers instead of persons) show greater stability between cities and geographic areas than respective travel times T. The reason for this is a very area-specific characteristic t (trip duration), which is strongly dependent on local distribution of generation and attraction points. The differences in trip duration t affect travel times T rather than trip rates N, which would support the previous theoretical analysis.

5. Transferability analysis for $N^{trav, veh}$, $T^{trav, veh}$, and $t^{trav, veh}$ between Baltimore and the Twin Cities shows consistently better transferability of trip rates N than respective travel times T (Table 5). Again, this is caused by differences in the area-specific characteristic $t^{trav,veh}$. Values t and T are not transferable between urban areas of Baltimore and the Twin Cities because of object system differences between these areas. However, trip rates N have low transferability errors.

CONCLUSIONS

The findings from the studies of Baltimore and the Twin Cities have already been detailed in this paper. Therefore, only the most general conclusions are presented here.

1. Both theoretical discussion and empirical findings from Baltimore and the Twin Cities seriously question the validity and applicability of any travel-expenditure-budget concept in urban transportation planning. Potential applications of the methodologies derived from travel-budget concepts should be carefully verified in light of the critique of the original concept.

2. There is a need for some methodological improvement and clarifications, as well as for a stronger behavioral background, in analyzing regularities in the traveling process. In particular, the proper choice of the analysis unit and its adequate categorization should be seen as a prerequisite for finding meaningful regularities and allowing reasonable comparisons of results.

3. Due to improper choice of the analysis unit (e.g., the traveler), some artificial regularities in travel budgets can be observed. Regularities in travel budgets often reflect only other, more meaningful regularities in trip rates. Trip rates appear to be more regular and stable than the respective travel-time budgets. This finding is agreeable with recent findings of other authors.

4. An alternative concept presented in this paper, which is satisfactorily verified by Baltimore and Twin Cities data, could be formulated as stability of activity budgets (represented by trip rates) of homogeneous groups of persons.

5. A simple travel-demand model proposed for American cities, based on eight homogeneous person categories (differentiated by age, employment status, and car availability), reveals meaningful regularities in many travel characteristics studied.

Table 5. Comparison of transferability errors between Twin Cities and Baltimore for main tripmaking attributes (travelers and vehicular trips only).

	Urban Area (%)		Suburban Area (%)		Entire Area (%)	
Characteristic	Error 1	Error 2	Error 1	Error 2	Error 1	Error 2
Daily trip rate ($N^{trav, veh}$)	-8.1	-4.3	-7.7	-6.6	-10.6	-7.6
Daily travel time ($T^{trav, veh}$)	28.2	25.6	7.5	-4.9	17.5	10.8
Avg trip duration ($t^{trav, veh}$)	43.6	31.2	16.7	14.7	31.3	23.8

The model appears to be transferable within the Baltimore metropolitan area and between Baltimore and the Twin Cities.

6. The universality of the proposed model will not be known until more transferability tests are performed. The first results are encouraging. Further development of the model will concentrate on the interrelation between transportation demand and supply. The following principle is adopted: One should expect that travel choices made by a homogeneous group of persons will be stable if external conditions (options, constraints, etc.) relevant to these choices remain unchanged.

ACKNOWLEDGMENT

This paper is based on the results of a research project sponsored by the Federal Highway Administration, U.S. Department of Transportation, and performed when I was with the State University of New York at Buffalo. I would like to thank Anthony DeJohn for conducting the necessary computations, as well as William Waddell and Woon Sin Chin for their help in preparing this paper. The responsibility for the views expressed in this paper rests solely with me.

Discussion

Yacov Zahavi

Supernak's paper is timely in that it includes a number of the currently prevalent misunderstandings about the concept of a travel-time budget. A travel-time budget does not mean that each and every traveler must travel a fixed time per day each and every day--an interpretation that is quite absurd. Nor does it mean that travel-time expenditures will be regular, regardless of how they are stratified. It is quite obvious, for example, that segmenting travelers or persons by such groups as housewives versus working husbands, or age 20-30 versus age 70-80, will result in significantly different daily travel-time expenditures per average traveler or person.

The question, therefore, is not whether the daily travel times of travelers or persons are fixed--which, obviously, they are not--but whether regularities that are transferable in both space and time exist at a useful level of disaggregation. Only when such regularities are fully transferable can they serve as the basis for transferable travel models.

It is also obvious that there are many ways by which such travel times can be analyzed for their regularities versus their variations, and the results depend more on the researcher's attitude and approach than on the data. It should be emphasized, therefore, that the statistical nonrejection of one hypothesis based on one choice of data stratification does not necessarily reject other hypotheses based on other choices of data stratification.

Perhaps the best way of explaining the above general comments is by showing how the same Baltimore data set displays results that are contradictory to those shown by Supernak. Even so, both results can be regarded as valid, and each researcher can then structure his or her own model, based on his or her own convictions and analysis results. However, 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. This is why the following Baltimore (1977) results are compared with those of Washington, D.C. (1968), as well as those in London and Reading (1977) in the United Kingdom, as summarized by the respective transportation authorities (20). Because of space limitations, the results are shown graphically.

The following regularities are per traveler, averaged by his or her household socioeconomic characteristics, including income, household size, and car ownership. A traveler is defined as a person making one or more trips per day by a motorized mode (e.g., car, bus, taxi, urban rail, motorcycle). (The issues of travelers versus persons and of walking versus motorized travel are discussed later.)

Figure 10 shows that the proportions of households generating at least one motorized trip during the survey day versus car ownership levels can be regarded as transferable between the three cities (no such data were available in the Washington, D.C., tabulations). Figure 11 shows that the number of travelers is strongly related to household size and that the relation is transferable among the four cities. Figure 12 shows the daily travel-time frequency distributions per traveler by household income in Baltimore. Contingency-table analysis indicated that the null hypothesis of equivalency among the six distributions is accepted (at the 95 percent confidence level). Figure 13 shows gamma functions fitted to the six income groups. Figure 14 shows gamma functions fitted to the four distributions by car ownership levels. Equivalency was accepted for the three-car ownership levels, namely 1, 2, and 3+, while significant differences were found between zero-car and car-owning travelers. Figure 15 shows gamma functions fitted to the daily travel distance distributions per traveler by car ownership.

The relations shown in Figures 14 and 15 suggest that (a) travel speeds increase with car-ownership levels, and (b) travelers at higher speed spend less daily travel time for more daily travel distance. It may also be concluded that part of the times saved by speed increases are traded off for more travel distance. Another way of showing the effect of speed on travel is depicted in Figure 16, where the data are stratified in three ways: by income, by cars per household, and by household size. Figure 17 shows that the travel-time frequency distribu-

Figure 10. Percentage of households traveling versus cars per household.

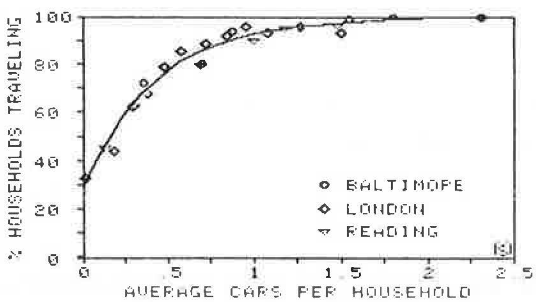


Figure 11. Travelers per household versus household size.

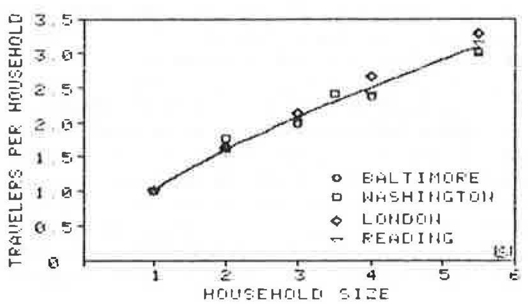


Figure 12. Travel time per traveler distributions by household income.

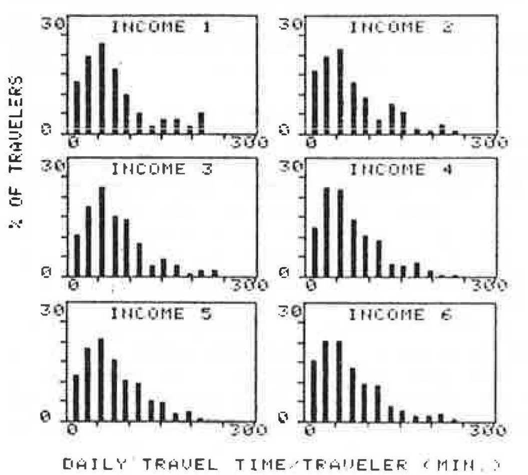
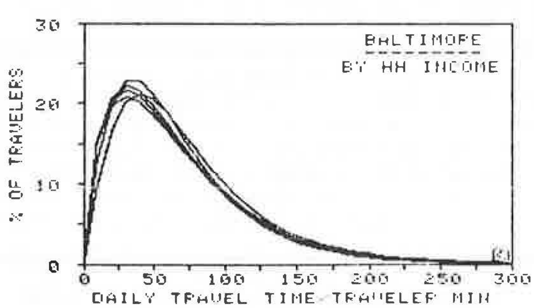


Figure 13. Travel time per traveler distributions shown in gamma functions for six income groups.



tions are transferable among the four cities when accounting for travel speed.

It may be concluded from the above sample relations that regularities of travel-time frequency distributions are transferable among the four cities, cities that are markedly different by such factors as size and car-ownership levels. Furthermore, travel speeds do affect the daily travel times and daily travel distances of travelers.

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. Thus, while walking should be considered as a separate mode in travel and urban structure models, especially when dealing with the inner parts of a city, the amount and characteristics of motorized travel can be estimated by the above relations per traveler who uses motorized modes.

The last comment refers to the issue of traveler versus person. Supernak prefers to relate daily travel times per person. Furthermore, he argues

Figure 14. Travel time per traveler distributions by car ownership level.

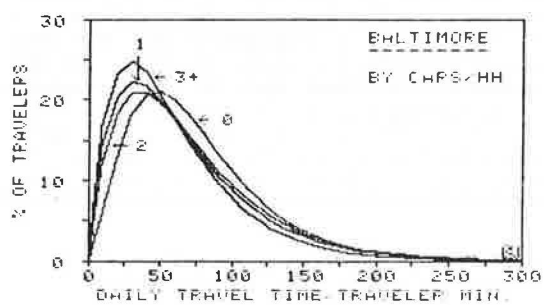


Figure 15. Travel distance per traveler distributions by car ownership level.

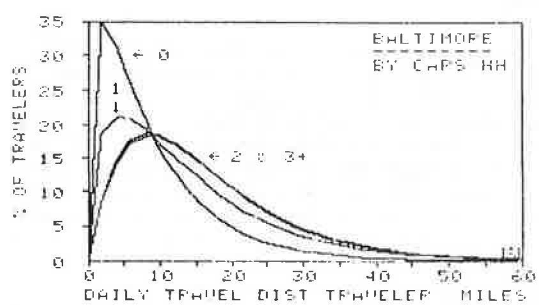


Figure 16. Distance per traveler versus speed.

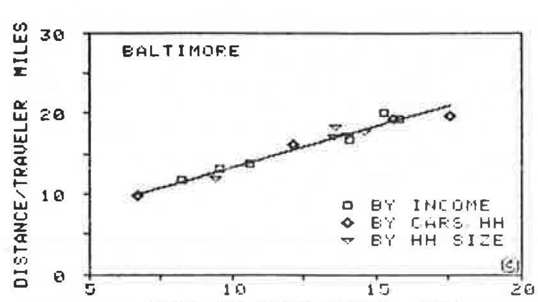


Figure 17. Travel time per traveler distributions: all travelers in four cities.

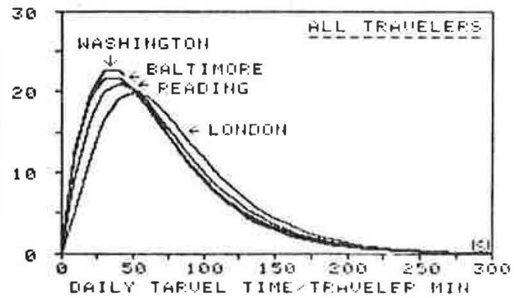


Table 6. Daily travel time per traveler and per person by household size: Baltimore, 1977.

	Household Size					
Item	1	2	3	4	5+	Avg
Households observed	89	161	130	112	172	664
Households traveling	73	150	122	109	165	619
Travelers per household	1.00	1.59	1.96	2.28	2.88	2.06
Daily travel time (hours)						
Traveler	1.27	1.21	1.23	1.34	1.25	1.26
Person	1.04	0.71	0.59	0.57	0.42	0.57

against the notion of an average household by socioeconomic characteristics and prefers to segment all persons by their individual characteristics, such as by age and employment. However, his preferences are not consistent. First, his argument against an average household can be applied equally well to an average person. Second, the same inconsistency also applies to his averaging a daily travel time reported by a traveler over nontravelers; a daily travel time per traveler of, say, 60 min, is not the same as 20-min travel time per average person when averaged over three persons, not even after segmenting the persons by their individual characteristics (see Table 1). Last, reallocating members of one household to different groups misses not only the possible interactions and trade-offs between members of the same household but also the effect of household size on travel characteristics.

The effect of household size on travel time can be best appreciated by the data in Table 6. As can be seen, while the daily travel time per average traveler per household remains similar for all household sizes, it drops sharply when applied per person. This is so because the proportions of travelers per household are related to household size. In Table 1, on the other hand, the daily travel time per person is averaged over households of different sizes, thus confounding the results.

The last comment also refers to Table 3: The travel times for nonwalking trips in Minneapolis-St. Paul appear to be far below those available from other sources (21). For instance, the total weighted average daily travel time per traveler is 67.8 min, but in Supernak's table only 1 class out of 16 is above this value. It would be advisable to recheck these values before reaching final conclusions.

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Life Cycle and Household Time-Space Paths: Empirical Investigation

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The results of a research effort that explored some of the effects of stage in life cycle on the evening paths of urban households are summarized. The stage in life cycle was used as a descriptor of microscopic household factors, such as interpersonal linkage constraints and needs and propensities for evening activities, that affect activity and travel behavior. A statistical investigation that used trip records of husband and wife couples from a conventional origin-destination data set was carried out. The large sample allowed the spatial analysis of a geographic subsample and the analysis of interaction effects by means of multiway contingency-table analysis. Travel patterns of husband and wife couples were collectively represented as paths in time and space, and the associations between various path characteristics and life-cycle stages, as well as the interactive effects of other factors such as household work-trip status and individuals' household roles, were examined. The results indicate that the life-cycle stage of the household is related to many aspects of the evening path: engagement in evening out-of-home activities, type of path, participation of the spouse in the evening out-of-home activities, number of sojourns, and time of returning home. The presence of children in the household was found to have substantial impacts on the adult members' activities and travel. The stage in household life cycle was not found to be directly related to the spatial distributions of sojourns in the evening paths.

The formulation of the existing frameworks of travel-behavior analysis has involved various simplifying assumptions. Although these assumptions have made the models developed within such frameworks operational and immediately applicable to practical forecasting, at the same time they have placed the subject of analysis--travel behavior--somewhat out of context. For example, the effects of interpersonal interactions on household tripmaking (1), interdependencies among the decisions for respective trips and activities (2), and spatial and temporal dependence of travel behavior (3) have been, at best, only remotely represented. The recognition of such limitations in the existing approaches has led to recent proposals and research efforts for the development of more relevant analytical frameworks of activity and travel analysis (4-7). It is now well acknowledged that viewing urban travel as a linkage between activities offers a way to gain a better understanding of travel behavior, especially of how people modify their activity and travel when faced with changes in the general transportation and activity environment. It has also been recognized that activity scheduling and tripmaking are subject to various constraints and travel patterns developed within this constrained framework (1,8,9).

When travel is viewed as a linkage between activities, it is logical to examine the factors that have important effects on individuals' and households' activity patterns. As such a factor, life cycle has received extensive attention (9-14). It has been found that the presence of children in a household has significant effects on the adult members' travel behavior (9,10,15,16). Many empirical observations indicate strong correlations between the life-cycle stage and simple measurements of travel patterns (3,9,11,17). These results suggest that life cycle is strongly correlated with the types and frequencies of activities pursued and hence with travel patterns. Particularly important are the needs for additional activities such as child care and the interpersonal linkage constraints (1,8) that are brought about by the presence of children in the household. Who takes the responsibility of child care and chauffeuring will largely prescribe the household members' activity and travel patterns (16-17). In light of the rapidly changing life-cycle-stage composition and labor force participation by women in the United States, a thorough understanding of the association between life cycle and travel behavior appears to be of extreme importance.

The objective of this study is to identify the effects that household life cycle has on travel patterns in time and space of adult members of households. The life-cycle stage is viewed as a variable that is relatively easy to forecast but at the same time can be expected to be closely correlated with microscopic factors that affect activity and travel behavior (e.g., interpersonal linkages and other household contraints, needs and propensities toward out-of-home and in-home activities, time use, and attitude). It can be expected that a better understanding of travel behavior can be obtained by inferring the effects of these factors from the observed correlations between life cycle and travel patterns. Knowing the distinctiveness in travel patterns across life-cycle stages will assist in making long-term travel forecasting more robust. The spatial and temporal characteristics of household travel identified in this study will also provide basic information for future model-building efforts.

In exploring the effect of life cycle on travel behavior, this study treats the travel patterns of adult household members as trajectories (or paths) in time and space. This representation is based on the work of Hagerstrand (8), who has provided a comprehensive paradigm for the analysis of travel behavior. Representing an individual's activities and travel as a path within a prism defined by a set of constraints offers a legitimate framework for studying travel behavior. This prism of feasible activity space is a particularly useful concept in investigating spatial and temporal characteristics of the path.

Earlier efforts by Kostyniuk and Kitamura de-