Regularities in Travel Time and Money Expenditures

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The regularities in travel time and money expenditures of households and travelers in urban areas are examined. Data from both developed and developing countries are analyzed and compared. The data analyses suggest that travel time and money expenditures display regularities that are associated with such factors as household socioeconomic characteristics, transport system supply, and urban structure. Special attention is given to the possible segmentation of households for travel demand analyses, as inferred from the travel time and money expenditures. The analyses suggest that travel time and money expenditures can be conveniently summarized as travel time and money budgets and that their relatively stable functions can be transferred between cities and over time in a country. Use of these travel budgets in travel forecasting and transport policy planning is discussed, and suggestions are made for future research into travel time and money expenditures.

Expenditures on travel in terms of time and money have always been a cornerstone in travel modeling. These expenditures, either separate or combined into generalized expenditures, are found in trip-generation, trip-distribution, and mode-choice models. All these models describe the behavior of trip makers. A trip will be generated only when the utility of making the trip surpasses its disutility, such as its cost in terms of time and money. However, trip expenditures are rarely aggregated to total daily travel expenditures per household or per traveler. These considerations raise the following question: If the time and money expenditures of single trips, by purpose, are found to be related to the household's socioeconomic characteristics, such as income, would not the same be expected of the total daily travel time and money expenditures?

This paper deals with the above question and suggests that, indeed, the total daily travel time and money expenditures are strongly related to the household's socioeconomic characteristics. It is also suggested that, when the mean expenditures on travel display predictable regularities that can be attributed to such factors as the socioeconomic characteristics of households, transport system supply, and urban structure, they can be regarded as travel budgets and under certain conditions may be applied as constraints on travel behavior.

The concept of transferability is central to both the conventional trip models and the budget models. Conventionally, model transferability is summarized in the coefficients of the independent variables, such as the value of time. However, the verification of transferability of current statistical models is a long and costly process. Results to date are not conclusive and, from recent evidence, not even encouraging (1-3). The budget models, on the other hand, are very clear as to what is expected of the data, and they can be confirmed or rejected reasonably quickly and simply. Thus, the basic assumption of model transferability is ascertained in a fundamentally different way.

The handling of time and money constraints in the two types of models is also different. In the current trip models the constraints are implicit. The choice set is assumed to contain only those choices that are within the budgets. In practice this means that no constraints exist, because the models deal with individual trips, each consuming a very small proportion of total resources. In the budget models, the constraints drive the models.

It should be noted finally that the travel budgets, and especially the money budget, relate travel to other sectors of the economy. This opens up a way for a meaningful exploration of how transportation policies might affect the rest of the economy and vice versa.

DATA CONSIDERATIONS

Before evidence is presented on the regularities of travel time and money expenditures, it is necessary to discuss four principal problems regarding data collection and reduction.

First, only some household trips recur on a daily basis on weekdays, such as trips to work and school, whereas trips for other purposes occur intermittently. Hence, a weekly travel diary would be required to make a thorough study of travel behavior at the household level.

Second, the definition of household travel time and money expeditures is not unambiguous. We prefer to consider travel money expenditures on a per-household basis: Money earned by one or more household members can be shared and spent by any and all members of the household. For travel time the situation is less evident. Time cannot be transferred easily from person to person. Therefore, in this case we prefer to relate travel time per traveler. All travel times presented in the following sections are door-to-door times as reported by the respondents.

The third data consideration has to do with how the travel time and cost should be computed.

Finally, there are many other data problems that cause our measurements to be inaccurate and that impose a distribution on the average travel time and money expenditures. These include the following:

1. Differences in tastes and preferences: The following analyses use aggregate data; in the absence of diary data, households of similar type form the aggregate. Part of the variations in the travel expenditures is then due to taste and preference differences between households, and part is due to unobserved attributes.
2. Differences between days for the same travelers: Because only some trips recur on a daily basis, part of the variations in travel expenditures, perhaps a very large part, must be attributed to daily variations.
3. Travelers who travel extensively on their jobs: It is suggested that travelers whose jobs call for extensive traveling should be excluded from the analyses.
4. Sampling and coding errors: These errors, especially the latter, can cause large errors in analysis.

EMPIRICAL EVIDENCE OF TRAVEL TIME BUDGETS

Studies That Use Cross-Sectional Data

Table 1 summarizes the results of an international survey of the use of time for the daily activities of urban

Table 1. Use of time in 12 countries.

	Time Spent per Person[a] (h)								
						Travel			
Place	Work	House-work	Household, Child, and Personal Care	Sleep	Leisure	Work	Non-work	Total	Grand Total
Belgium	4.38	2.42	3.23	8.35	4.73	0.40	0.50	0.93	24.04
Kazanlik, Bulgaria	6.05	1.67	4.37	6.97	3.55	0.68	0.70	1.48	24.09
Olomouc, Czechoslovakia	5.07	2.87	3.47	7.80	3.77	0.55	0.45	1.03	24.01
Six cities, France	4.25	2.70	4.03	8.30	3.85	0.37	0.52	0.97	24.10
Federal Republic of Germany									
100 electoral districts	3.88	2.95	3.92	8.50	4.18	0.30	0.28	0.65	24.08
Osnabrück	3.63	2.78	3.82	8.34	4.68	0.27	0.42	0.97	24.26
Hoyerswerda, German Democratic Republic	4.63	3.43	3.38	7.90	3.70	0.53	0.43	1.00	24.04
Gyor, Hungary	5.55	2.73	3.57	7.88	3.10	0.68	0.50	1.23	24.06
Lima-Callao, Peru	3.57	2.87	3.10	8.28	4.68	0.62	0.87	1.50	24.00
Torun, Poland	4.97	2.67	3.25	7.87	4.10	0.62	0.63	1.30	24.07
Forty-four cities, United States	4.03	2.37	3.78	7.83	4.75	0.42	0.83	1.30	24.06
Pskov, USSR	5.65	2.18	3.25	7.70	3.77	0.55	0.92	1.47	24.02
Kragujevac, Yugoslavia	4.00	2.80	3.28	7.87	4.78	0.45	0.80	1.28	24.01

[a]Because of rounding in the original table, subtotals do not sum to totals.

Table 2. Daily time spent per person by activity in Germany, 1976.

	Daily Time Spent per Person (h)									
						Travel				
Item	Home	Work	Busi-ness	Educa-tion	Shopping	Walk, Cycle	Car	Transit	Total	Rest
Average value										
Workdays (N = 251)	17.43	3.03	0.23	0.82	0.52	0.32	0.50	0.27	1.08	0.88
Saturdays (N = 50)	19.35	0.77	0.07	0.33	0.60	0.33	0.52	0.17	1.02	1.87
Sundays and holidays (N = 65)	20.18	0.35	0.02	0.03	0.07	0.40	0.50	0.08	0.98	2.37
Total (N = 366)	18.17	2.25	0.17	0.62	0.45	0.35	0.50	0.22	1.07	1.28
Maximum value	21.90	3.87	0.48	1.48	1.10	0.75	0.83	0.52	1.50	3.52
Minimum value	16.25	0.01	0	0	0	0.15	0.27	0	0.60	0.40
SD	1.25	1.22	0.12	0.42	0.22	0.08	0.10	0.10	0.15	0.70

and suburban populations in 12 countries (4). After considering all relevant factors, the researchers make the following statement (4, p. 117):

> Where the more efficient forms of transport are common, average distances to work increase dramatically while the amounts of time given over to achieving this general end seem to be kept within a remarkably narrow range. The resulting similarities in commuting times that emerge across cities certainly cannot be attributed to parallel effects of industrialization, for it is exactly these conditions that show marked variance.

And later they state (4, p. 123),

> There seems to be a distinct preference toward using increased efficiency of transport to spread out in space, and modal distances to the workplace across our sites vary by a factor of 15 or more, while time allocations remain in the average within an impressively narrow range. Much of the same pattern of similarity holds for total travel as well as the trip to work. Nonowners of automobiles only spent 6 percent more time on travel than owners, although clearly the owners travel much greater distances.

The researchers concluded that the allocation of time for travel on an aggregate basis tends to be both stable and transferable between countries. Moreover, it was observed that, when speeds increase, most of the travel time saved is traded off for more travel distance.

Activity Time Allocation in the Federal Republic of Germany

Table 2 summarizes the results of the Continuing Survey of Travel Behavior of daily activities of persons over 10 years old, conducted in Germany during 1976 (5). Two results are noteworthy. First, the most stable time budget over 366 days is time at home, followed by travel time. Second, the daily travel time budget per person, including walking, is just over 1 h.

Daily Travel Time per Traveler in the United States

In-depth analyses of all travel components were carried out in Washington, D.C., in 1955 and 1968, and in Minneapolis-St. Paul, Minnesota (Twin Cities), in 1958 and 1970 (6). This study differed from the studies mentioned above in that all travel data were related to the travelers by travel mode.

In the daily travel times of car travelers per traveler and per person reported for Twin Cities in 1958 and 1970, shown below, it is seen that, while the daily travel time per traveler is similar in all cases, it does vary per person (6).

	Travel Time (h)			
	Per Person		Per Traveler	
Household Size	1958	1970	1958	1970
1	1.04	1.09	1.04	1.08
2	0.93	0.95	1.16	1.17
3-4	0.68	0.69	1.18	1.14
5+	0.46	0.57	1.08	1.14
Avg	0.64	0.70	1.14	1.13

Analyses based on daily travel time per person do not display any stability over extended periods of time. This is because the proportion of travelers in a population tends to increase with increases in income and car ownership and with decreases in household size, both of which took place during the last two decades in developed countries. For this reason we prefer to allo-

Table 3. Daily travel time per traveler and coefficient of variation by income in Bogotá, Colombia.

Monthly Household Income (Pesos)	Initial			Second[a]		
	Number of Travelers	Travel Time per Traveler (h)	Coefficient of Variation	Number of Travelers	Travel Time per Traveler (h)	Coefficient of Variation
Up to 500	78	2.12	0.93	73	1.78	0.60
500-1000	628	1.94	0.78	594	1.69	0.57
1000-1500	707	1.89	0.92	662	1.56	0.58
1500-2000	723	1.86	0.86	685	1.60	0.59
2000-3000	702	1.79	0.85	676	1.58	0.55
3000-5000	847	1.77	0.84	812	1.56	0.55
5000-15 000	931	1.68	0.89	896	1.48	0.56
15 000-30 000	129	1.62	0.95	123	1.36	0.47
30 000 and over	12	1.38	0.91	11	1.05	0.51
Total	4757			4532		
Avg		1.81	0.87		1.57	0.57

Note: 1 peso = U.S. $0.045.
[a]Data retabulated to exclude travelers recorded as having traveled more than 4 h/day.

cate the travel times to those who reported them, namely, to the travelers.

A summary of the daily door-to-door travel time and speed per traveler, by mode used (car mode includes both driver and passenger), in Washington, D.C., Twin Cities, and the whole United States, including interurban travel (6), is given below.

Area	Year	Car		Transit	
		Time (h)	Speed (km/h)	Time (h)	Speed (km/h)
Washington, D.C.	1955	1.09	18.8	1.27	10.7
	1968	1.11	23.3	1.42	10.0
Twin Cities	1958	1.14	21.5	1.05	12.0
	1970	1.13	28.5	1.15	12.1
United States	1970	1.06	47.4	0.99	23.6

The point to note here is that when door-to-door speeds are reasonably high, the daily travel time per traveler remains stable at a minimum value of about 1.1 h both between cities and over time. Most of the travel time saved due to increased speeds (24 percent in Washington, D.C., and 33 percent in Twin Cities) was traded off for more travel distance. However, when door-to-door speeds are below a minimum threshold of about 10 km/h, the daily travel time per traveler tends to increase. The same patterns are also noted in cities of developing countries.

In conclusion to the above macro samples, it appears that the daily travel time per motorized traveler displays stable trends transferable both between cities and over time in the United States. The robustness of this stability is exemplified by the significant improvements that took place over time in the transportation systems in Washington, D.C., and Twin Cities, resulting in high increases in the door-to-door speeds of car travelers.

Daily Travel Time per Traveler in Bogotá, Colombia

The Urban Projects Department of the World Bank recently tabulated travel characteristics as reported in a household survey in Bogotá in 1972. To determine what effect travelers with abnormally long travel times had on the data, it was decided to retabulate the data to exclude all travelers who were recorded as having traveled more than 4 h/day. Table 3 summarizes these two sets.

Three principal conclusions may be inferred from this table. First, the deletion of only 4.7 percent of travelers reduced the daily travel time per traveler by 13.3 percent and the coefficient of variation by 34.5 percent. Second, the coefficients of variation in the second tabulation are very similar at all income levels—about 0.57. Third, the mean travel times display a consistent trend. The daily travel time per traveler decreases with increasing income.

Further tests were carried out by stratifying travelers in various ways. The results were as follows:

1. The coefficients of variation of daily travel time remained similar under all stratifications for segments of 25 and more travelers.
2. Employed travelers spend more time on travel than unemployed travelers, but the differences are small.
3. The daily travel time of both male and female employed travelers is about the same.
4. The daily travel time decreases while the proportion allocated to car travel increases.
5. The proportion of time allocated to walking is relatively small and similar at all income levels.

Daily Travel Time per Traveler in Singapore

The following is a summary of analyses of travel data collected by interviewing the same households before and after the introduction of the Area License Scheme (ALS) in Singapore's central business district in June 1975. The ALS scheme imposed a fee on each car and taxi carrying fewer than four persons and entering a restricted central zone during the morning peak period.

Table 4 summarizes the daily travel time per traveler (including walking trips) by income and private vehicle ownership (car and/or motorcycle) before and after the ALS. The following conclusions are suggested:

1. The daily travel time per traveler is stable for a wide range of incomes in both periods. The daily travel time per traveler from households not owning a private vehicle is appreciably higher than that of travelers from vehicle-owning households.
2. The coefficients of variation are stable in most cases (again for segments that have more than 25 travelers) and similar to those observed in other cities. Even when some instabilities are noted in the "before" survey, they disappear in the "after" survey, and conversely.

Studies That Use Diary Data

The analyses of data sets to be described in the following sections suggest that the variations in the mean travel times of travelers by population segments show consistent trends in which the coefficient of variation asymptotically approaches a value of about 0.5. While this value is still high (it probably can be reduced by additional stratification and segmentation of the data), its similarity across all population groups is important.

Table 4. Daily travel time per traveler and coefficient of variation by income and private vehicle ownership in Singapore, 1975.

	Before ALS						After ALS					
	Households Owning Vehicles			Households Not Owning Vehicles			Households Owning Vehicles			Households Not Owning Vehicles		
Household Monthly Income, S$	Number	Travel Time (h)	Coefficient of Variation	Number	Travel Time (h)	Coefficient of Variation	Number	Travel Time (h)	Coefficient of Variation	Number	Travel Time (h)	Coefficient of Variation
Up to 200	9	1.06	0.39	36	1.29	0.40	4	0.54	0.46	38	1.12	0.40
201-400	136	1.17	0.52	257	1.40	0.78	129	1.17	0.50	184	1.21	0.49
401-700	612	1.25	0.58	581	1.30	0.51	403	1.25	0.62	521	1.25	0.52
701-1000	630	1.31	0.74	342	1.51	0.88	669	1.34	0.56	463	1.36	0.54
1001-1500	1036	1.28	0.54	232	1.49	0.73	971	1.29	0.59	312	1.35	0.48
1501-2000	618	1.25	0.54	97	1.42	0.51	812	1.25	0.51	64	1.47	0.48
2001-2500	473	1.23	0.55	20	1.65	0.43	392	1.20	0.51	49	1.56	0.41
2501 and over	838	1.27	0.64	8	1.26	0.40	678	1.14	0.48	4	2.50	-
Total	4352			1573			4058			1635		
Avg		1.27	0.60		1.40	0.70		1.25	0.56		1.31	0.51

Note: S$1.00 = U.S. $0.42.

Such distributions serve as a link between micro and macro analyses in which a representative (average) traveler or household is identified in deterministic terms and an individual traveler or household can depart from average group behavior.

Daily Variations in Use of Cars

A study was conducted recently in Oxford, England, to analyze the variations in the intensity of car use (7). The sample of cars was small—43 cars; of these, 33 were in one-car households and 10 in households of two or more cars; the data included a seven-day travel diary for each car.

Of special interest here are the following tentative results. First, the actual car use on a day (like the daily travel time per traveler) was found to be 55.4 min per car in use in one-car households and 55.6 min per car in use in households of two or more cars—practically identical results. Second, the variations in the daily travel time per car in use are less when the period of analysis is longer. The coefficients of variation decrease from 1.1 for one day to 0.7 for five weekdays to 0.6 for the full seven days. The results suggest that a survey over a long period would still find substantial variations in the intensity of car use but considerably less than that suggested by a one-day survey. Consequently, part of the variations noted in car use during one day should be attributed to differences in use among days of the week for each car rather than to differences among car users.

Daily Variations in Travel Time per Traveler, Munich

This section presents some results of an analysis of a three-weekday trip in Munich, Germany, in 1976.

The available data were stratified by 55 household types; the dimensions were household size, car ownership, and employment status (no income data were available) (8). To make the number of household types manageable, they were condensed into 12 groups according to car ownership (0, 1+, 2+) and household size (1, 2, 3, 4+).

From a tabulation of the mean travel time expenditure per average traveler for each factor level and the average values and coefficients of variation per day for all travelers (8), it can be seen that the daily travel time per traveler on an aggregate level is stable both between days and within each day. Also, the coefficients of variation are practically identical to those noted earlier.

Factor		Day			
Car Ownership	Household Size	1	2	3	Total
0	1	1.12	1.32	1.16	3.60
0	2	1.23	1.12	1.32	3.67
0	3	1.01	1.06	1.12	3.19
0	4+	1.35	1.60	1.30	4.25
1+	1	1.06	1.13	1.10	3.29
1+	2	1.14	1.10	1.10	3.34
1+	3	1.10	1.19	1.23	3.52
1+	4+	1.24	1.13	1.19	3.56
Total		9.25	9.65	9.52	
Mean		1.15	1.16	1.16	
Coefficient of variation		0.57	0.56	0.56	

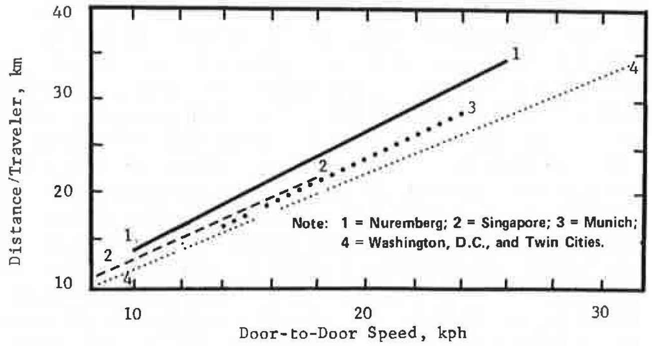
The effect of the factors of car ownership and household size on travel time expenditures can be conveniently analyzed as a multifactor experiment. Results are shown below (8).

Factor	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	$F^{crit}_{0.05}$
Days	2	0.010	0.005	0.65	3.74
Household size	3	0.118	0.039	5.06	3.34
Car ownership	1	0.042	0.042	5.44	4.60
Interaction	3	0.090	0.030	3.89	3.34
Error	14	0.108	0.0077		
Total	23	0.368			

It is seen from the above that car ownership, household size, and interaction between household size and car ownership all have statistically significant effects on travel time expenditures but that travel time expenditures do not vary between days. After reflection, the first of the two tabulations above indicates that the household size and interaction effects are most likely due to the no-car, three-member households. These households may be husband-wife-child types where the wife is at home with an infant and has little desire to travel on what is often "child-repellant" public transport.

This issue was examined by making an analysis of variance by car ownership levels. At the same time, such analysis of variance shows whether there are differences in travel time expenditures for car-owning

Figure 1. Daily travel distance per traveler versus speed in selected cities.



households; the results showed that the travel time expenditures of such households are not dependent on household size or level of car ownership. Again, there are no differences in travel time expenditures between days for either household type.

The major conclusion of this section can be summarized thus: Travel time budgets per traveler do not vary by day. This should not be interpreted to mean that individual travelers would spend equal amounts of time for travel every day but rather that on the average, within a given homogeneous group of travelers, travel time budgets do not vary over the weekdays. Furthermore, travel time budgets vary with car ownership levels and household size. Specifically, there is a difference in travel time budgets between households that own cars and those that do not own cars. There also appears to be a household-size effect, but it is minor and confined to households that have three household members and that do not own cars.

Difference in the travel time budgets between travelers from households owning and not owning cars is not necessarily an intrinsic characteristic of travelers but rather stems from different travel speeds available to these car travelers.

RELATIONSHIP BETWEEN TRAVEL TIME BUDGET AND SPEED

It was noted in the above examples that the range of the daily travel expenditures per representative traveler of different population segments is relatively narrow, within 1.0-1.5 h in cities of developed countries. The daily travel distance per traveler, on the other hand, varies within a wide range (8).

We may hypothesize that the travel time budget per traveler is a constant minimum at high speeds, which is approached asymptotically:

$$\text{TT budget/traveler} = b + (a/\text{speed}) \tag{1}$$

By using the results of the previous section, Equation 1 (multiplied through by speed) was estimated for three market segments: no-car, one-car, and two-or-more-car households. The mean distances traveled by members of these three household types differed substantially (23.4, 31.8, and 37.6 km), which also justified the division. The regressions were designed to show whether the slopes of the regression lines are different for each market segment, whether the intercepts are different for each market segment, and whether the overall relationship is homogeneous over the three car-ownership groups. Data from Nuremberg, Germany, were used.

The results of the analysis suggested that the hypothesis of equal regression slopes (b) for the three car-ownership groups is accepted, whereas the hypothesis of equal intercepts (a) is rejected (visually speaking, the difference is between households owning cars and carless households). This rejection concentrates on the intercepts of the relationship, at zero speed, which is beyond the range of observations.

Following an approach similar to that used in the Nuremberg case, several regression analyses were also performed for Munich data. The salient results are reported here (8). The important regressions are of the following type:

$$\text{Distance/traveler} = b_0 + b_1 A + b_2 A(\text{speed}) + b_3(1 - A)\text{speed} \tag{2}$$

where A = 1 if cars per household > 0; A = 0 otherwise. The results showed that the coefficients for speed are statistically equal, as are the intercepts for the car-owning and carless households.

In conclusion, the statistical tests using Munich and Nuremberg data give conflicting results. It will be shown next that, in spite of these statistical results, the Munich and Nuremberg models are very similar from a practical point of view.

The two final models of the distance-versus-speed relationships in Nuremberg and Munich can be expressed by a single equation for travelers of both car-owning and carless households: in Nuremberg,

$$\begin{aligned} D/TR = {} & 0.268 + 4.305\,A + 1.094\,A\,(\text{speed}) \\ & + 1.410\,(1 - A)\,\text{speed} \end{aligned} \tag{3}$$

In Munich,

$$\begin{aligned} D/TR = {} & -6.359 + 7.511\,A + 1.083\,A\,(\text{speed}) \\ & + 1.667\,(1 - A)\,\text{speed} \end{aligned} \tag{4}$$

where D/TR is the daily travel distance per traveler (km) and A = 1 if cars per household > 0; A = 0 otherwise.

When many distance-versus-speed relationships in Nuremberg and Munich were compared and assessed by using subsets of data, the intercepts were found to fluctuate widely. Thus, the results of the statistical analyses could not be regarded as conclusive. Most importantly, the actual differences in travel distance resulting from applying either the two separate relationships (for car-owning and carless households) or the combined relationship are very small within the range of observations. The differences in travel distance between the separate and the combined relationships within each group of travelers are quite small—less than 1 km/day. Thus, from a practical point of view, the combined relationship could be used in the travel demand analyses. Figure 1 summarizes these relationships for the cities of Munich; Washington, D.C., and Twin Cities; Singapore; and the Nuremberg region. It appears that the relationships for the cities overlap within the range of observations, while the relationship for the Nuremberg region is somewhat higher. A possible reason for this difference is the inclusion of both urban and regional travel in the Nuremberg data.

The importance of Figure 1 is that it suggests the possibility that the relationship between distance and speed, and thus the time budget, is a transferable function between cities and therefore also over time. Travel distance per traveler is an output of conventional models, resulting generally from the phases of trip generation, trip distribution, modal split, and trip assignment. Figure 1, on the other hand, suggests that the travel distance per traveler is strongly related to the level of service supplied by the transportation system. Development of travel demand models with travel distance as an input might lead to improved insight in demand-supply relationships (8).

TRAVEL MONEY BUDGET

Previous analyses of aggregate data from national surveys have already indicated that travel money expenditures per household are strongly related to the household income level (9). No such direct data on travel money expenditures were available in the above urban travel surveys. Therefore, the travel money expenditures in these cases had to be derived indirectly as a product of observed travel distance per household and cost per unit distance by mode.

Such analyses were carried out for the cases of Washington, D.C., in 1968, Twin Cities in 1970, and Nuremberg in 1975. For lack of space, only the salient results are reported here (6, 8):

1. The travel money expenditure of car-owning households is found to be a stable proportion of income, about 10.5 percent in the two U.S. cities and 11.8 percent in Nuremberg, at practically all income levels.
2. The travel money expenditure of carless households is found to be low, about 3-5 percent of income in the two U.S. cities and 3.5 percent in Nuremberg, at a wide range of income levels.
3. The coefficient of variation of travel distance per household, by segment, was found to be somewhat higher than that for travel time per traveler, about 0.8 versus 0.6, respectively, but very similar at all population segments. This is an expected result, as money is more transferable between days than is time.
4. It may therefore be concluded that travel money expenditure, like travel time expenditure, can be regarded as travel money budgets.

It should be noted that there are strong indications that travel money budgets per household are much higher in developing countries than in developed countries. Car-owning households in developed countries were also observed to be reluctant to change their travel money budgets even when gasoline costs increased significantly during 1973-1975. People saved on their fixed costs (such as by decreasing the rate of car replacement) rather than decrease their travel. Nonetheless, there may be a critical threshold after which increases in gasoline prices could result in increases in the travel money budget. The identification of such a critical threshold is of extreme importance, since crossing it will have adverse effects on all segments of the economy.

CONCLUSIONS

Several conclusions can be drawn. First is a recommendation that exploratory data analyses be carried out before any modeling of travel demand is done. Travel time and money expenditures are one useful way of organizing and exploring travel data. In this context also, such questions as how a traveler should be defined, how travel time and cost should be measured, what a concise stratification of population is, and other related issues should be addressed.

The second conclusion is that these types of data analyses have led us to the inescapable conclusion that travel time and money budgets exist. These budgets show trends, on the average, that are quite stable within a country. Furthermore, the relatationship between travel time budget and speed appears to be transferable from country to country.

The third conclusion is that, even though there are regularities in the household travel time and money budgets, there exists substantial variation in these budgets among households and travelers. For the travel time budget this variation seems to be quite stable and has a coefficient of variation of about 0.6. In this context it is also appropriate to express our belief that travel time and money budgets are not constant, but they are functions of several variables. For instance, the travel time budget is related to travel speed (level of service) available to travelers and also to car ownership or household income and possibly to urban structure.

The travel money budget is also a function of many variables. It is most clearly related to income, car ownership, and location of residence with respect to place of work and services. It probably is also related to the prices of other goods in the economy. Much more needs to be known about travel money budgets and their trade-offs with budgets for other goods and services, and it is an important area for future research.

The fourth and final conclusion is that travel time and money budgets are useful both for predicting travel and for evaluating policy. Most importantly, no lengthy calibration process to observed data is required. The concepts are powerful in anticipating what data will show, and they are also simple enough for detecting changes quickly, should they occur.

The concepts of travel time and money budgets also give enormously useful insights about travel behavior that are important for policymakers. Two examples are given. First, the stability of the relationship between travel time and speed suggests that increases in travel speeds do not necessarily lead to real time savings. Rather, only part of the time is allocated to other uses, while often most of the saved time is traded off for more travel. This undoubtedly has happened in the United States. By using the budget concept, this result is obtained immediately; by using the traditional demand-forecasting process, such a result would only be obtained after a lengthy and costly process, if at all.

The second example is related to free transit. The budget concepts suggest that, other things being equal, free transit would increase both transit and vehicle kilometers of travel. This is because free transit would attract walkers to transit, but at the same time it would also enable reallocation of money otherwise spent on transit to car travel. Indeed, the free-transit experiment in the central business area in Rome, Italy, tends to support this indication.

We would like to end this paper with a note that travel time and money budgets are useful concepts. They certainly are worthy of the research effort expended on other approaches to behavioral models. We do caution that there will always be variance in travel behavior because of powerful personal and social reasons, which cannot be included in mathematical models and must be identified and quantified in another manner, for example, by analysis of time and money budgets allocated to travel.

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Stability of Travel Components over Time

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A critical assumption underlying the application of transportation models to forecasting is that their base-year relationships, developed on the basis of cross-sectional data, will hold over time. This assumption is based on studies that have tested selected components of travel and have indicated, for example, that trip rates and trip times to work in a given city tend to remain stable over time. It has not been clear, however, how travel components that do change over time interact with one another. This paper summarizes the results of a study that analyzed the entire range of characteristics of motorized personal travel by private and public modes and their interactions in two U.S. cities: Washington, D.C., 1968 versus 1955; and Twin Cities (Minneapolis-St. Paul), 1970 versus 1958. The main findings are that (a) the time and money spent on travel per traveler and per household display regularities that can be attributed to such factors as household characteristics and transportation system supply and may be regarded as travel budgets and (b) all travel components, such as trip rate, trip time, trip distance, and proportions of trips by purpose, are products of the interactions among travel demand, system supply, and urban structure as constrained by the two principal travel budgets. These findings, if verified in additional cities and on a disaggregate level, may allow travel demand, system supply, and urban structure to be integrated within one modeling framework that would be more readily transferred between cities and over time.

Studies of urban travel behavior typically rely on the support of cross-sectional data. These data are further used to estimate models that are applied in a variety of transportation analyses. Many of these applications attempt to predict behavior under conditions that are significantly different from those observed in the base data. As a result, a recurring issue in transportation planning is transferability: the validity of model forecasts in settings that are beyond the range of base-year cross-sectional data.

Past research on this issue generally focused on specific travel demand models. For example, a number of efforts examined the transferability of coefficients in logit mode-choice models for work trips (1-3). These investigations produced mixed results. Other work examined the stability of trip rates, average trip distance, and travel times for households in an urban corridor undergoing a significant transportation improvement (4). The results indicated that speed increases were correlated with increases in trip distance, while changes in trip rates appeared unrelated to system improvements. However, other investigations of time-series data rejected hypotheses on the time stability of trip-generation models (5). Unexplained variations of 10-20 percent were found in trip rates over a 12-year interval.

A different approach to the problem is a recent handbook for transportation planners that provides travel characteristics from a large number of urban travel studies in American cities (6). Data are provided on such characteristics as trips per household, vehicle-kilometers of travel per person, average trip distances, and mode shares. This handbook is useful in checking the reasonableness of model forecasts against observed travel characteristics in similar urban areas. For longer-range forecasts in particular, these checks are important in ensuring that relationships developed from cross-sectional data do not produce misleading forecasts.

Potential problems remain, however. One is that the analysis in question may deal with conditions that have not been observed in any existing travel data. Consequently, no information exists on "reasonable" travel behavior under these conditions. Prolonged limitations on the availability of gasoline or severe increases in its price are prime examples. A second problem is that the characteristics of travel data eventually become less than representative. Changes in tastes, life-style,