TRANSPORTATION RESEARCH RECORD 879

Household Activities and Behavior

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D.C. 1982

TRANSPORTATION RESEARCH BOARD
National Research Council

ERRATA 1982-1985

Special Report 201

page 17, column 2, second paragraph, should read
"Tools also need to change as the nature of options changes significantly. Emerging policy options are not largely focused on network-expansion investments, whereas traditional models were developed long ago to deal with such options."

Special Report 200

page 3, column 1
Change the caption for the bottom figure to
"A new AM General trolley bus starts down the 18 percent grade on Queen Anne Avenue North in Seattle in October 1979 (photograph by J. P. Aurelius)".

Transportation Research Record 1040

page ii
Under "Library of Congress Cataloging-in-Publication Data," delete "Meeting (64th: 1985: Washington, D.C.)" and "ISBN 0361-1981"

Transportation Research Record 1020

page 7, Figure 1
The histogram should reflect that the rail mode is represented by the black bar and that the highway mode is represented by the white bar.

Transportation Research Record 1017

page 19, column 1, 7 lines above Table 1
Change "ranged from 1 $in.^2$ to nearly 30 $in.^2$ of runoff" to "ranged from 1 area inch to nearly 30 area inches of runoff"

page 22, column 1, last line
Change "1 to nearly 30 $in.^2$" to "1 to nearly 30 area inches"

page 22, column 2, first line
Change "13 $in.^2$" to "13 area inches"

Transportation Research Record 1011

page 12, Figure 4
Figure does not show right-of-way structure for O-Bahn. See discussion on page 11, column 1, paragraph 3.

Transportation Research Record 996

page 49
Insert the following note to Figure 2:
"The contour lines connect points of equal candlepower."

page 49
Insert the following note to Figure 3:

"The candlepower contours are superimposed on a 'headlight's-eye-view' of a road scene. The candlepower directed at any point in the scene is given by the particular candlepower contour light that overlays that point. For example, 1400 candlepower is directed at points on the pedestrian's upper torso. For points between contour lines, it is necessary to interpolate."

page 50
Insert the following note to Figure 3:

"Where

ρ = the azimuth angle from the driver's eye to a point P on the pavement;
θ = the elevation angle from the driver's eye to a point P on the pavement;
EZ = the driver's eye height above the pavement; and
DX, DY, DZ = the longitudinal, horizontal, and vertical distance between the headlamp and eye point.

Then

$EX = EZ/\tan\theta$ $HZ = EX-DZ$
$H1^2 = EZ^2 + EX^2$ $HX = EX-DX$
$EY = H1 \tan\rho$ $HY = EY-DY$
$H2^2 = H1^2 + EY^2$ $H3^2 = HX^2 + HZ^2$
$\alpha = \tan^{-1}(HZ/HX)$, $\beta = \tan^{-1}(HY/H3)$, $H4^2 = H3^2 + HY^2$"

Transportation Research Record 972

page 30, column 2, 22 lines up from bottom
Reference number (5) should be deleted

page 31, column 2, 5 lines up from bottom
Reference number should be 5, not 4

page 34, column 2, 8 lines above References
Reference number (5) should be deleted

Transportation Research Record 971

page 31, reference 3
Change to read as follows:

Merkblatt fürLichtsignalanlagen an Landstrassen, Ausgabe 1972. Forschungsgesellschaft für das Strassenwes en, Köln, Federal Republic of Germany, 1972.

Transportation Research Record 965

page 34, column 1, Equation 1
Change equation to

$$r_u = \gamma_w \cdot h/\gamma \cdot z$$

where

γ_w = unit weight of water,
γ = moist unit weight of soil,
h = piezometric head, and
z = vertical thickness of slide.

Transportation Research Record 905

page 60, column 1, 9 lines up from bottom
Change "by Payne (6)" to " by us"

Transportation Research Record 819

page 47, Table 1

Replace with the following table.

Table 1. Summary of interactions between signal-timing parameters and MOEs.

Timing Method	Parameter	Total Delay	Stops	Fuel Consumption	Emissions		
					HC	CO	NO_x
Manual	Cycle length	⊕	⊕	⊕	⊕	⊕	⊕
	Speed of progression	+	⊕	+	+	+	+
	Priority policy	+	+	+	+	+	+
	Split method	+					
TRANSYT	Cycle length	⊕	⊕	⊕	⊕	⊕	⊕
	K-factor	+	⊕				
	Priority policy				+		

Note: + = main effect detected from TRANSYT output, and ○ = main effect detected from NETSIM output.

Transportation Research Record 869

page 54, authors' names

The second author's name should read "Edmond Chin-Ping Chang"

Transportation Research Record 847

page 50, Figure 3

Add the following numbers under each block in the last line of the flowchart:

R1, R2, R3, R4, D1, D2, D3, A1, A2

page 50, Figure 4

Make the following changes in the last line of the flow-chart.

Change "R4" to "D1" and "Recognition" to "Decision"

Change "R5" to "D2" and "Recognition" to "Decision"

Change "R6" to "D3" and "Recognition" to "Decision"

Change "R7" to "R4"

Change "R8" to "D4" and "Recognition" to "Decision"

Change "R9" to "A1" and "Recognition" to "Action"

Change "R10" to "A2" and "Recognition" to "Action"

Transportation Research Record 840

page 25, column 1, line 5

Change "money" to "model"

Transportation Research Record 831

page ii, column 1

Change ISBN number to "ISBN 0-309-03308-X"

Transportation Research Circular 255

page 6, column 1, third paragraph

Change "Marquette University" to "Northern Michigan University"

NCHRP Synthesis of Highway Practice 87

page ii

Change ISBN number to 0-309-03305-5

NCHRP Synthesis of Highway Practice 84

page ii

Change ISBN number to 0-309-03273-3

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

ADDRESS CORRECTION REQUESTED

Transportation Research Record 879
Price $7.40
Edited for TRB by Scott C. Herman

modes
1 highway transportation
2 public transit

subject areas
12 planning
13 forecasting

Library of Congress Cataloging in Publication Data
National Research Council. Transportation Research Board.
Household activities and behavior.

(Transportation research record; 879)
1. Transportation planning–Congresses. 2. Transportation–Forecasting–Congresses. I. National Research Council (U.S.). Transportation Research Board. II. Series.
TE7.H5 no. 879 [HE11] 380.5s [388.4] 83-4163
ISBN 0-309-03406-X ISSN 0361-1981

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Patterns of Time-Budget Expenditure in Nigeria

G. ADEGBOYEGA BANJO AND PETER J.B. BROWN

By using data relating to Nigeria, this paper reports the results of analyses directed toward examining the validity, in a Third World context, of the postulate advanced by a number of authors that the amount of time spent traveling has certain stable properties and can serve, therefore, as an alternative parameter to trip rate for use in deriving estimates of future travel demand. Analysis of relations between traveler characteristics and time-budget-expenditure patterns reveals the significant influence of engagement in supplementary employment on both travel and nontravel activities. Explanations are put forward to account for similarities and differences found in patterns of daily travel-time variation displayed by residents of Lagos and Ibadan. These explanations lead to the formulation of tentative hypotheses about the relations between different aspects of travel-time variation and transportation system characteristics as a settlement evolves. In particular, it is suggested that mean daily travel time is likely to be reduced as a result of implementing measures introduced to resolve problems diagnosed during a period of transportation system overload. Attention is drawn to the implications of this and other relations for transportation modeling and time-valuation practice in Third World cities.

In recent years, a considerable amount of research effort has been devoted to examining the usefulness of travel-time budgets in the explanation of patterns of travel behavior (1-4). Much of this work has been concerned with investigating the possibility that the amount of time (or money) spent in daily travel has certain stable properties in different conditions and that people sharing certain characteristics will display similar patterns of time (and money) expenditure. As a result, time-budget expenditure has been suggested as an alternative parameter to trip rate for use in deriving estimates of future levels of travel demand. This paper contributes further to this debate concerning the usefulness of travel-time budgets by examining the validity of the above postulate in a Third World context by using data gathered in the course of an investigation of theoretical and methodological aspects of time-valuation practice in developing countries (5,6).

Following an examination of the relations between socioeconomic characteristics and time-budgeting behavior, a detailed comparison is presented of daily travel-time allocations reported by residents of Lagos and Ibadan, Nigeria. This analysis seeks to establish whether the observed patterns of variation display any form of consistency or stability and, if so, how such stability might be explained.

DAILY TIME-BUDGET EXPENDITURE IN LAGOS AND IBADAN

Data and Survey Background Information

Before presenting the results of the analyses, it is appropriate to draw attention to a number of important features of the survey and the country in which it was carried out. The analyses were performed on data gathered in a questionnaire survey carried out over a three-week period in May and June 1978. The survey yielded an effective sample size of 423. At the time of the survey, the interviewees, all of whom were in employment, were engaged in traveling between the cities of Lagos and Ibadan either by air or by road (car-taxi or midibus modes). The majority of the respondents were residents of either Lagos or Ibadan (those resident elsewhere accounted for only 8 percent of the observations included in the tabulations headed All in Tables 1 and 2).

A notable feature of the developing Nigerian economy over the past decade has been the high rate of growth in the gross national product (GNP), which has been sustained at an annual rate of roughly 10 percent. This rapid expansion has given rise to a serious shortage of suitably qualified and skilled personnel and, as a consequence, there has been an increasing tendency for members of the labor force to engage in the practice of multiple employment. For this reason, in collecting information about the daily allocation of time, a distinction was made between main and supplementary employment. From the survey it was found that as many as 27 percent of the respondents were engaged in supplementary employment. This was despite the fact that, at the time of the survey, legislation directed toward making such activity illegal on the part of government employees was given much publicity and might have been expected to discourage respondents from disclosing such involvement.

Trade-Off Patterns in Allocation of Time Among Discretionary, Economic, and Travel Activities

The aim of this section is to draw attention to important features of the patterns of time-budget expenditure displayed by survey respondents. The amount of time devoted to seven broad groups of activities is given in Table 1, in which mean time values are tabulated with respect to engagement or otherwise in supplementary employment and place of residence. For convenience, these activities are further grouped according to a threefold categorization often adopted in the time-budget literature. This information, which is the main focus of the present discussion, is also presented in Figure 1, together with an indication of the time spent on the same seven activities, broken down in turn with respect to sex, individual car ownership, income, and occupation of the respondent. Table 2 provides information on the distribution of respondents across these subgroups and the extent of their engagement in supplementary employment.

Table 1 reveals that there is a broad similarity between the overall patterns of time allocation reported by Lagos and Ibadan residents. The only notable differences appear to be in the lesser amounts of time devoted to sleep and social and leisure activities by those residents of the two cities who are engaged in supplementary employment. However, if engagement or otherwise in supplementary employment is itself used as the basis for comparison, then more significant differences in time allocation can be distinguished.

Engagement in supplementary employment can be seen to be associated with less time being spent on both travel (0.8-1.0 h) and social and leisure activities (0.6-0.7 h) in each city. Furthermore, the 7.6-7.7 h devoted to main employment by those with supplementary employment is 0.5 h less than the time reported by those with only one source of employment.

The amount of time devoted to supplementary employment by residents of Lagos and Ibadan is 2.6 and 2.8 h, respectively, which represents approximately one-third of the time devoted to main employment (7.7 and 7.6 h). Making even the conservative assumption that the wage rate associated with this supplementary employment is the same as that received from main employment, it is evident that a significant proportion of income is derived from this source. The possible effects of supplementary

Table 1. Time (in hours) devoted to different activities by employed respondents.

Activity	Lagos A	Lagos B	Ibadan A	Ibadan B	All A	All B
Discretionary						
Sleeping	7.1	6.8	7.2	7.7	7.1	7.2
Eating	1.4	1.1	1.3	1.2	1.4	1.1
Social and leisure	4.0	3.3	4.1	2.5	4.1	3.0
Total	12.5	11.2	12.6	11.4	12.6	11.3
Economic						
Main employment	8.2	7.7	8.2	7.6	8.2	7.7
Supplementary employment	-	2.6	-	2.8	-	2.6
Total	8.2	10.3	8.2	10.4	8.2	10.3
Travel						
To work	1.5	1.2	1.3	1.0	1.4	1.1
For other purposes	1.8	1.3	1.9	1.2	1.8	1.3
Total	3.3	2.5	3.2	2.2	3.2	2.4
Total	24.0	24.0	24.0	24.0	24.0	24.0

Note: A = employed respondents who are not engaged in supplementary employment, and B = employed respondents who are engaged in supplementary employment.

Table 2. Proportions of respondents not engaged or engaged in supplementary employment.

Criterion Variable	A (%) Column	A (%) Row	B (%) Column	B (%) Row	All (%) Column	All (%) Row
Sex						
Male	74	70	74	30	74	100
Female	26	70	26	30	26	100
Car ownership						
Noncar owners	59	73	63	27	62	100
Car owners	41	37	37	30	38	100
Income						
Low	47	72	46	28	47	100
Middle	38	74	25	26	37	100
High	15	67	19	33	16	100
Occupation[a]						
Group 1	40	73	37	27	39	100
Group 2	35	69	40	31	36	100
Group 3	25	74	23	26	25	100

Notes: The table is set up to show column- and row-wise proportions. A and B are defined in Table 1.

[a]The occupation groups are specified as follows: group 1 = administrators, managers, and self-employed professionals; group 2 = middle-management personnel; and group 3 = clerical and skilled and unskilled manual workers.

employment on total income (and travel behavior) are discussed elsewhere (6).

Figure 1 provides a graphical impression of the effect of engagement in supplementary employment on the time-budgeting behavior of different socioeconomic groups. A pattern that emerges from an examination of the figure is that those in high-income and higher-occupational-status groups tend to devote more time to supplementary employment. This is reflected in the observation that car owners spend approximately 20 percent more time in this way than noncar owners.

With respect to travel activities, on average, respondents without supplementary employment spend 1.4 h traveling to and from work and 1.8 h for other purposes, thereby producing a mean daily travel time of 3.2 h. The corresponding figures for those with supplementary employment are 1.1, 1.3, and 2.4 h, respectively. The resultant difference in total daily travel time of 0.8 h (48 min) represents 25 percent of the former employment group's total.

It is further evident from Figure 1 that engagement in supplementary employment has a marked influence on the amount of time devoted to travel for nonwork purposes, especially among males and high-income Lagos respondents. With this latter exception and the shorter travel-to-work times reported by medium-income and middle-management Ibadan residents with supplementary employment, the patterns of variation in travel-time use displayed by Lagos and Ibadan residents are broadly similar. Finally, it is interesting to note that car owners derive a fractional time advantage over noncar owners and slightly more so for those with supplementary employment.

The main conclusion to emerge from this brief discussion is that the above analyses provide evidence of the significant impact of engagement in supplementary employment on the pattern of daily time-budget expenditure. Almost without exception, those respondents engaged in this activity have been found to sacrifice time, which would otherwise be devoted to the six other activities recorded, in order to supplement their income from their main employment. This time substitution is most noticeable with respect to social and leisure activities, followed by the time devoted to travel for purposes other than the journey to work. In the former case it appears that the proportion of variation in social and leisure time attributable to engagement or otherwise in supplementary employment is greater than that accounted for by differences in sex, car ownership, income, or occupation group. The apparent similarity between the amounts of time devoted to travel in Lagos and Ibadan is discussed further below. Meanwhile, the discussion now turns to a closer examination of the above daily travel-time information, following an initial comparison with corresponding data derived from studies undertaken in other countries.

DAILY TRAVEL-TIME EXPENDITURE IN LAGOS, IBADAN, AND OTHER LOCATIONS

One of the major difficulties encountered in carrying out comparative time-budget investigations is that much of the information available was originally collected for purposes other than a time-budget analysis. Often the data employed relate to population subgroups specified according to different criteria; in some cases travel times are recorded for the population as a whole while in others only for travelers. Similarly, some sources specifically exclude consideration of walk trips, while in others it is assumed that the time devoted to all forms of travel is included, and this applies in the case of the Nigerian data. The time periods over which information is gathered also varies, the usual and least-satisfactory source being one-day surveys. Nevertheless, as far as it is possible to judge from the sources of information used in compiling Table 3, the figures are broadly comparable insofar as all data relate to travelers only. However, the above observations dictate that caution be exercised in drawing inferences from the information presented.

It is apparent from Table 3 that more time is devoted to travel, both to work and for other purposes, in Lagos and Ibadan than in any of the other cities, with the exception of Lima-Callao in Peru. It appears that residents of the two Nigerian cities spend between 50 and roughly 200 percent more time traveling than the residents of relatively densely developed Western European countries such as Belgium and England. These are very large differences that are likely to be explained by, among other factors, marked differences in modal split, the quality of provision of transportation networks and services, and perhaps differences in the relative locations of residential areas and employment and other activities.

Of course, it is always possible that the respondents in the Nigerian survey consistently overestimated their travel time, although there is no other

Figure 1. Time devoted to different activities: comparison between those respondents engaged and not engaged in supplementary employment.

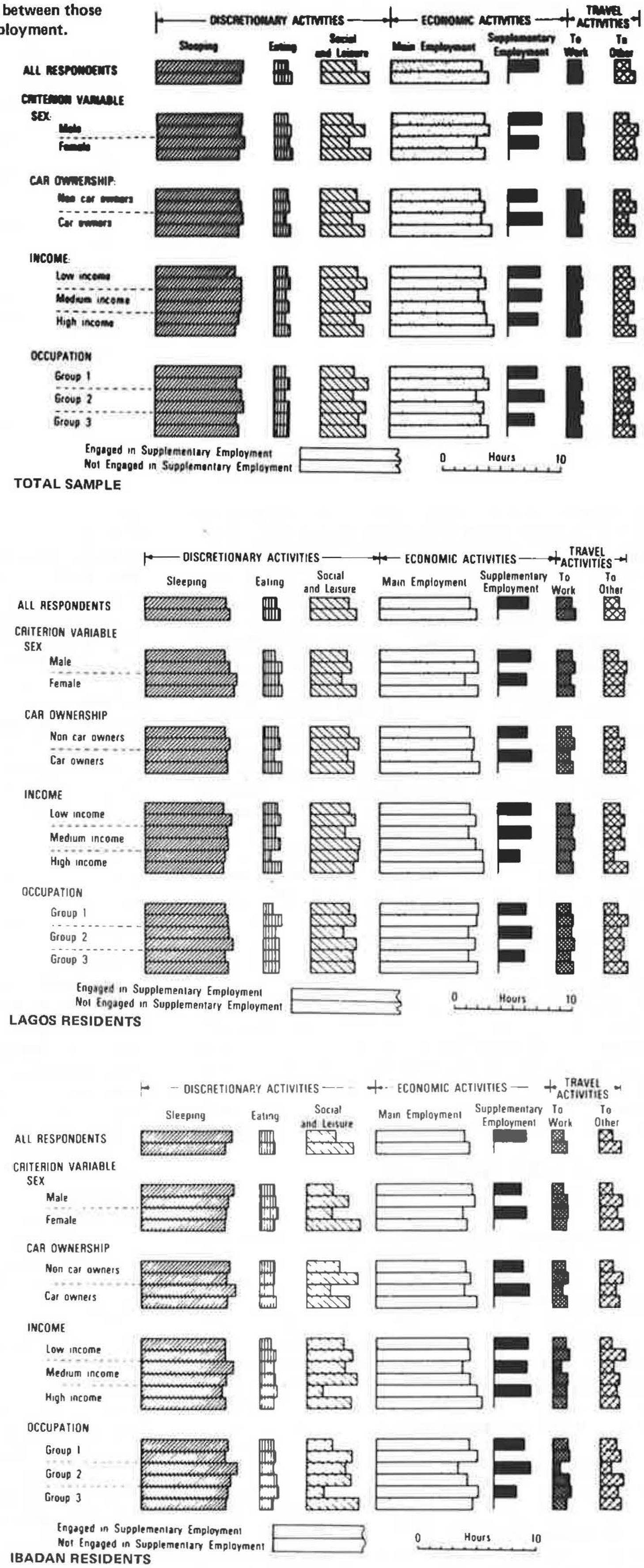


Table 3. Mean daily travel times and percentages for selected locations.

Location	Source	Travel to Work and Back		Travel for Other Purposes		Total (min)
		Minutes	Percent	Minutes	Percent	
Ibadan, Nigeria		74	42	104	56	178
Lagos, Nigeria		84	45	102	55	186
Six cities, France	7	50	51	49	49	99
Osnabruck, Federal Republic of Germany	7	45	44	58	56	103
Hayerswerda, German Democratic Republic	7	61	57	46	43	107
Gyor, Hungary	7	62	58	45	42	107
Four cities, United States	7	49	43	65	57	114
Kazanlik, Bulgaria	7	56	48	61	52	117
Olomouc, Czechoslovakia	7	58	49	61	51	119
Belgium	7	65	52	60	48	125
Lima-Callao, Peru	7	89	51	74	49	163
England	8	48	69	22	31	70
Reading, England	9	-	-	-	-	86
London, England	10	-	-	-	-	88
Washington, D.C.	1	-	-	-	-	73
Singapore	11	-	-	-	-	79
Bogota, Colombia	11	-	-	-	-	94

evidence to support this deduction. Furthermore, it is interesting to note that the only other data presented in the table relating to a city in a developing country of a similar size and pattern of development, Lima-Callao in Peru, displays the closest similarity to the Nigerian figures, especially with respect to travel-to-work time. Close examination of Table 3 further reveals that a lesser proportion of travel time is devoted to the journey to work in Lagos and Ibadan than in virtually all other cases. These differences raise a number of questions to which it is difficult to supply definitive answers.

First, it is not clear, for example, whether the Nigerian journey times are associated with a similar or greater number of trips or individual journeys than is the case in the other locations. However, the recent Lagos Metropolitan Area Transportation Study (12) indicated that trip rates were similar to those recorded in Western countries. Second, it is perhaps likely that a significantly greater proportion of journeys in Lagos and Ibadan are undertaken on foot or by means of relatively slow or inefficient forms of public transportation. A further explanation could lie in the observation that traffic conditions in the two cities during the peak and off-peak periods are equally poor or display less difference than is found in Western cities--a feature that might result in longer journey times for other purposes than would otherwise be expected. These points will be returned to in later discussion.

VARIATION IN MEAN DAILY TRAVEL TIMES IN LAGOS AND IBADAN

The above observations that relate to the unusually high values of daily travel time recorded by residents of Lagos and Ibadan prompted the closer analysis of variation in these values among survey respondents. The mean daily travel times, which were featured in Table 1 simply by place of residence, are presented in Table 4 for each of the respondent subgroups used in Table 2; the variation around subgroup means is expressed, for the sake of comparability, in terms of the coefficient of variation.

The table reveals more clearly the earlier-noted differences in the travel times of respondents with and without supplementary employment, their respective means being 146 and 197 min. The reduction in the amount of time devoted to travel for nonwork purposes, which is associated with involvement in such activity, is again seen to be substantial, i.e., a 36-min difference (79 compared with 115 min), which contrasts with the difference of only 15 min (67 and 82 min, respectively) in journey-to-work times. However, the significance of this difference may perhaps be called into question by the relatively small size of the Ibadan resident sample.

In an effort to seek explanations for the above travel-time differences, it is possible to examine the influence of socioeconomic and other factors in the light of the earlier discussion of overall time allocations. A possible explanation is that supplementary employment leads to a higher relative income and thus a greater likelihood of car ownership and greater propensity to make motorized trips that, in turn, could be interpreted as an increased ability to purchase time savings (6).

With respect to income, it can be seen from Table 2 that almost half (46 percent) of those engaged in supplementary employment fall in the low-income group, and that the participation rate among low-income respondents is relatively low (28 percent). In contrast, while high-income respondents account for only 19 percent of those engaged in supplementary employment, the rate of involvement of this group is relatively high (33 percent). Although this suggests a greater propensity to engage in supplementary employment among those with a higher income, this evidence of the influence of income is not conclusive by virtue of the fact that significant differences in behavior may well be obscured within the low-income group, accounting as it does for such a large proportion of the population. This qualification is required because it is likely that the participation rate is affected by (at least) two very different motives. On the one hand, respondents with a very low basic income may literally need to secure supplementary employment in order to ensure their survival; alternatively, high-income and high-status respondents may well be driven by aspirations to a still higher standard of living in seeking to exploit the opportunities open to them. Indeed, support for this view exists in the finding by Banjo (6) that those of low income spend comparatively more time in supplementary employment than their high-income counterparts while in fact earning less for these longer hours compared with higher-income respondents.

In Table 4 there is evidence of only a marginal overall reduction in travel time with increasing income, which conceals significant variation, both in terms of journey to work and other purposes, in Lagos and Ibadan. Indeed, the consistency of the relation between increasing income and travel-time

Table 4. Mean daily travel times for respondents engaged and not engaged in supplementary employment.

	Lagos Residents						Ibadan Residents						All Respondents[a]					
	Travel to Work		Travel for Other Purposes[b]				Travel to Work		Travel for Other Purposes[b]				Travel to Work		Travel for Other Purposes[b]			
Criterion Variable	Time (min)	V	Time (min)	V	Total Travel Time (min)	Sample Size	Time (min)	V	Time (min)	V	Total Travel Time (min)	Sample Size	Time (min)	V	Time (min)	V	Total Travel Time (min)	Sample Size
Sex																		
Male																		
A	88	0.6	115	0.5	203	44	78	0.7	117	0.6	195	50	80	0.6	117	0.5	197	137
B	80	0.6	70	0.6	150	36	61	0.8	67	0.5	128	14	72	0.6	75	0.6	147	58
Female																		
A	92	0.6	100	0.4	192	14	73	0.6	128	0.5	201	16	84	0.6	113	0.5	197	47
B	65	0.4	101	0.4	166	13	77	1.1	92	0.4	169	6	72	0.6	99	0.3	171	20
Car ownership																		
None																		
A	91	0.6	109	0.6	200	63	78	0.7	118	0.6	196	51	84	0.6	113	0.6	197	175
B	71	0.5	87	0.5	158	44	66	0.7	69	0.6	135	14	71	0.5	83	0.6	154	65
One or more																		
A	83	0.6	113	0.5	196	27	79	0.5	105	0.6	184	36	78	0.6	107	0.5	185	102
B	71	0.7	67	0.4	138	24	46	1.0	71	0.4	117	13	62	0.8	74	0.4	136	43
Income																		
Low																		
A	90	0.6	107	0.6	197	43	82	0.8	129	0.5	211	30	86	0.6	110	0.6	196	110
B	69	0.5	81	0.6	150	33	67	0.8	61	0.7	128	6	70	0.5	80	0.7	150	42
Medium																		
A	87	0.6	110	0.6	197	27	79	0.5	108	0.6	187	33	80	0.6	108	0.6	188	90
B	77	0.5	88	0.5	165	18	41	0.7	66	0.5	107	11	63	0.6	78	0.5	141	32
High																		
A	81	0.6	119	0.4	200	9	74	0.5	99	0.7	173	9	74	0.6	113	0.5	187	35
B	69	0.9	46	0.2	115	7	75	0.8	86	0.3	161	5	62	0.9	73	0.4	135	17
Occupation																		
Group 1																		
A	86	0.6	119	0.5	205	24	81	0.5	110	0.6	191	39	79	0.6	115	0.5	194	109
B	72	0.7	67	0.5	139	18	76	0.8	82	0.4	158	13	71	0.7	76	0.4	147	40
Group 2																		
A	94	0.6	100	0.6	194	42	86	0.7	122	0.5	208	24	90	0.6	104	0.6	194	96
B	76	0.5	87	0.6	163	29	36	0.6	52	0.6	88	11	68	0.6	82	0.7	150	43
Group 3																		
A	83	0.6	124	0.5	207	22	66	0.8	107	0.6	163	22	77	0.7	114	0.6	191	69
B	64	0.5	84	0.5	148	21	91	0.7	91	0.6	182	2	64	0.6	82	0.5	146	24
All respondents																		
A	89	0.6	111	0.5	200	163	78	0.6	113	0.6	191	87	82	0.6	115	0.6	197	277
B	71	0.6	79	0.5	150	68	60	0.9	74	0.5	134	27	67	0.6	79	0.5	146	108

Notes: V = coefficient of variation, A = employed respondents who are not engaged in supplementary employment, B = employed respondents who are engaged in supplementary employment. Occupation groups are defined in Table 2.

[a]Includes residents of Lagos, Ibadan, and elsewhere. [b]These values are from smaller sample sizes, as fewer people responded to this question.

savings is only found in the case of journey-to-work travel by those not engaged in supplementary employment. Travel for other purposes by the same groups displays conflicting trends in Lagos and Ibadan, which contributes to the similarity of the overall travel times. Furthermore, the variation of travel times recorded by those with supplementary employment does not follow any systematic pattern in relation to income, except in the case of the overall sample. If anything, the supplementary-employment group shows more variability in terms of travel time for other purposes, as indicated by the higher values of the coefficient of variation.

Careful interpretation is also required in examining the second stage of the above-hypothesized relation between engagement in supplementary employment and the ability to purchase time savings, which is displayed in its relation with car ownership. As noted earlier, while only 37 percent of those with supplementary employment were car owners, the participation rate among car owners was relatively high at 30 percent compared with only 27 percent among noncar owners. This shows some consistency with the notion that the propensity to engage in supplementary employment is stronger among higher-income groups, as it can be assumed (and demonstrated) that there is present the familiar high correlation between car ownership and income. However, the relation between car ownership and travel-time variation, not to say time savings, is more subtle and appears to be subject to the influence of local traffic and travel conditions.

To introduce this discussion, note that the differences in total travel time between car owners and noncar owners are not very great and only slightly larger for those respondents in supplementary employment (see Table 4). However, when the times recorded by Lagos and Ibadan residents are examined, more interesting distinctions can be drawn. In the case of journey-to-work travel by those not engaged in supplementary employment, Lagos car owners have a slightly shorter journey time than noncar owners (83 compared with 93 min), whereas in Ibadan the two groups have almost identical travel times (79 and 78 min, respectively). On the other hand, for those engaged in supplementary employment, this pattern is reversed. Indeed, in this case, the Lagos resident figures are identical (71 min) while the work journey travel time by Ibadan car owners is only 46 min compared with 66 min for noncar owners--a difference of 20 min. However, the Ibadan times are subject to greater variability, as reflected by the higher values of the coefficient of variation.

Interpretation of these differences must be made in the light of knowledge of the local travel conditions. In simple terms, it can be stated that traffic congestion and general movement problems are more serious in Lagos than Ibadan, which is in part reflected in the higher overall travel times recorded by Lagos residents. What this suggests is that, while car owners in Lagos are unable to gain any significant travel-time savings over noncar owners in the journey to work, Ibadan car-owning residents with supplementary employment are better able to take advantage of the less-congested local traffic conditions and thus achieve a significant saving in travel time. This saving could also be due in part to the greater likelihood of the latter group traveling outside the relatively congested evening peak periods during which those car owners without supplementary employment gain no advantage. Persistence of congestion outside the peak period in Lagos could equally account for the similarity of the car owner and noncar owner supplemetary employee times recorded by Lagos residents. These differences in the peak and off-peak conditions experienced in Lagos and Ibadan could also go some way toward explaining the earlier-noted greater overall variability present in the reported Ibadan travel times.

What emerges from the above discussion is a measure of support for the hypothesized relation between engagement in supplementary employment and an ability to purchase time savings through increased income and propensity to own a car, mediated by the effects of local travel conditions. What is not evident, of course, is the direction in which these relations might operate. It remains unclear, for example, whether it is engagement in supplementary employment that provides the means to purchase and run a car and secure the consequent achievement of time savings, or whether it is higher basic income and vehicle ownership that makes it more practical for such respondents to engage in supplementary employment. Given the apparent extent of the influence on travel time of engagement in supplementary employment, these issues appear to justify further study but would need to be the subject of a more detailed investigation than that pursued here.

To conclude this empirical section, which is concerned with daily travel-time variation, the principal findings are now summarized. The most striking feature of mean daily travel-time variation to emerge from the analysis is the consistently high overall values recorded by both Lagos and Ibadan residents. It has been shown that these high values conceal a fair degree of variation in the time devoted to both journey to work and other travel, with an unusually large proportion of travel time reported as being attributable to nonwork purposes, especially among those not engaged in supplementary employment. Engagement in supplementary employment greatly influences travel-time expenditure, which reduces the travel time associated with nonwork purposes and increases its variability. Furthermore, there is some degree of consistency in the effect of involvement in this activity on the patterns of travel-time use reported by Lagos and Ibadan residents, once the differences in travel time that here have been attributed to differences in the characteristics of the local transportation systems and patterns of development are taken into account. Finally, the greater variability observed in Ibadan resident travel times than that reported by Lagos residents may be explained by the greater contrast experienced in Ibadan between peak and off-peak period travel conditions.

The apparent importance of the transportation system and development characteristics in accounting for the differences in travel time prompted the further exploration of some of the ways in which features of the local pattern of travel demand and local travel conditions are likely to be reflected in variations in travel times. In the final section of this paper, an initial attempt is made to identify some of the relations between these characteristics and the amount of variation in travel-time values that can be expected as a major settlement evolves.

TRAVEL-TIME VARIATION IN CHANGING CONDITIONS

To gain a clearer understanding of how various sets of conditions contribute toward the occurrence of variation in observed travel times, both at one point in time and between different points, it is appropriate to first seek to adequately describe the patterns of variation before proceeding to formulate theories and models that can serve to explain and simulate such variations. What is attempted here is a tentative start on this process of description. Inevitably, the ideas put forward are hedged about with a multitude of assumptions, most of which remain implicit in this exploratory discussion. However, it is hoped that the exercise of setting down the ideas will at least provoke further thought as to how the approach pursued might be better developed and how the relations hypothesized might be tested empirically.

Dimensions of Travel-Time Variation

It is useful initially to distinguish the various dimensions of travel-time variation. With respect to a particular journey, these can include day-to-day or trip-to-trip differences in travel times recorded by individuals traveling by the same mode or by different modes via different routes or at different times of the day. In the longer term, variation can be attributed to changes in transportation networks and their methods of operation or to changes in the pattern of demand. Similarly, overall amounts of time devoted to travel, as opposed to the time required to complete a particular journey, will be subject to variation as these broader system characteristics change over the longer term.

In the travel-time-budget literature, the term "stability" is often used rather loosely to refer to similarity in the mean daily travel times recorded by different groups of travelers. In this context, however, it is suggested that this term might be better used to refer to invariance of observed travel-time values over relatively lengthy intervals between observations. From observations that relate to one point in time or, more precisely, a cross-sectional day survey, it might be more appropriate to use the term "uniformity" in the description of limited differences in travel times between groups of travelers such as, for example, car users or bus users. This notion of uniformity can be extended to relate to uniformity or little variability between modes, as in the case of a particular journey that takes roughly the same time by bus or by car. Alternatively, it can be used to refer to little variability within modes, which would relate to there being little variation in the time taken to complete a particular journey undertaken many times by the same mode.

The likelihood of the occurrence of such uniformity in the short term and stability in the longer term can be seen to be a function of the complex interaction of (at least) three sets of factors, which can be summarized as follows:

1. The spatial pattern of demand;
2. The configuration and relative efficiency, cost of use, etc., of road and public transportation networks; and
3. The temporal pattern of demand (here taken to refer to variation in demand throughout the day).

variation in travel times associated with a particular journey can arise, for example, from a mismatch between the spatial pattern of demand and the capacity of transportation networks leading to overloading, congestion, and delays at particular points, the extent and frequency of which are influenced by the temporal pattern of demand. Thus, the degree of uniformity observed will depend on the state of these interrelations at one point in time, while stability will be dependent on the way in which these factors covary with the passage of time.

Hypothetical Example of Travel-Time Variation and Settlement Evolution

It is possible to identify a range of sets of conditions in which the relation between the demand for different modes of transportation and the quality of service provided by those modes (itself a function of system supply) can give rise to differing ranges of variation in travel times. This can best be illustrated in the simple case of the availability of the car and bus-based public transportation. The sets of conditions can be represented in diagrammatic form, again in simple discrete terms, as displayed in Figure 2. In the diagram, there is an implicit time dimension and chronology of events or states that here are intended to trace the stages of evolution of a growing settlement.

Figure 2. Travel-time variation at different stages of settlement development.

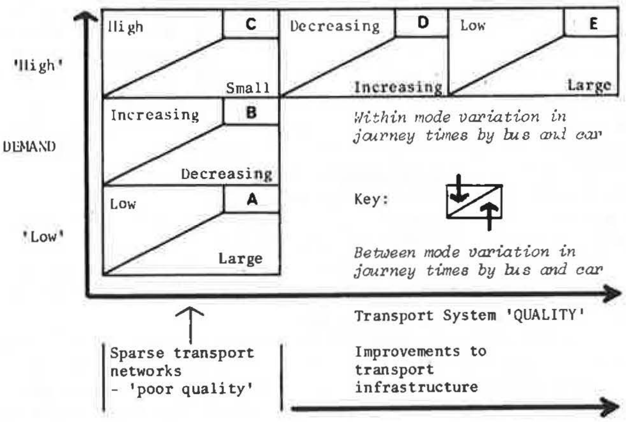


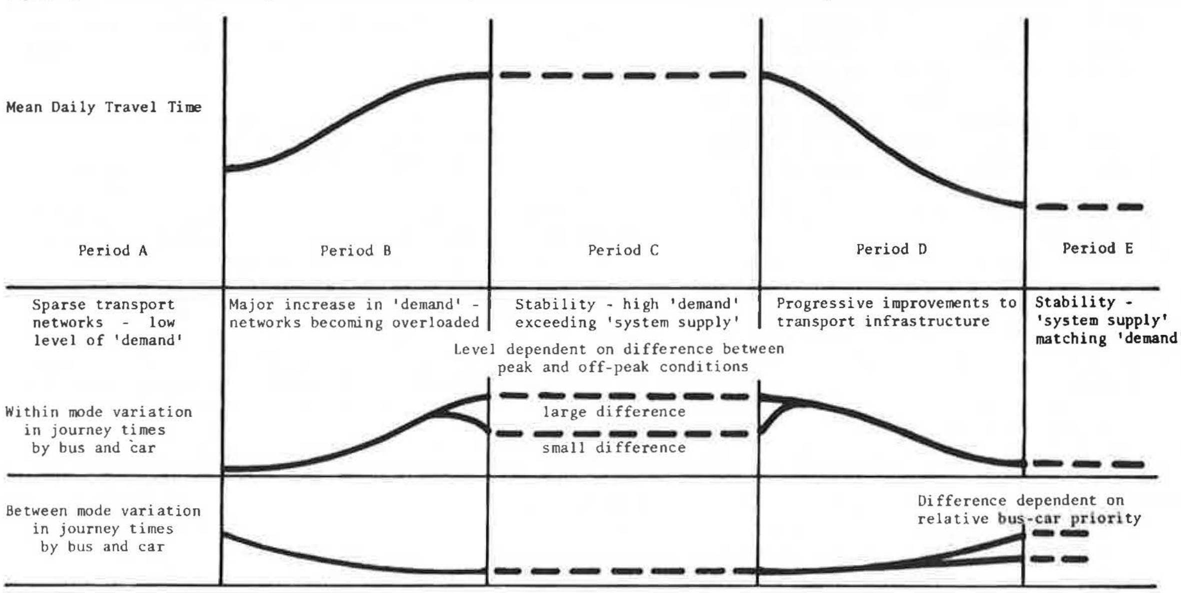
Figure 3 is a diagrammatic representation of the hypothesized trajectory of mean daily travel-time variation as a settlement passes through the five stages of development referred to in Figure 2 but, in this case, with the process of change treated in a continuous rather than discrete manner. This treatment introduces the requirement to describe the rates of change of different conditions, the form and timing of which it is possible to represent only crudely. However, what is sought at this stage is not necessarily precision but a first approximation to the direction and degree of change that are likely to be observed in each of the parameters of travel-time variation, as represented in the lower part of Figure 3.

The conditions represented by A (Figure 2) are taken to correspond to the very early stages (predevelopment stage) of a settlement's existence, during which travel demand is relatively low and within the capacity of infrastructure provision. Under these conditions, it is likely that there will be little adverse interaction between the performance of car and bus, little variation in travel time from journey to journey by the same mode, but a marked advantage to car users in terms of travel time, which assumes a relatively low frequency of public transportation service.

If demand grows significantly and the capacity of the transportation system is not increased to match this growth, the resulting mismatch can be expected to give rise to the progressive deterioration in conditions represented by B. The effect of the increasing level of demand on the performance of inadequate transportation networks is assumed to be reflected in an increase in mean daily travel time (Figure 3), while the range of difference in mean travel time for a particular journey by bus and car decreases, which reflects a reduction in car traffic speed due to congestion. At the same time, the range of variation in individual journey times by bus and car will increase, in part reflecting a growing contrast between peak and off-peak conditions.

It is suggested that eventually, with demand continuing to exceed supply, a degree of stability in

Figure 3. Variation in mean daily travel time and other aspects of travel-time variation at different stages of settlement development.



mean daily travel times is likely to be observed (period C), perhaps over a number of years, together with a stabilization both of differences between mean journey times by bus and by car and of variation in individual journey times by bus or car. It is further suggested that it is when or even before such conditions prevail that initial attempts may be made to eliminate causes of congestion through local road network improvements, to upgrade public transportation services, and generally to improve the quality of service experienced by car and bus users. As these piecemeal improvements are made to the transportation infrastructure (period D), the travel times recorded by car and bus users can be expected to fall, contributing to a decrease in mean daily travel time (Figure 3), which assumes--and this may be a key assumption--that the rate of improvement achieved exceeds the rate at which demand for movement continues to grow. Efforts to alleviate problems can be expected to result in a progressive decrease in the variability of travel times by car and by bus. Meanwhile, as such benefits are gained, there is likely to be an increase in the difference between average car and bus times for a specified journey.

Ultimately, following a sustained program of investment and improvement, it is suggested that a stage may be reached (period E) at which road and bus system capacities more closely match the higher level of demand. In these conditions, journey-to-work variation in travel time within each mode is likely to be low, but the difference between car and bus mean journey times relatively high, which reflects their relative operational capabilities, the extent of this difference in part being dependent on the relative priority given to each mode. Thus, with car and bus able to operate in nearer to ideal conditions, it can be expected that mean daily travel time will flatten out, but at a lower stable level than that observed during the period of system overload represented by period C.

Discounting for the moment the effect of assumptions about, among other factors, actual modal split, relative modal costs, changes in trip orientation, peaking of demand, etc., this seems to be a simple but plausible description of the evolution of transportation conditions in a developing settlement.

Observed Conditions and Extension of Hypothesis

With respect to the earlier empirical analysis of travel-time variation, it is appropriate at this point to note that the conditions described as corresponding to stage C appear to coincide quite closely with those currently observed in Lagos. As described in the earlier discussion, these can be characterizied by acute problems of traffic congestion, little difference between travel times attainable by car and bus and between the conditions experienced during the peak and so-called off-peak periods, together with a high value of overall daily travel time. Ibadan, on the other hand, is thought to be a little behind Lagos on the evolutionary curve, perhaps approaching stage C, where it has less acute congestion problems, a degree of between-mode variability, and a greater contrast between peak and off-peak conditions, but increasing within-mode variability.

By contrast, it is suggested that, in many cities in developed countries, conditions are closer to those associated with stage E at which a relatively low mean daily travel time is observed, accompanied by low between-mode and high within-mode variability. This is not to suggest that these conditions are necessarily stable at this relatively low point on the curve depicted in Figure 3. Indeed, stability in these terms is seen to be dependent on the existence of a balance or equilibrium between demand and rate of system supply. Thus, this hypothesis could be extended to suggest that further growth in demand, which exceeds the rate of supply, can be expected to result in an upward swing in the curve (and associated changes in the other parameters) and a subsequent downswing as further improvements are implemented. The pattern of change could in this way be expected to display damped oscillations, with a tendency toward a lower mean daily travel time as technology provides progressive improvements in modal performance.

Some Implications of Hypothesized Relations

After this brief digression, we can now return to the main line of argument. If the above can be taken to be a reasonably realistic representation of the changes in some of the key components of travel-time variation as a settlement evolves, it raises a number of important questions about the assumptions that can be made concerning future changes in travel-time parameters at the different stages of this evolutionary path.

It was suggested above that it is at stage C, the period when demand greatly exceeds system supply and there is relative stability in mean daily travel time accompanied by low between-mode and high within-mode variability, that the first steps are taken to alleviate the more acute problems of congestion. It is further suggested that it is at this stage that recognition of the existence or persistence of movement problems is likely to prompt the seeking of professional advice as to how these problems might be resolved in the longer term. In other words, consultants are most likely to be called on to draw up plans for the development and improvement of the transportation system only when this stage has been reached. Furthermore, it is observations of travel conditions prevailing at this time that are likely to provide the information on which forecasts of future changes in travel behavior and justification for such plans will be based.

If the logical assumption is made that an aim in formulating these plans will be the achievement of a balance between demand and system supply, then this analysis points to the need to recognize that such a balance is likely to be attained in, or result in, very different conditions of travel-time variation from those currently observed. The fundamental point to be noted is the likelihood of the pattern of travel-time variation at the plan realization stage of settlement evolution, which is characterized by the following:

1. A lower level of mean daily travel time,
2. A greater range of difference between mean journey times by bus and by car for a particular journey (greater between-mode variation), and
3. The possibility of a lower range of variation in individual journey times for a particular journey by bus or car (less within-mode variation).

This has important implications for both the predictive use of models of travel behavior and the values of time employed in the evaluation of future plans. If model parameters are estimated by using data that relate to conditions in which demand greatly exceeds supply, and the model parameters used in forecasting future patterns of travel behavior are dependent on the existence of a particular set of travel-time-variation conditions, then clearly such forecasts must be used with great caution.

Similarly, it is argued that the valuation placed by travelers on time savings, which are gained in the observed period of system overload and congestion, is likely to be different from that attached to corresponding time savings achievable under the conditions that this analysis suggests will prevail when a better balance between demand and system supply has been attained. This and other aspects of travel-time valuation are the subject of extended discussion elsewhere (6).

CONCLUSIONS

In the earlier sections of this paper, various aspects of the pattern of time-budget expenditure in Nigeria were examined. Engagement in supplementary employment was demonstrated to be an activity that has a significant effect on the allocation of time to the other activities recorded by survey respondents. In particular, engagement in this activity was shown to be associated with a reduction in daily travel time, especially that with respect to travel for purposes other than to or from work, and with greater variability in the time devoted to such travel.

The unusually high values of mean daily travel time recorded by Lagos and Ibadan residents, together with the explanations offered for the similarities and differences in travel-time variation in the two cities, in addition to that attributable to income and car-ownership effects, prompted the further exploration of possible relations between such variation and features of the local transportation system. It was concluded that, should the hypothesized relations between mean daily travel time and transportation system evolution be confirmed by other studies, they can be expected to have important implications for transportation modeling and time-valuation practice in Third World cities.

In the introduction to the final section of the paper it was noted that the ideas put forward are still somewhat tentative and require further elaboration. However, it is hoped that they will serve to stimulate further thought on the dynamics and implications of changes in the pattern of travel-time variation.

ACKNOWLEDGMENT

We gratefully acknowledge the financial support provided to Banjo by the Rees Jeffreys Road Fund, and we wish to express our thanks to J.A. Proudlove for his helpful comments. However, any errors, omissions, and shortcomings must remain our responsibility.

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Publication of this paper sponsored by Committee on Traveler Behavior and Values.

Analytically Derived Classifications of Daily Travel-Activity Behavior: Description, Evaluation, and Interpretation

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One phase of a research study designed to enhance our understanding of urban travel behavior is discussed. In particular, this paper comprises the description, evaluation, and interpretation of analytically derived classifications of daily travel-activity behavior. A methodology that facilitates systematic identification of groups of similar travel-activity patterns is used to derive the typologies reported and examined here. This methodology is applied to a sample of 236 daily travel-activity patterns drawn from the Baltimore travel demand data set. Each of the sample observations is described by the set of stops made in a 24-h period; each stop is characterized by activity and time of day. The paper explores the hypothesis that a set of daily travel-activity patterns can usefully be described by its membership in a limited number of interpretable general classes. The results reported here show that the 236 daily patterns can be grouped into between 12 and 5 relatively homogeneous groups while retaining between 64 and 46 percent of the information in the data. The results also show that the

clusters may be interpreted by defining a small number of representative daily travel-activity patterns for each group. The analytically derived general classes of travel-activity behavior that are described and examined define a categorical response variable for use in models and analyses of daily urban travel behavior.

Recent research has begun to address two of the complexities of urban travel behavior; namely, that urban travel is a derived demand and that the elemental travel episodes (trips) over a day or week are not independent. The importance of accounting for these complexities in the understanding of urban travel behavior is well documented (1-5). The research reported in this paper is part of the ongoing effort to improve our understanding of urban travel behavior by recognizing and incorporating the above-mentioned complexities of the phenomenon in analyses and models. In particular, this paper reports the description, interpretation, and evaluation of classifications of individual daily urban travel-activity behavior. These classifications are derived analytically by applying a flexible and integrated methodology (5,6) to a sample of daily travel-activity patterns.

In order to analyze and model daily travel-activity patterns as complex entities, it is necessary to measure this behavioral phenomenon. Classification, which is a form of measurement, is employed in this research as well as in other recent efforts to examine and model complex travel-activity patterns (7-9, and paper by Kostyniuk and Kitamura elsewhere in this Record). Classification has also been employed by a number of travel-behavior researchers in the past. Some researchers have used a priori classifications (10,11), while others have classified travel behavior analytically (12-15). Because classification is the lowest form of measurement, an ability to classify is a necessary condition for analyzing and modeling daily travel-activity behavior as a complex entity.

In this paper, the hypothesis that a set of daily travel-activity patterns can usefully be described by its membership in a relatively small number of interpretable classes is examined. This hypothesis is based on the notion that general classes of daily travel-activity behavior can be identified because people with the same motivations and constraints relative to travel-activity behavior have similar daily patterns (5).

The remainder of this paper is structured as follows. First, the methodology is outlined briefly. Second, the data used in this research are described. Third, the cluster analysis results are reported. Fourth, two particular typologies of daily travel-activity behavior are evaluated and interpreted. Finally, the results reported here are discussed, and the analyses that have been undertaken by using the classifications described and evaluated in this paper are outlined.

METHODOLOGY

The classifications of daily urban travel-activity behavior reported in this paper are derived by using a flexible and integrated methodology (5,6). Briefly, the methodology comprises three stages (see Figure 1), which consist of a total of five interrelated steps that allow the systematic identification of classes of similar daily travel-activity behavior, as well as facilitating the interpretation and evaluation of these groups. In the first stage of the approach, raw input data that describe the 24-h travel-activity behavior of a sample of individuals are transformed into a configuration of points in a real Euclidean space, where each point represents one of the daily patterns being analyzed. This transformation is achieved in three steps. First, a modified version of the Burnett and Hanson (16) extension of the Hagerstrandian time-geography model is used to describe each daily travel-activity pattern. Second, the patterns are compared analytically by using a similarity measure (5). Third, principal-coordinates analysis (17) is used to determine the real-space configuration that best preserves the interpattern relations captured by the similarity measure. Thus, the more similar a given pair of patterns, the closer they are in the multidimensional space. The real-space representation is used as input to the group formation stage, which produces a selected number of relatively homogeneous groups of daily travel-activity behavior by using a well-known cluster-analysis algorithm. In the interpretation and evaluation stage, one or more representative patterns are identified for each group to facilitate interpretation of the cluster-analysis results, and sum-of-squares measures are used to evaluate the derived classifications.

The results reported and evaluated here are derived by using the methodology outlined above. In particular, these results are based on a description of each daily travel-activity pattern as a set of stops, where each stop is characterized by the activity at the stop and the time of day the stop was made. The index of similarity between daily travel-activity patterns used in this research allows for differential weighting of the characteristics used to describe each stop (5). Because activity type is considered more important than time of day in differentiating daily travel-activity behavior, the results reported below are based on a similarity index (between travel-activity patterns), in which activity type is weighted more heavily than time of day.

DATA

The data used in this research were collected in the Baltimore metropolitan area in 1977 (18). The data were collected by home-interview surveys conducted in a total of 966 households and include household and individual sociodemographic information as well as travel-activity behavior data. The latter includes all movements greater than one block in length, by all modes, during a 28-h reporting period that extends from 12:00 midnight to 4:00 a.m. the following day. The information obtained for each movement includes purpose (activity) at the destination, mode of travel, time of departure and arrival, land use at the destination, and the origin and destination of the movement (in terms of census block, tract, and traffic analysis zone).

The results reported in this paper are based on a subsample drawn from the Baltimore data set. This sample consists of data that describe the daily travel-activity patterns of 236 people who are 16 years of age or older. Examination of the distributions of the number of stops per day and number of tours per day reveals that more than one-third of the daily patterns in this sample incorporate two or more tours, while the majority of individuals in this sample make more than one nonhome stop in 24 h (5).

The daily travel-activity patterns analyzed in this research are described by the activity at each stop and the time of day at which the stop is made. The Baltimore data set differentiates 21 activity types at the destination end of each movement. In identifying general classes of daily travel-activity behavior, it is unnecessary and probably undesirable to differentiate such a large number of activity types. Reichman (19) is one of the first researchers to introduce the concept of life-style in the travel-behavior literature. In this context, he

Figure 1. Overview of methodology.

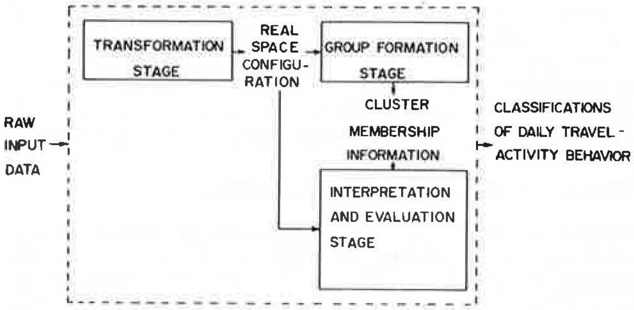
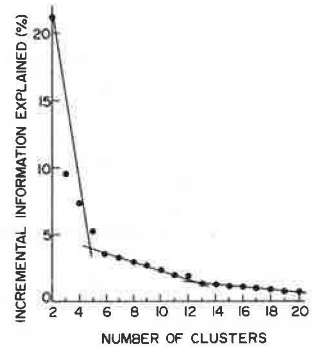


Figure 2. Incremental information explained as function of number of clusters.



suggests the grouping of out-of-home activities into three categories: subsistence (work, school), maintenance (shopping, personal business), and leisure. These categories, as well as return home, are selected for use in the research reported here. Five distinct time periods of the 24-h day are recognized in this research: early morning (4:00-7:00 a.m.), morning peak (7:00-9:30 a.m.), midday (9:30 a.m.-4:00 p.m.), afternoon peak (4:00-6:30 p.m.), and evening (6:30 p.m.-4:00 a.m.).

CLUSTER-ANALYSIS RESULTS

The output of the first stage of the methodology outlined above is a set of points in a real Euclidean space, where each point represents a daily travel-activity pattern. A real space of 32 dimensions is found to provide a good representation of the relations among the 236 daily patterns in this sample (5). This real-space configuration is used as input to the group formation stage. Ward's algorithm (20) is employed here to cluster the sample daily travel-activity patterns into a small number of relatively homogeneous groups.

Ward's algorithm is a cluster-analysis procedure in which objects and clusters are agglomerated hierarchically into nonoverlapping groups. Each step of the iterative procedure is guided by the objective of minimizing the within-group sum of squares, which is given by the following equation:

$$WSS_G = \sum_{g=1}^{G} \sum_{i=1}^{N_g} \sum_{\ell=1}^{L} (X_{i\ell g} - \bar{X}_{\ell g})^2 \quad (1)$$

where

WSS_G = within-group sum of squares for G groups,
$X_{i\ell g}$ = location on dimension ℓ of observation i of group g,
$\bar{X}_{\ell g}$ = mean location on dimension ℓ of observations in group g,
N_g = number of observations in group g,
G = number of groups, and
L = number of dimensions in the real-space configuration.

Because the total sum of squares is a constant for a given set of observations, minimizing the within-group (or error) sum of squares implicitly maximizes the between-group (or explained) sum of squares. That is, Ward's algorithm attempts to maximize the information (variance) accounted for by the classification of a large set of objects into a relatively small number of groups.

The cluster-analysis results are subjected to a preliminary examination in order to determine which cluster solutions should be interpreted and evaluated. This is accomplished by considering the incremental information accounted for by each unit increase in the number of clusters in the solution. This measure is defined as the reduction in the within-group sum of squares, which is expressed as a percentage of the total sum of squares, as follows:

$$\Delta I_G = [(WSS_{G-1} - WSS_G)/TSS] \cdot 100 \quad (2)$$

where

ΔI_G = incremental information explained by G clusters (relative to G-1 clusters),
WSS_G = within-group sum of squares for G clusters (see Equation 1),
WSS_{G-1} = within-group sum of squares for G-1 clusters, and
TSS = total sum of squares, i.e.,

$$TSS = \sum_{g=1}^{G} \sum_{i=1}^{N_g} \sum_{\ell=1}^{L} (X_{i\ell g})^2 \quad (3)$$

The incremental information explained by each additional cluster as a function of the number of clusters is shown in Figure 2 for 2 through 20 clusters. This diagram consists of three distinct segments. First, when the number of clusters is very small (<5), the amount of information explained is substantially increased by increasing the number of clusters, as expected. Second, there is an intermediate portion in which the incremental information due to an additional cluster is noticeable but not very large. Third, beyond 12 clusters the graph is very flat and is close to the horizontal axis, which indicates that each additional cluster accounts for only a very small incremental amount of information and that this increment is nearly constant with increasing dimensionality of the cluster solution. These data suggest that the 12 through 5 cluster solutions be examined in more detail. The results of such investigations are presented below.

INTERPRETATION AND EVALUATION OF CLUSTER-ANALYSIS RESULTS

The results of a cluster analysis have no inherent validity and should always be interpreted and evaluated (21). In this research, the cluster-analysis results are interpreted by identifying one or more representative patterns for each cluster in the solution. The need for such representative patterns and the rationale for the procedure used in their selection are discussed elsewhere (5,6). For each cluster, representatives are identified as those travel-activity patterns that are within some given distance of the cluster centroid. In particular, the patterns selected are those that satisfy the following relation:

$$d_{ig} \leq \bar{d}_g + F\sigma_g \quad (4)$$

where

d_{ig} = distance between the centroid and the ith pattern of cluster g,
d_g = distance between the centroid and the closest pattern in cluster g,
σ_g = standard deviation of the distances between the patterns and centroid of cluster g, and
F = empirically determined parameter.

Equation 4 allows for the fact that some groups are very homogeneous and require few representative patterns, while other groups are relatively more heterogeneous and a number of representative patterns are needed for proper interpretation. Based on the results of exploratory analyses (5), the parameter F in Equation 4 is set equal to 0.10 to obtain the results reported here.

Ward's algorithm seeks to minimize the within-group sum of squares (see Equation 1). This measure is the sum of squares about the cluster centroids; therefore, the between-group sum of squares (the difference between the total and within-group sum of squares) may be thought of as the information explained by the cluster centroids. The between-group sum of squares is a useful measure of the information in the data set that is explained by the classification per se. However, it does not account for the fact that the representative patterns, which are used to interpret the classification results, do not capture all the information explained by the cluster centroids. The measure of information explained by the representative patterns is defined as follows:

$$I_G' = \left\{ 1 - \left[\sum_{g=1}^{G} \sum_{i=1}^{N_g} \sum_{\ell=1}^{L} (X_{i\ell g} - X_{\ell g}^*)^2 \right] / TSS \right\} \cdot 100 \quad (5)$$

where I_G' is the information explained by the representative patterns for the G cluster solution (percent), and $X_{\ell g}^*$ is the mean score on dimension ℓ of the representative patterns for cluster g, i.e.,

$$X_{\ell g}^* = (1/N_g') \sum_{r=1}^{N_g'} X_{r\ell g} \quad (6)$$

where $X_{r\ell g}$ is the score on dimension ℓ of the rth representative pattern of group g, and N_g' is the number of representative patterns in group g.

The above formulation enables us to partition the total information in the data set into a number of components, because if N_g' in Equation 6 is set to equal to N_g (the number of patterns in cluster g), then $X_{\ell g}^*$ defines the centroid of cluster g and Equation 5 yields the percentage of information accounted for by the cluster centroids.

Figure 3 shows the breakdown of the total information for 12 through 5 cluster solutions into three components:

1. The information explained by the representative patterns for each cluster;
2. The incremental information due to the cluster centroids, relative to the representative patterns for each cluster; and
3. The information lost within clusters.

The results shown in Figure 3 confirm that, for a given set of travel-activity patterns, cluster solutions with fewer groups are less homogeneous, as expected. They also show that the information explained by the cluster centroids is considerable, even with a small number of clusters. For example, the 236 daily travel-activity patterns may be grouped into as few as six clusters while retaining almost 50 percent of the information in the similarity matrix. In general, the representative patterns do retain much of the information explained by the clusters. However, the representative patterns lose a significant proportion of the information accounted for by the cluster centroids when the set of patterns is grouped into a small number of clusters.

Interpretation of 12-Cluster Solution

Figure 4 shows the representative patterns identified by the criterion in Equation 4 for each of the groups in the 12-cluster solution. The representative pattern closest to the centroid of each cluster is also designated in this figure. The table below reports measures of the percentage of the information in each cluster that is accounted for by the cluster centroid and by the representative patterns:

	Information Explained (%)	
Cluster No.	By Cluster Centroid	By Representative Patterns
1	78.7	75.6
2	91.4	89.9
3	68.0	49.5
4	95.0	94.7
5	61.9	53.6
6	73.4	56.1
7	49.9	34.9
8	36.8	20.3
9	51.0	35.5
10	66.6	53.4
11	60.1	52.3
12	47.3	40.8
Total Sample	64.0	53.9

These measures are analogous to those defined earlier (Equation 5), except that the table reports cluster-specific measures. The overall measures are weighted averages of those for the individual clusters. The results reported in Figure 4 and the above table show that most clusters are relatively homogeneous. In 10 of the 12 clusters, the centroid accounts for 50 percent or more of the information in the cluster. Overall, the cluster centroids explain almost two-thirds of the information (64.0 percent) in the data. Also, for 6 of the 12 clusters, a single representative pattern accounts for 50 percent or more of the information in the cluster.

The pattern types in the 12-cluster solution are interpreted on the basis of the representative patterns depicted in Figure 4, and the results are reported in Table 1. Types 1 through 6 of this classification comprise a single nonhome stop. These groups differ in the activity at the nonhome stop and/or the time of day at which the stop is made. For example, types 1 and 2 both comprise a single stop for a maintenance activity, but they differ in terms of when the stop is made. Types 4 through 6 are single nonhome stop patterns for a subsistence activity and differ only in the time of day at which the stop is made.

Types 7 through 9 are daily travel-activity patterns comprising two nonhome stops made on two excursions from the home. Types 7 and 8 have a subsistence stop on the first out-of-home excursion, followed by either a leisure or maintenance stop, generally in the evening. Type 9 comprises two nonhome stops, both for a leisure activity. Pattern type 10 consists of multiple maintenance stops during the midday period. Types 11 and 12 are patterns comprising multiple nonhome stops made on numerous excursions from the home.

Interpretation of the Five-Cluster Solution

The interpretation and evaluation of the five-cluster solution, which uses the procedures described above, are reported here. The 5 clusters are found to be considerably more heterogeneous than the 12 clusters described above. The cluster centroids account for nearly half the information (45.6 percent) overall and for more than 40 percent of the information in four of the five clusters. However, a total of 26 representative patterns account for approximately 30 percent of the information in the similarity matrix (5).

The 26 representative patterns selected for the five-cluster solution provide the interpretations reported in Table 2. Pattern types 1, 2, and 5 each comprise a single nonhome stop. These pattern types differ in terms of the activity in which the individual participated as well as the time of day at which the nonhome stop is reached. Pattern types 1, 2, and 5 are maintenance, leisure, and subsistence-oriented patterns, respectively. Pattern type 3 consists of two or three nonhome stops made on two excursions from the home. The first nonhome stop is for a subsistence activity, and each pattern includes a maintenance and/or leisure stop. Pattern type 4 is an agglomeration of patterns of various forms, the common factor being that they contain numerous nonhome stops.

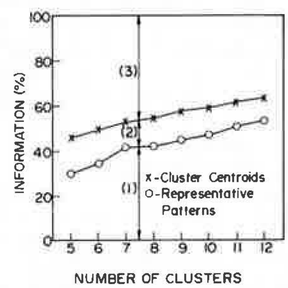
DISCUSSION OF RESULTS

The stability of the results reported above was examined by undertaking a parallel analysis that used a random hold-back sample of 223 observations. The results of the two analyses were found to be very similar (5). The interpretation of the identified classes of daily travel-activity behavior converged, but only at the five-cluster level. This is probably due to the relatively small samples employed in this research, and future research should explore the robustness of the classification results.

The results reported above verify the major hypothesis examined in this paper; namely, a set of daily travel-activity patterns may be grouped into a relatively small number of interpretable categories that account for a considerable proportion of the variance in the data. The results also show that the classes of daily travel-activity behavior may be interpreted by identifying one or more representative patterns for each distinct group of behavior. Finally, the results reported here show the analytically derived clusters to be intuitively acceptable.

The classifications of daily travel-activity behavior reported in this paper are intuitively acceptable. However, although it is difficult to choose between two different classifications of travel-activity behavior on an objective basis, the reader might subjectively prefer other 12- or 5-group classifications than those reported above. The virtue of the approach used to derive the results reported here is that it is objective in many respects, while subjective decisions are made explicit. For example, in defining a classification of travel-activity patterns, one might implicitly use a differential weighting of activity and time of day. In this research, such choices are made explicit.

Figure 3. Components of total information as function of number of clusters.



(1)-Information explained by representative patterns.
(2)-Incremental information explained by cluster centroids, relative to representative patterns.
(3)-Information lost within clusters.

Figure 4. Representative travel-activity patterns: 12-cluster solution.

GROUP NO.	REP. NO.[a]	ATTRIBUTE[b]	STOP NO. 1	2
1	1	ACTIVITY	M	H
		TIME	2	2
2	1	ACTIVITY	M	H
		TIME	4	4
3	1	ACTIVITY	L	H
		TIME	2	4
4	1	ACTIVITY	S	H
		TIME	1	3
5	1	ACTIVITY	S	H
		TIME	1	2
	2[c]	ACTIVITY	S	H
		TIME	5	3
	3	ACTIVITY	S	H
		TIME	5	2
6	1	ACTIVITY	S	H
		TIME	2	4

GROUP NO.	REP. NO.[a]	ATTRIBUTE[b]	STOP NO. 1	2	3	4
7	1	ACTIVITY	S	H	L	H
		TIME	1	3	4	4
	2[c]	ACTIVITY	S	H	L	H
		TIME	1	3	3	4
8	1[c]	ACTIVITY	S	H	M	H
		TIME	1	3	4	4
	2	ACTIVITY	S	H	M	H
		TIME	1	3	3	4
9	1	ACTIVITY	L	H	L	H
		TIME	2	2	2	2
	2[c]	ACTIVITY	M	H	L	H
		TIME	2	2	2	4
10	1	ACTIVITY	M	M	M	H
		TIME	2	2	2	2

GROUP NO.	REP. NO.[a]	ATTRIBUTE[b]	STOP NUMBER 1	2	3	4	5	6	7	8	9
11	1[c]	ACTIVITY	S	M	H	M	L	M	L	M	H
		TIME	2	2	2	2	2	3	3	4	4
	2	ACTIVITY	M	H	M	S	H	L	M	M	H
		TIME	1	1	2	2	2	2	2	2	2
	3	ACTIVITY	M	M	M	M	M	H	L	H	
		TIME	1	1	1	2	2	2	3	3	
12	1	ACTIVITY	S	H	M	H	S	H			
		TIME	2	2	3	3	3	4			
	2	ACTIVITY	S	H	S	H	S	H			
		TIME	2	2	2	3	4	4			
	3	ACTIVITY	S	H	M	H	S	L	H		
		TIME	2	2	2	2	3	4	4		
	4	ACTIVITY	S	H	S	H	S	H			
		TIME	1	2	2	2	3	3			
	5	ACTIVITY	L	H	S	S	M	S	M	S	H
		TIME	2	2	2	2	2	2	3	3	4
	6[c]	ACTIVITY	S	S	S	H	S	H			
		TIME	2	2	2	3	3	4			

a - representative pattern number

b - activity and time of day codes used in this table are as follows:

S - subsistence M - maintenance

L - leisure H - home

1 - morning peak 2 - midday period

3 - afternoon peak 4 - evening

5 - early morning

c - representative pattern closest to centroid

Table 1. Daily travel-activity pattern types: 12-cluster solution.

Type No.	Description	Proportion of Sample
1	Single nonhome stop patterns for a maintenance activity with movements in midday period	0.09
2	Similar to type 1 except that movements are in evening period	0.03
3	Single nonhome stop patterns for a leisure activity; non-peak-period movements	0.06
4	Single nonhome stop for subsistence activity; movements in morning and afternoon peak periods	0.13
5	Similar to type 4 except that movements are generally before the morning and afternoon peaks	0.08
6	Similar to type 5 except that movements take place after morning and afternoon peaks	0.10
7	Two nonhome stops separated by a return home after first stop; first stop is for a subsistence activity with peak-period movements; second nonhome stop is for a leisure activity with movements generally in evening period	0.07
8	Similar to type 7 except that second nonhome stop is for a maintenance activity	0.12
9	Two nonhome stop patterns with a return home after the first stop (as for types 7 and 8); both stops for leisure activity with movements mainly in midday period	0.06
10	Multiple maintenance stop patterns; all movements in midday period	0.08
11	Many out-of-home activities, generally including one stop for a subsistence activity; many maintenance stops with one or more leisure stops; at least two returns home during the 24-h period; movements in many time periods	0.09
12	Similar to type 11 except that these patterns contain at least two subsistence activities, and generally not more than one nonsubsistence activity	0.08

Table 2. Daily travel-activity pattern types: five-cluster solution.

Type No.	Description	Proportion of Sample
1	Single nonhome stop for maintenance activity; movements in midday period	0.14
2	Single nonhome stop for leisure activity; movements generally in evening	0.10
3	Two or three nonhome stops with the first for a subsistence activity; these stops take place on two forays from home; each pattern includes a maintenance and/or leisure stop; movements take place in peak periods, as well as in evening	0.20
4	"Long patterns", which consist of a large number of stops of all types and in all time periods	0.22
5	Single nonhome stop for subsistence activity; peak-period movements	0.34

This paper reports the results of an effort to classify daily travel-activity behavior analytically. Such classification is only a means to an end. The underlying objective is to explain and ultimately predict urban travel behavior. However, the classes of daily travel-activity behavior reported and examined above define a categorical variable. The latter may be used as a response variable in models and analyses of daily travel-activity behavior. The five-group classification reported in Table 2 has been used to examine relations between daily travel-activity behavior and selected sociodemographic characteristics (22). The latter are used as proxies for the role, life-style, and life-cycle attributes. These statistical analyses show that daily travel-activity behavior, which is characterized by general pattern classes, can be explained by particular characteristics of the individuals undertaking the different patterns. These analyses also isolate the specific differences in daily travel-activity behavior between people who have different roles and life-styles and who are at different stages in the life cycle.

ACKNOWLEDGMENT

This paper is based on my Ph.D. dissertation, which was supported by a Transportation Center Dissertation Year Fellowship at Northwestern University. The assistance provided by this fellowship, the use of Transportation Center facilities, and the advice and encouragement of Frank S. Koppelman, Joseph L. Schofer, Peter R. Stopher, and Alice M. Tybout are gratefully acknowledged. Individuals and organizations too numerous to be mentioned here also contributed to the completion of this research, but I assume all responsibility for any errors.

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Publication of this paper sponsored by Committee on Traveler Behavior and Values.

Travel-Time Budget: A Critique

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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.,

$$N = (1/2)n_1 + n_2 \tag{1}$$

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).

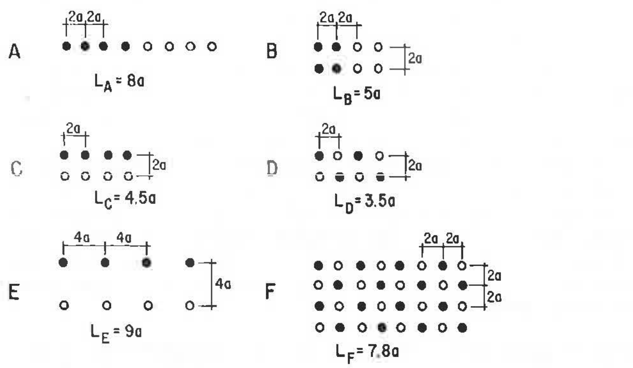
This principle is also valid for obligatory trips with the exception that the nearest activity place is also the only place (sometimes not near at all). It can be argued that one would try to find a job near the residence place or move as close as possible to the job place itself. This is, however, not 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

$$t^{obl} = T^{obl}/N^{obl} \qquad (2)$$

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.

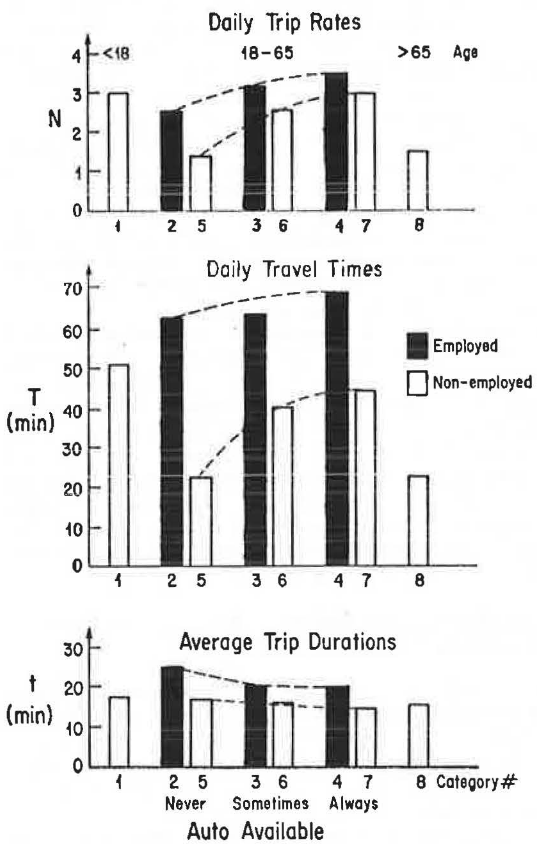
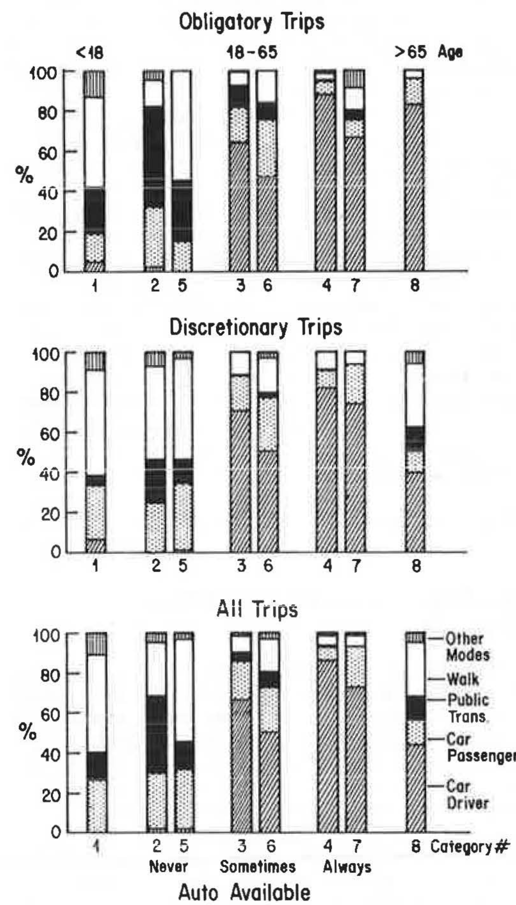


Figure 3. Basic modal splits for person categories 1-8 in Baltimore.



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 $Nc_i = 0$.

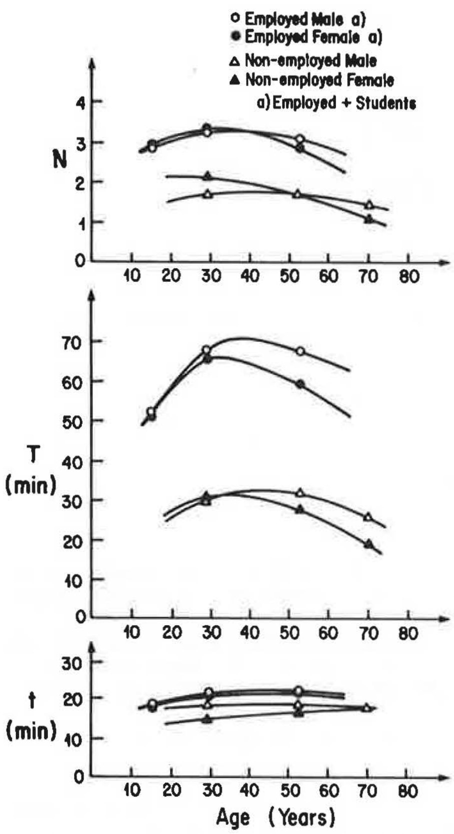
Analysis done here strongly supported a person data-aggregation level (as opposed to a household level) and revealed some interesting findings (17). For example, two variables--family status (single, family with children, family without children, etc.) and income--were not statistically significant. 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.

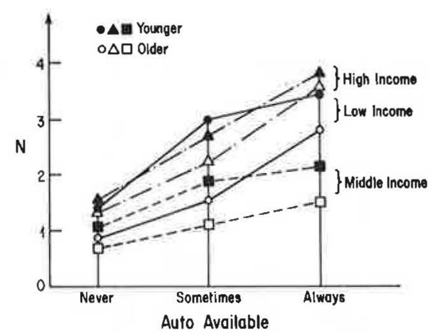


Table 1. Basic travel characteristics of person categories 1-8 in Baltimore.

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.

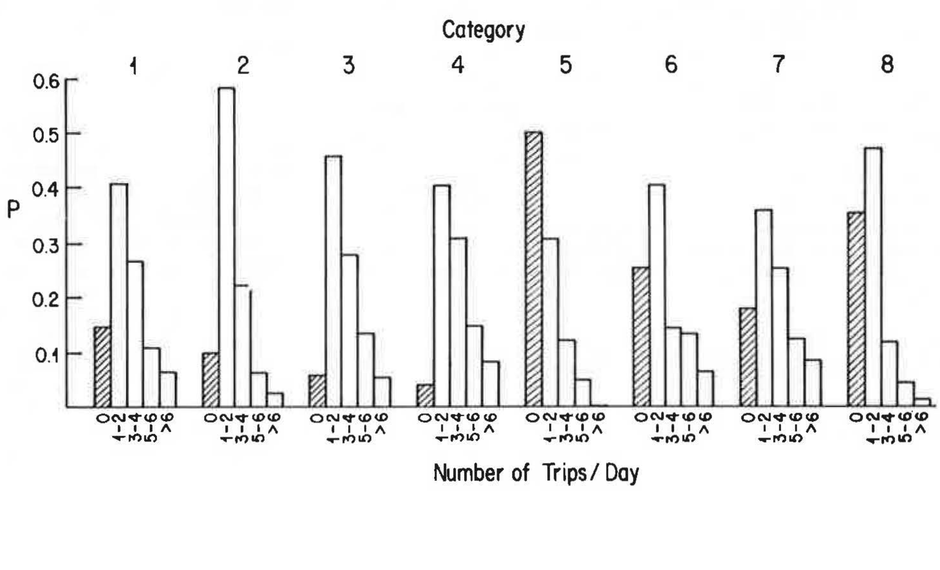


Figure 7. Hourly trip histograms for person categories 1-8 in Baltimore.

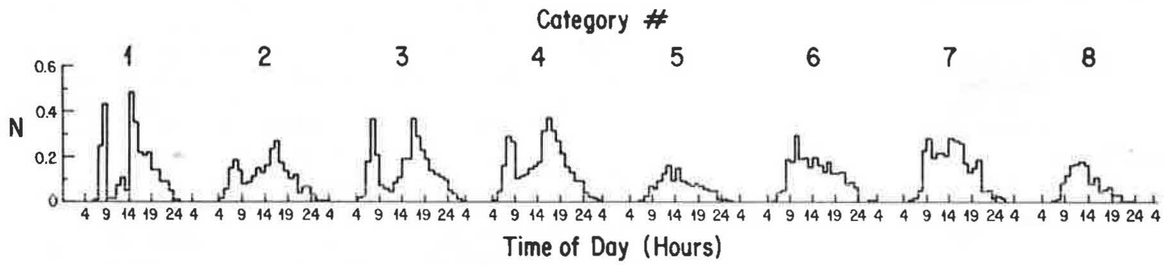
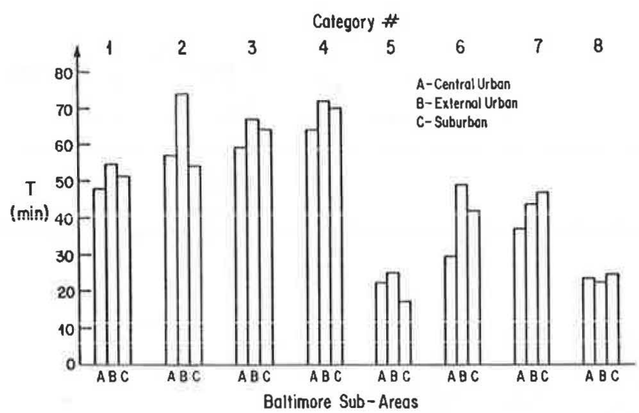


Table 2. Category percentages of α_{ij} in three Baltimore subareas.

	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 α_2:α_3:α_4 and α_5:α_6: α_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):

	F-Values			
Factor	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."

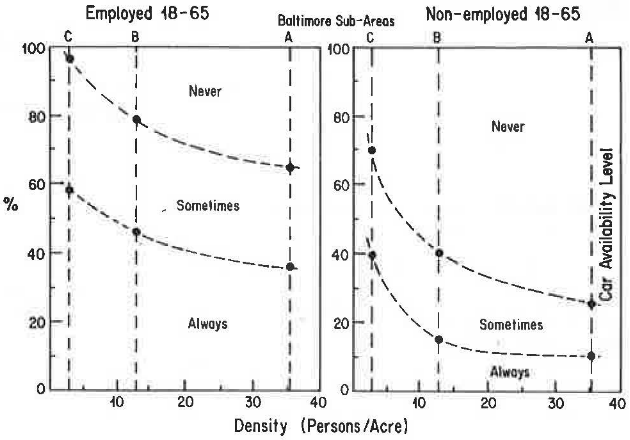
4. Differences between person categories are statistically significant for all three basic travel characteristics--trip rate N, travel time T, and average trip duration t--which supports once again a person data-aggregation level and the need for proper market segmentation of this analysis unit.

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:

$$N_{calc}^{MINN} = \sum_{i=1}^{8} \alpha_{i,\,surv}^{MINN} \cdot N_{i,\,surv}^{BALT} \qquad (4)$$

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.

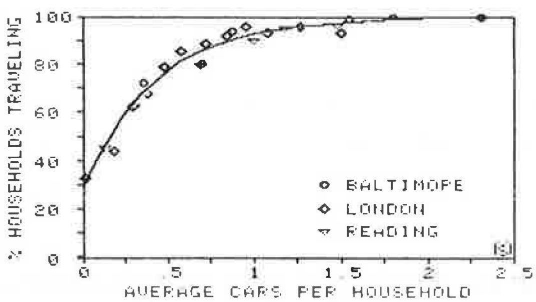


Figure 11. Travelers per household versus household size.

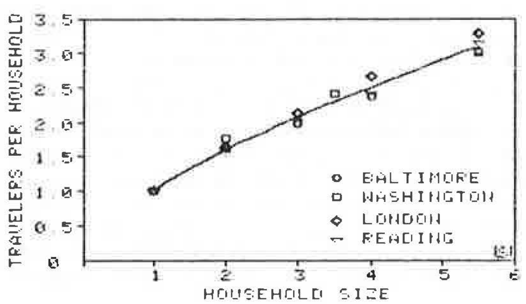


Figure 12. Travel time per traveler distributions by household income.

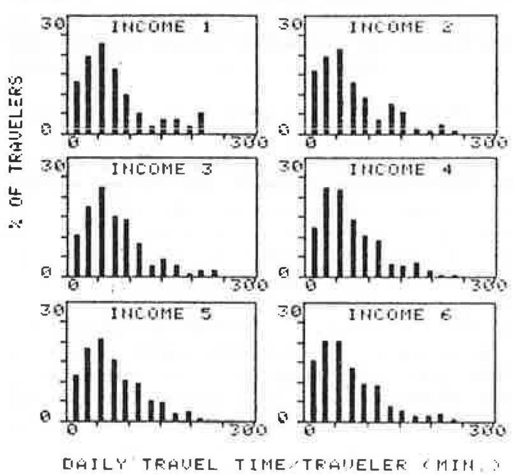
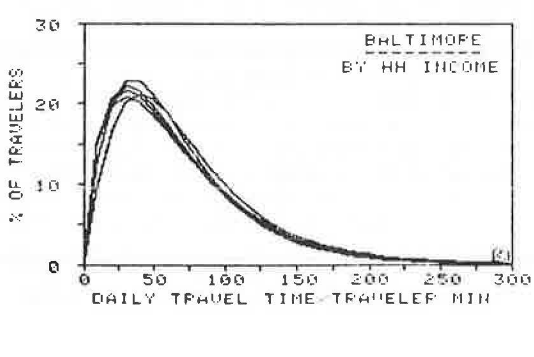


Figure 13. Travel time per traveler distributions shown in gamma functions for six income groups.



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.

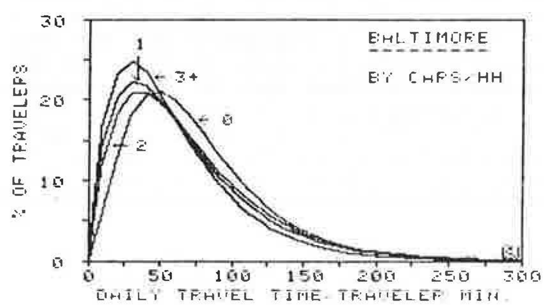


Figure 15. Travel distance per traveler distributions by car ownership level.

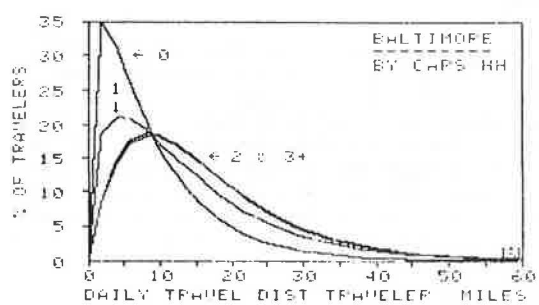


Figure 16. Distance per traveler versus speed.

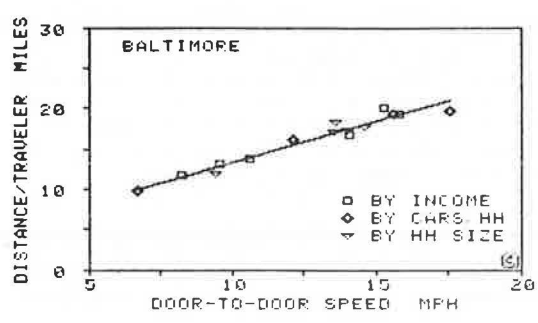


Figure 17. Travel time per traveler distributions: all travelers in four cities.

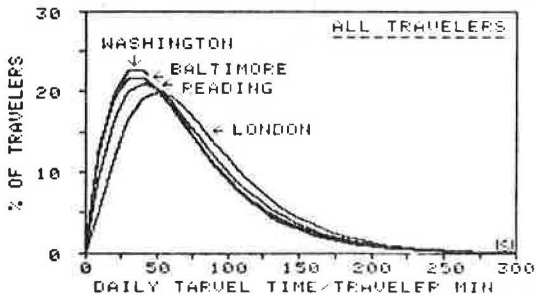


Table 6. Daily travel time per traveler and per person by household size: Baltimore, 1977.

	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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Publication of this paper sponsored by Committee on Traveler Behavior and Values.

Life Cycle and Household Time-Space Paths: Empirical Investigation

LIDIA P. KOSTYNIUK AND RYUICHI KITAMURA

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 developed an analytical framework by which the time-space path was analyzed within a constrained framework (3) and showed that life cycle was a promising variable for examining characteristics of household time-space paths (18). The present study extends these efforts and attempts to explain the differences in path characteristics by using the life-cycle stage and several additional variables. The present study also extends the earlier effort by analyzing the paths of adult members in a household collectively and emphasizing the interactions among the household members that are closely related to the life-cycle stage.

This study considers the effect of such interactions on households' time-space paths while focusing on two aspects: First, the effects of the constraints that children impose on adults' activity and travel (e.g., when a small child stays at home, an adult usually must also stay home), and second, the differences in the spatiotemporal characteristics between the paths that are made jointly by adult household members and those that are made individually. Although the importance of interdependence of tripmaking among household members has been noted and several studies have offered valuable insights (1,9,10), most of the empirical work in the past has been concerned with the behavior of individuals (3,19). Accordingly, the spatial and temporal characteristics of household paths largely remain unexplored. This study may be viewed as an effort to statistically infer the nature and magnitude of this interdependence by using the life-cycle stage as a key descriptor of household characteristics.

Because there is no standard terminology on the subject (20,21), we define some key terms used in this study. A "time-space path" is defined as an individual's trajectory in the time-space dimensions over a study period. This study deals with only those paths that originate and terminate at the home within the study period (a day). Now, consider a site where a tripmaker can pursue one or more out-of-home activities. A site may be a complex of more than one facility in close proximity. A stop made at such a site is called a "sojourn", and the site where a sojourn is made is called a "sojourn location". A "trip" is defined as the movement between two successive sojourn locations or between a sojourn location and home.

STUDY DESIGN AND STATISTICAL METHOD

In order to analyze the complex household paths in a practical yet meaningful manner, a decision was made to consider only the paths made by the husband and wife during the evening period (from 5:00 p.m. on). This period of day is selected for this study for several reasons. First, activities and travel of most workers during the daytime are almost completely determined. Second, it is expected that activities in the evening period are less obligatory; hence, the paths will be affected largely by desires, needs, and constraints arising within the household. Third, the weekday evening is a time when members of a family can act together. Hence, the effect of interpersonal linkages can be more frequently observed in the evening paths. Analysis of one specific time period of the day can be justified, since it has been found that people perceive a day as a set of time periods with distinct characteristics appropriate for particular sets of activities (1,2).

Although life cycle is expected to be a dominant factor that influences household paths, it is recognized that other factors must be simultaneously incorporated into the analysis or else erroneous conclusions may be obtained. As such additional factors, household work-trip status and household role (defined in the next section) are introduced into the analysis. It is expected that these factors interactively affect individuals' behavior. Even when faced with the same situation, individuals with different characteristics may behave differently; a particular combination of factor values may result in an effect that cannot be expressed as a sum of the independent effects of the respective factors. Such interaction effects are expected, especially for household role and responsibilities, and it is the intention of this study to identify them. Available travel data are usually categorical in nature and can be characterized by a lack of factorial design. Thus, the statistical techniques required for appropriate analysis of these data must be able to handle complex interactions in such data.

Contingency-table analyses have been a useful tool in this respect for years; however, as the number of variables and categories increases, the commonly used simple contingency-table methods lose their usefulness. Attempts to collapse multidimensional tables into simple ones can result in apparently paradoxical situations, a striking example of which has been noted by Simpson (22).

A particularly useful way of analyzing multiway tables and identifying significant interactions is through the use of log-linear models (23-25), where the logarithm of the expected cell frequency is expressed as a linear combination of main and interaction effects, as in this example from a simple two-way contingency table:

$$\log f_{ij} = \mu + \lambda_i^A + \lambda_j^B + \lambda_{ij}^{AB} \quad (1)$$

where

f_{ij} = expected cell frequency of cell i,j;
μ = grand mean;
λ_i^A = main effect of category i of variable A;
λ_j^B = main effect of category j of variable B; and
λ_{ij}^{AB} = two-way higher-order effect of category i of variable A and category j of variable B.

A particular model specifies a particular pattern of variation by the set of interaction terms included and can be used to state a particular hypothesis about the relations in a contingency table. Because the population probabilities are unknown, the observed cell frequencies are used to estimate them. The computer program ECTA (26) can be used to estimate the expected cell frequencies by the maximum-likelihood method and to test the goodness of fit of the model by using the likelihood ratio. ECTA also provides the estimates of the effect parameters. [One assumption of this method is that the model is hierarchical (i.e., if a higher-order interaction is included in the model, all lower-order effects involving the same variables are also included).]

The analysis of this study employs the log-linear models in a search for a model specification that, at the same time, involves an extensive examination of potential interaction effects (23,24). The analysis starts with the fitting of a saturated model that perfectly replicates the observation and exhausts all the degrees of freedom. The next step involves the fitting of a model with a single parameter (i.e., a set of interaction terms) removed. The contribution of this parameter is determined by comparing the log-likelihood statistic (Y^2) of the two models. The procedure continues with a forward-selection, backward-elimination process that establishes the significance of all possible parameters. This exhaustive examination of interaction parameters classifies all the effects as either important, unimportant, or in need of further study. The final choice of a best model is subjective, where complexity is balanced against the extent of explained variation. The effect parameters from the best model can be normalized and used to indicate the degree and significance of interactions that involve each category of each variable in the model. This procedure is used in this study in identifying intricate interaction effects that affect the household's evening paths.

DATA SET AND VARIABLE DEFINITION

A conventional origin-destination survey data set is used to statistically explore many spatiotemporal characteristics of household paths. Although the use of such a data set imposes a limitation on microscopic information available to the analysis (27,28), conventional large-scale data sets are the only existing ones that contain geographical subsamples whose sizes are adequate for spatial analyses of the paths. The intention of examining higher-order interaction effects also precludes the use of a small sample data set.

The data used in this analysis are from the 1965 Detroit Area Transportation and Land Use Study (TALUS) data set. The data set consists of a household sample of trip records that include information on the entire set of trips made by each member of the household on the survey day and of socioeconomic information of the individual and household. In this study, approximately 10 percent of the original trip records were sampled according to residential locations. This sampling employed nine geographic areas, which were selected to represent a wide spectrum of socioeconomic status.

The final sample used consists of 1884 households, each owning at least one car. These households are made up of 3612 adult individuals who were classified as either head of household or spouse. The household screening employed a number of criteria, including whether both the head of household and spouse, if there was one, had closed paths originating and terminating at home within the one-day study period; both made all trips by car; the head of household had a driver's license; neither made work trips after 5:00 p.m. and neither made trips from the work place after 7:00 p.m.; and all trips were made within a three-countywide study area. Households with missing data were eliminated.

The seven stages of life cycle defined in the TALUS data set and used in this study are given in Table 1. Because life-cycle stages 1 and 7 include mostly single-person households, most of the tabulations in this paper are made for 1728 households of life-cycle stages 2 through 6. Of these, 1476 individuals from 1005 households pursued evening activities. The original coding of this 1965 data set automatically assigned the category "head of household" to an adult male in the household, if there was one. Thus, in this study the head of household is referred to as husband and spouse as wife.

The employment status of household (i.e., how many and which members of the household are employed) has also been reported to be related to the travel behavior of households (29-31). It is generally accepted that employment status largely prescribes the time use of households and influences evening (after work) activity engagements. The employment status is also related to household role and responsibilities of individuals (10), which, in turn, influence evening activity and travel patterns. Work-trip engagement, or whether or not the person had a work trip on the survey date, is used in this study instead of the employment status. This variable is selected because it is more directly related with the time use of the household member on that day. The household role variable is defined in this study in terms of husband and wife designation and work-trip engagement of the individual, which results in four levels: husband with no work trip, husband with work trips, wife with no work trip, and wife with work trips. [A similar definition of household role can be found in Chapin (10).]

The most important descriptor that facilitated effective analysis of household evening paths and the interpersonal interactions is the path type. The evening time-space paths are classified by whether they were made jointly or independently by husband and wife. A path is considered joint if all or part of the path was common for both of these individuals. Joint paths are further classified by the location where they became joint: the work place, the activity location, or at home. Because the observed frequency of the paths with contact points at the activity locations is small, the first two are merged into one category--other contact points--in this study. The independent paths are classified by the individual who made the out-of-home evening paths: the husband alone, the wife alone, or both husband and wife but independently. Also considered are the no-activity paths in which no out-of-home activity is pursued by the husband or wife. Examples of typical paths are shown for the respective path types in Figure 1.

Other descriptors of the evening path used are number of sojourns in the evening path, both by the individual and by the husband-wife pair collectively; time of returning home for the day; total travel time; total out-of-home time; and sojourn locations, which are classified according to the same concentric rings used in a previous study (3) and shown in Figure 2.

RESULTS OF DATA ANALYSIS

Path Types

The first analysis examined the effects of life-cycle stage and household work-trip status on path type. A log-linear analysis that incorporated these three factors was performed on data from 1728 households of life-cycle stages 2 through 6, which treated path type as the dependent variable. The best model included main effects and interaction effects of all paired combinations of the three factors. Figure 3 shows the interactions from this model. The magnitude of each effect is presented in the figure by the standardized coefficient value, which is asymptotically t-distributed. A positive (upward) vertical line in the figure represents an effect's positive contribution to the expected cell frequency. A value of 1.96, which corresponds to $\alpha = 0.05$, is indicated on the vertical axis. The main effects of factors are not presented in the figure, since they represent only the marginal frequencies of the respective categories of the factors, and the interaction of life-cycle stage and household work-trip status are not presented in the figure.

Many interesting observations can be made from this figure. The life-cycle and path type interaction indicates that older couples (stage 6) have a higher-than-expected frequency of no evening out-of-home activities (path type 1; significant $\alpha = 0.01$). Contrary to this, households of life-cycle stages 3 and 4 (married with preschool children and married with school-age children) can be characterized by their orientation toward evening out-of-home activities (both significant at α = 0.01).

Young married couples without children (stage 2) are joint-activity oriented (path types 5 and 6) and their paths frequently involve contact points other than home (path type 5). This group of households and those with preschool and school-age children exhibit the interaction patterns that are complete reversals of each other. As opposed to the joint-activity orientation of the former group, the latter group with children is independent-activity oriented. Particularly notable are the significant interaction effects for the wife-alone paths (path type 3) of the households with school-age children and for the independent paths (path type 4) of the households with preschool children. Both effects are positive and significant at α = 0.05. The couples with no children, on the other hand, show a negative interaction effect for the independent path. The result clearly demonstrates the substantial impact that children have on the adult household members' evening activities and travel. The result is consistent with intuition and previous results (8-10).

Table 1. Life-cycle stages in analysis.

Life-Cycle Stage	Marital Status	Age (years)	Children
1	Single	<45	-[a]
2	Married	<45	None
3	Married	-[a]	Youngest child aged 4 or younger
4	Married	-[a]	Youngest child between 5 and 18 years of age
5	Married	-[a]	Youngest child aged 18 or older
6	Married	≥45	None
7	Single	≥45	-[a]

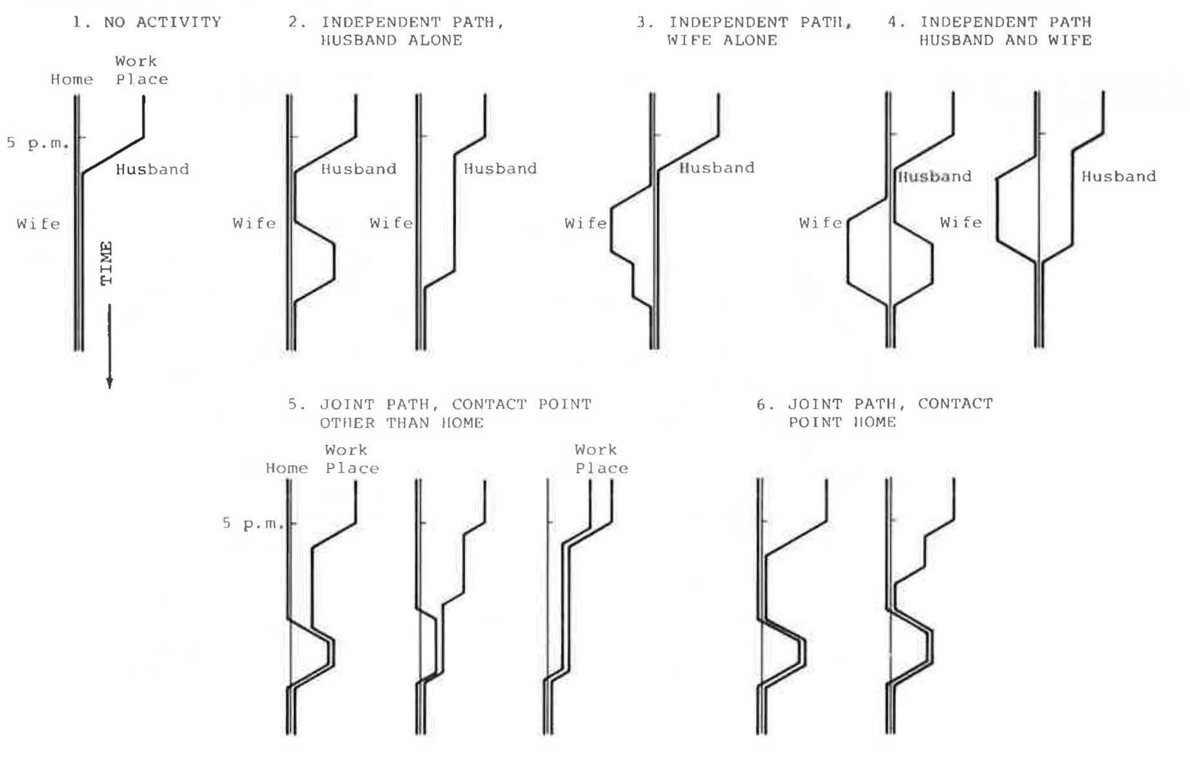
[a]Not used to define the stage.

Another interesting point to note is the similarity between the two sets of interaction effects for young and old married couples without children (stages 2 and 6). Although the magnitude of corresponding interaction effects are different, they completely coincide in terms of their signs. The interaction effects for households in life-cycle stages 3 and 4 (those with preschool or school-age children) are completely different from these, as noted above, and those of life-cycle stage 5 (couples with youngest child over 18 years of age) show a pattern that may be characterized as a transitional pattern from stages 3 and 4 to stage 6. This statistical result quite dramatically illustrates the evolution of evening path types through the stages of life cycle.

The interaction terms of household work-trip status and path type (shown in Figure 3b) indicate that those households with no workers tend not to pursue evening activities (α = 0.01), and also that when both the husband and wife work, they tend to pursue evening activities after getting together at a location other than home (path type 5, α = 0.02). Joint paths with home contact are less frequent for this group, but the group also shows less frequent no-activity paths (path type 1); i.e., this group has a higher propensity toward evening out-of-home activities (α = 0.01). Households where only one person works have a significantly less-than-expected frequency of joint paths with contact points other than home (path type 5, α = 0.1).

Similar analyses were repeated with factors such as household car ownership and household size. The results showed that car ownership and the frequency of independent paths both by the husband and wife are positively correlated, and also that the frequency of no-activity paths by the husband and wife is negatively correlated with household size. The latter indicates the increased needs or desires for evening out-of-home activities that larger households have. Overall, this analysis of path types has shown the strong and meaningful correlations the

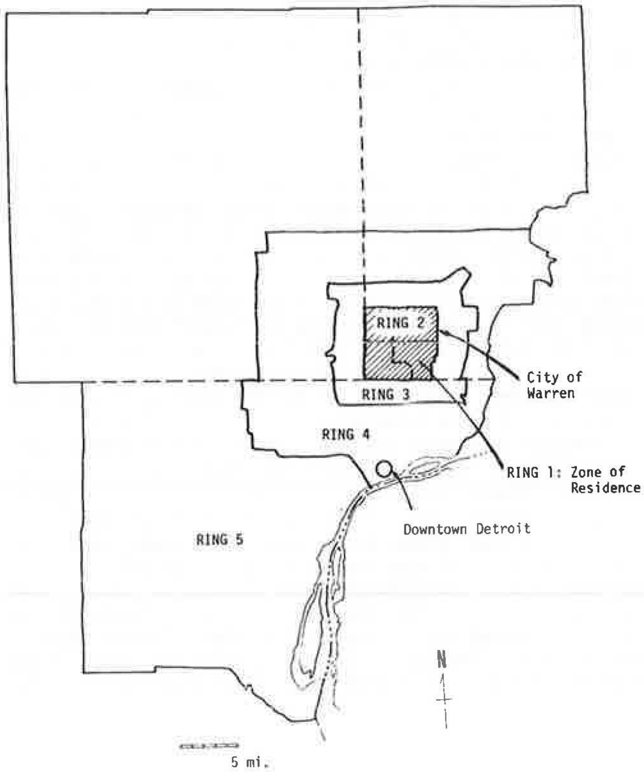
Figure 1. Examples of evening path types.



path type has with several factors that characterize households. The presence of children in the household results in dramatic changes in the evening paths. This may be seen as evidence of the constraints imposed by the children on the adult household members' activity and travel patterns.

A log-linear analysis of path type by household role (Figure 4) showed that both working and nonworking husbands tended to pursue independent (spouse at home) evening paths (path type 2 or 3, significant at $\alpha = 0.05$ and $\alpha = 0.02$, respectively). The wives, on the other hand, were more likely to have joint paths, with the path of the working wife becoming joint at a nonhome location ($\alpha = 0.01$) and that of the nonworking wife becoming joint at home ($\alpha = 0.01$). The wives also showed a clear tendency not to pursue independent (husbands at home) paths ($\alpha = 0.05$ for working wives, $\alpha = 0.02$ for nonworking wives), but the nonworking wife was likely to have an independent path if her husband was also out of the house (path type 4, $\alpha = 0.1$).

Figure 2. Concentric rings for spatial distribution of sojourn locations for Warren subsample.



Number of Sojourns

The data base of 1476 individuals in life-cyle stages 2 through 6 with evening activities is used to examine the number of sojourns made by individuals in the evening period. Other factors included in the analysis are life-cycle stage, path type (independent or joint), and household role. The best model selected includes the following interaction effects:

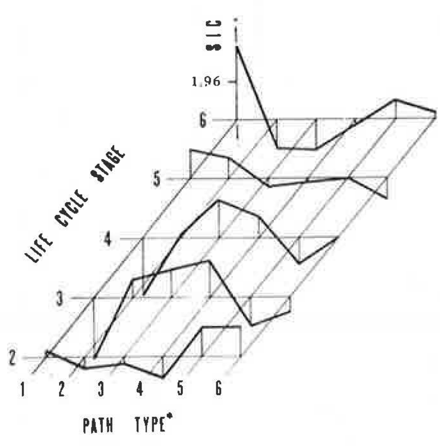
1. Life cycle, path type, and household role;
2. Number of sojourns and life cycle; and
3. Number of sojourns and path type.

The first higher-order interaction is automatically included in the model, since the number of sojourns is viewed in model specifications as the dependent variable. Because a hierarchical interaction structure is assumed, the interactions of all paired combinations of these three factors are also automatically included in the model (and therefore not listed above). Other higher-order interactions and the interaction of household role and number of sojourns are all not significant at $\alpha = 0.05$. The model is much simpler than the saturated one and effectively explains the variations in the sample by its simple structure.

The life cycle and number of sojourn interaction terms are presented in Figure 5. The tendency evident from the figure is that the older individuals

Figure 3. Interactions of path type with life-cycle stage and with household work-trip status.

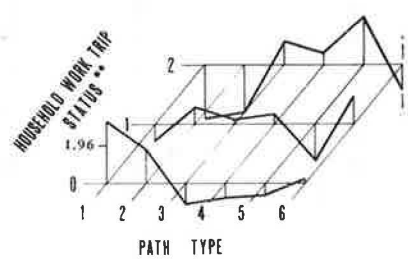
a. LIFE CYCLE-PATH TYPE INTERACTION



SIC: Standardized interaction coefficient

Sample: 1,728 households of life cycle stages 2 through 6.

b. HOUSEHOLD WORK TRIP STATUS-PATH TYPE INTERACTION



*PATH TYPE CATEGORIES:

1: No activity
2: Husband alone
3: Wife alone
4: Husband and wife independently
5: Joint, contact point other than home
6: Joint, contact point home

**HOUSEHOLD WORK TRIP STATUS:

0: None made a work trip
1: Either husband or wife made work trips
2: Both husband and wife made work trips

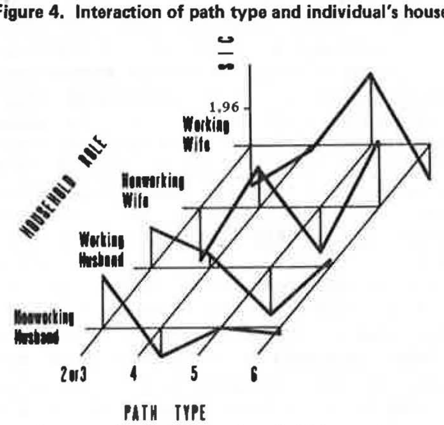
of stages 5 and 6 tend to have fewer sojourns while individuals of earlier stages of life cycle tend to make more sojourns. Individuals from households with preschool children (stage 3) have a higher-than-expected frequency of making three or more sojourns (α = 0.05), those from households with school-age children (stage 4) have a less-then-expected frequency of making only one sojourn (α = 0.05), and those older households with no children (stage 6) are likely to make only one sojourn (α = 0.01). The result reconfirms the difference in the orientation toward evening out-of-home activities across the life-cycle stages found in Figure 3, where the household path types were analyzed. Other interaction terms indicated that independent paths tend to involve only one sojourn (α = 0.05) and that nonworking wives tend to have joint paths (α = 0.02).

Out-of-Home Time and Travel Time

The first temporal aspect examined is the time spent by individuals outside the home together for activities and travel. Figure 6 presents the results of a two-way marginal analysis and shows that the total out-of-home time tends to be longer in the paths that involve joint activities for the same 1476 married individuals who pursued evening activities. Particularly notable are the much higher-than-expected frequency of short (less than 1 h) out-of-home durations in the independent paths by the husbands and the less-than-expected frequency of short durations in the joint paths with home contact points. Those individuals who had joint paths with contact points other than home stayed out frequently for a long period (4 h or more). Further analysis indicated that the individuals with work trips show this tendency, but not nonworkers. Individuals from younger households with no children (life-cycle stage 2) showed the same higher-than-expected frequency of spending a long time outside the home. The marginal two-way table presented in Figure 6 is significant at α = 0.005 (χ^2 = 132.2, df = 16).

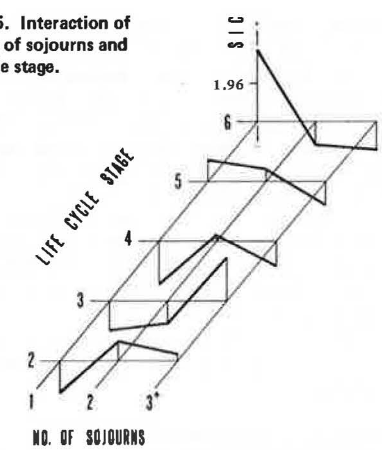
Whether or not a path involves a joint activity was found in the analysis to be most strongly correlated with the time spent out of home, while the correlations with the life-cycle stage, the individual's work-trip status, and the individual's household role were found to be relatively weak. The same statements can be made for the distribution of total travel times. Figure 7 shows that total travel time is longer when the paths are joint. Other factors are only weakly correlated with total travel time.

Figure 4. Interaction of path type and individual's household role.



Sample: 1,476 individuals of life cycle stages 2 through 6 with evening out-of-home activities

Figure 5. Interaction of number of sojourns and life-cycle stage.



Sample: 1,476 individuals of life cycle stages 2 through 6 with evening out-of-home activities.

Figure 6. Relative frequency of total out-of-home time by path type.

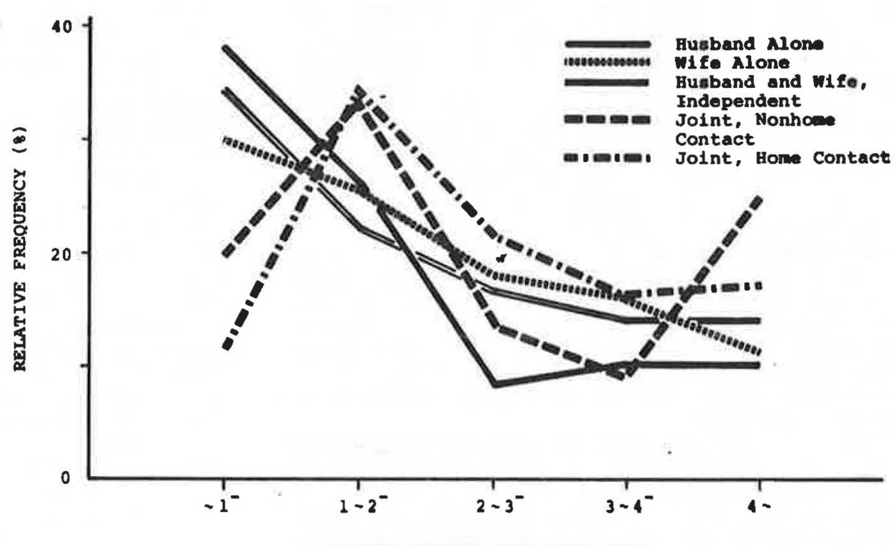
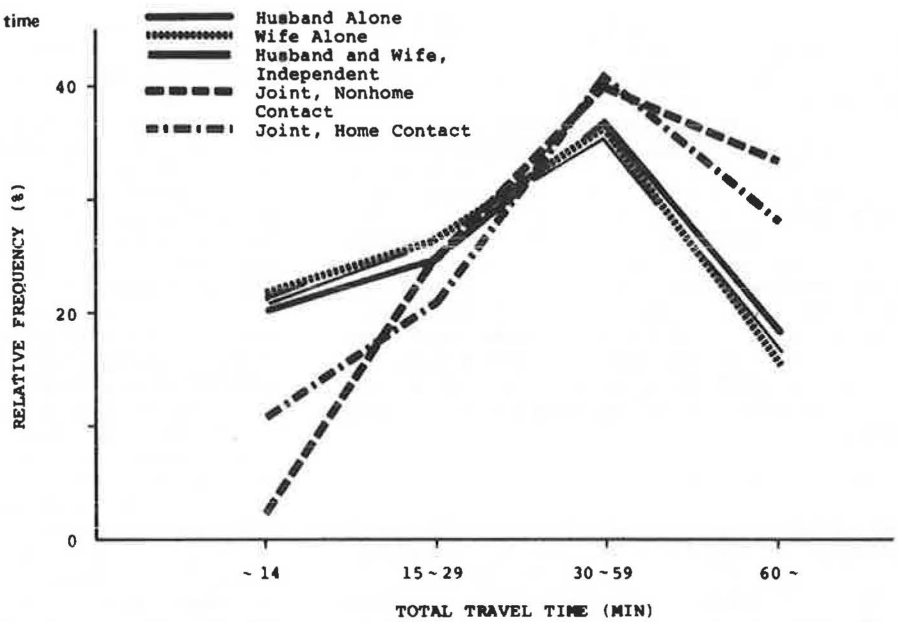


Figure 7. Relative frequency of total travel time by path type.



The marginal two-way table underlying Figure 7 is significant at $\alpha = 0.005$ ($\chi^2 = 66.2$, df = 12).

Quite notable is the surprising similarity in the distribution of travel times among the three path types that do not involve joint activities. Therefore, if an individual is pursuing evening activities without the spouse, the time spent for travel does not depend on whether the individual is a husband or wife or on whether the spouse is staying at home or not. The distribution of the total out-of-home times, on the other hand, shows certain differences among the three independent path types. Comparison of Figures 6 and 7 indicates that the wives tend to spend more time on activity participation relative to the time they spend in traveling than do the husbands.

Time and Probability of Returning Home

The above result suggests that the time of returning home for the day will be later if the path is joint, since both out-of-home and travel time tends to be longer in this case. The analysis of the return time on the same data base of 1476 individuals by using the log-linear model in fact showed this. The return time and path type interaction is significant with $Y^2 = 54$ and df = 3 ($\alpha = 0.005$). The other factors included in the analysis are life-cycle stage and household role. Other interaction term effects indicate that the older individuals of stage 6 tend to return home earlier if they go out at all ($\alpha = 0.05$), and that working husbands are more likely to return late ($\alpha = 0.01$).

The tendency that the return times of joint paths are later does not immediately imply that these paths are subjected to lesser constraints. A previous theoretical and empirical study of individuals' paths (3) indicated that as time constraints become tighter, the conditional probability of returning home, given that an activity is completed at that time, increases.

Figure 8 shows the observed relative frequencies of returning home by time intervals as estimates of this conditional probability. The observations are classified into two categories according to spouse participation in the activity. The estimated probability of returning home for the day after an independent activity starts out with a relatively large value in the early evening and increases slowly with time. Contrary to this, the probability of returning home after a joint activity starts out small but increases quickly. The difference (significant at $\alpha = 0.005$) indicates that the constraints on joint paths tighten more quickly than those on independent paths. It can be argued that joint paths are subject to tighter time constraints (e.g., baby-sitters must be released by a certain time). The result apparently supports this. It should be noted here, however, that the above difference may be due to the difference in the distribution of sojourn locations between independent and joint activities. The previous study (3) indicated that the conditional probability increases with the distance from home as well as with time. Unfortunately, the analysis here is inconclusive, since the spatial and temporal effects cannot be separated with the sample size available for this analysis.

Spatial Aspects of Evening Paths

The analyses thus far carried out, especially that of total travel time, suggest the possible correlations between spatial distribution of sojourn locations and other factors. A spatial distribution of sojourn locations by whether or not the activity was pursued jointly with one's spouse was obtained from 1421 sojourn records of 839 individuals from the City of Warren, a suburban industrial middle-class community. Each individual pursued at least one evening out-of-home activity on the survey day. Figure 2 defines the rings that are used in this analysis. Figure 9 shows that sojourn locations tend to be located farther from home if activities are jointly pursued and closer to home if they are pursued independently. This correlation is at least partly due to the correlation among activity types, spouse participation, and the distribution of opportunities by activity type.

The spatial distribution of household sojourn locations is further analyzed by estimating log-linear models with the following factors: number of household sojourns, household work-trip status, and path type (independent or joint). A sojourn made independently is weighted by 0.5 in this analysis.

The selected best model includes the following interaction terms:

1. Sojourn locations, number of sojourns, and path type;
2. Sojourn locations, work-trip status, and path type; and
3. Number of sojourns and work-trip status.

Figure 8. Relative frequency of returning home for the day by time and spouse involvement in activity.

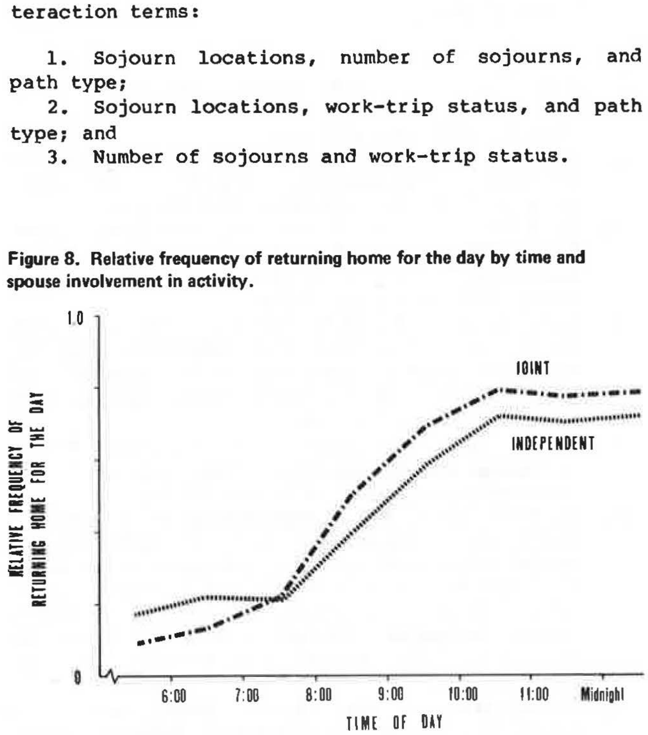
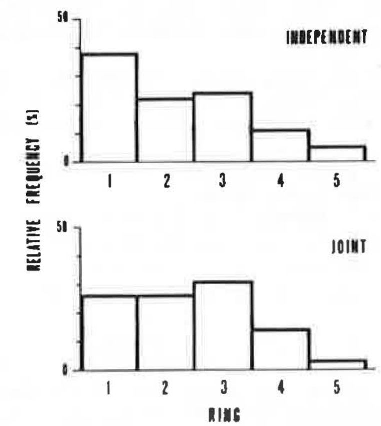
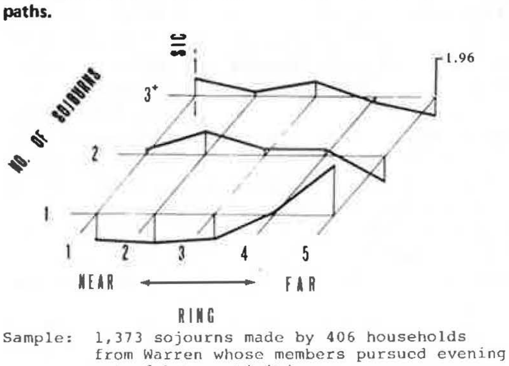


Figure 9. Distribution of sojourn locations by spouse involvement in evening activity.



Sample: 1,421 sojourns made by 839 individuals from Warren who pursued evening out-of-home activities.

Figure 10. Interaction of number of sojourns and sojourn locations for joint paths.



Sample: 1,373 sojourns made by 406 households from Warren whose members pursued evening out-of-home activities

This hierarchical model is applied to 1373 sojourn records of 406 households of life-cycle stages 2 through 6. As expected, the result confirms the association between sojourn locations and spouse involvement observed in Figure 9.

The interaction of household work-trip status and number of sojourns indicated that this geographical subsample has the same association between the two factors as found earlier (Figure 3). Figure 10 presents the interaction effects of sojourn locations, path types, and number of sojourns. The effects are shown for joint paths. Clearly indicated is the strong interrelation between the number of sojourns and the sojourn locations. If only one sojourn is made, its location tends to be farther from home, while when two or more sojourns are made in the joint paths, they tend to be located closer to home. This contraction in the sojourn-location distribution is consistent with the theoretical property of time-space paths derived earlier (3): Because a path is constrained by a prism, sojourn locations tend to be concentrated around the home when a large number of sojourns are pursued. It should be noted here that the interaction term effects for independent paths are just the opposite of those shown in the figure. Clearly, more effort is required for further investigation of these complex interaction effects of path characteristics and other factors.

Although sojourn locations in both households' and individuals' paths were also analyzed with several socioeconomic variables, including life-cycle stages, no clear tendency emerged. It seems appropriate to conclude that the distribution of sojourn locations is more strongly affected by the number of sojourns and the participation of spouse in activities, and that attributes of individuals or households affect sojourn locations only indirectly through their correlations with these path characteristics.

CONCLUSION

It is accepted in this field that the key to the prediction of travel demand is in the understanding of travel behavior. Observation of travel behavior by hypotheses formulation and testing is one way in which theories of travel behavior are developed and eventually applied to prediction.

Time-space paths of travelers are observable indicators of travel behavior. If patterns exist in these paths, then they can be used to identify regularities and help detect underlying constraints. If a set of basic properties of time-space paths exists, then these properties should not be violated in models of travel behavior. As part of an ongoing effort to identify basic properties of time-space paths of urban travelers, this study explored the effect of life cycle on the evening travel behavior of adult household members. The life-cycle stage is used to represent the microscopic factors that affect activity and travel behavior of households, such as interpersonal linkage constraints and needs and propensities for evening activities. In this exploration, 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 were examined. Emphases were placed on the interactive effects of contributing factors, including household work-trip status and individuals' household roles.

This study used a conventional origin-destination survey data set in analyzing households' activities and travel. The large sample size allowed the spatial analysis of activities by using a geographic subsample and also the analysis of higher-order interaction effects by using multiway contingency tables. Use of appropriate variables such as life-cycle stages and household roles made it possible to statistically obtain many relations that are sufficient to infer the effects that interpersonal linkages and other constraints have on the paths. 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 out-of-home activity, 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. For example, young couples without children jointly pursue evening activities more frequently than those with preschool or school-age children. The result indicates the constraints created by the children and provides additional empirical evidence of the constrained framework within which these household paths evolve.

Not all aspects of the evening path can be explained by the life cycle. Out-of-home time, travel time, and the distribution of sojourn locations were more directly correlated with the path type, especially whether the activities were pursued jointly or independently. Thus, life cycle is related to these aspects only indirectly through its correlations with the path types and spouse participation in the activity. This, however, is intuitively agreeable. When a husband and wife who are raising children decide to go out together at all, naturally a baby-sitter is arranged; therefore, the couple can behave like a couple without children, while whether they will go out together or not is strongly affected by the life-cycle stage.

Although this study confined its scope to the analysis of household time-space paths in the evening period, the study result has the following general implications. Travel behavior of urban residents is closely correlated with the life-cycle stage of households and household roles of individuals. The population distribution of life-cycle stages is continuously changing and household roles of individuals are shifting rapidly due to the increasing labor force participation of women. Travel-demand forecasting, therefore, cannot neglect these factors. The effect of children on travel behavior found in this study also suggests that an appropriate definition of life-cycle stages should incorporate the presence or absence of children in the household and their ages. Such refinements in travel-demand forecasting seem to be especially important in the current planning context, where the weight of nonwork trips has increased, compared with the time when the peak-period demand and the capacity of urban transportation facilities, and accordingly work trips, were of primary concern.

The findings of this study offer empirical evidence that substantiates the viewpoint that time-space paths of urban travelers evolve under the influence of many constraints. Moreover, the statistical indications of this study are consistent with the hypothesized association between these normally unobservable constraints and the household's stage in the life cycle. Validating the many properties of urban time-space paths found in this study with observations from different geographical areas and survey dates remains as a future task.

ACKNOWLEDGMENT

A portion of this research was supported by a National Science Foundation grant to the University of California at Davis. The help of Kuo-Liang Ting, Department of Civil Engineering, University of Michigan, in the ECTA log-linear analysis is gratefully acknowledged.

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Publication of this paper sponsored by Committee on Traveler Behavior and Values.

Life-Style Segmentation in Travel-Demand Analysis

ILAN SALOMON AND MOSHE BEN-AKIVA

Market segmentation, when used as a method for accounting for cross-sectional taste differences, is often applied in travel-demand analyses. This paper suggests the employment of the life-style concept as an improved basis for segmentation. Life-style is defined as the behavioral pattern that results from three major life decisions: the decision to form a household, the decision to participate in the labor force, and the orientation toward leisure. By using available socioeconomic variables, an attempt is made to identify life-style groups and to use them as market segments in a joint mode and destination choice model. Two tests are presented. One is the use of life-style-specific variables in the model specification and the other is the estimation of separate models for each market segment. Both approaches have shown an improvement in the model performance compared with either a pooled model or an income-based and a life-cycle/occupation-based segmentation. Further refinement of the ability to identify life-styles is suggested.

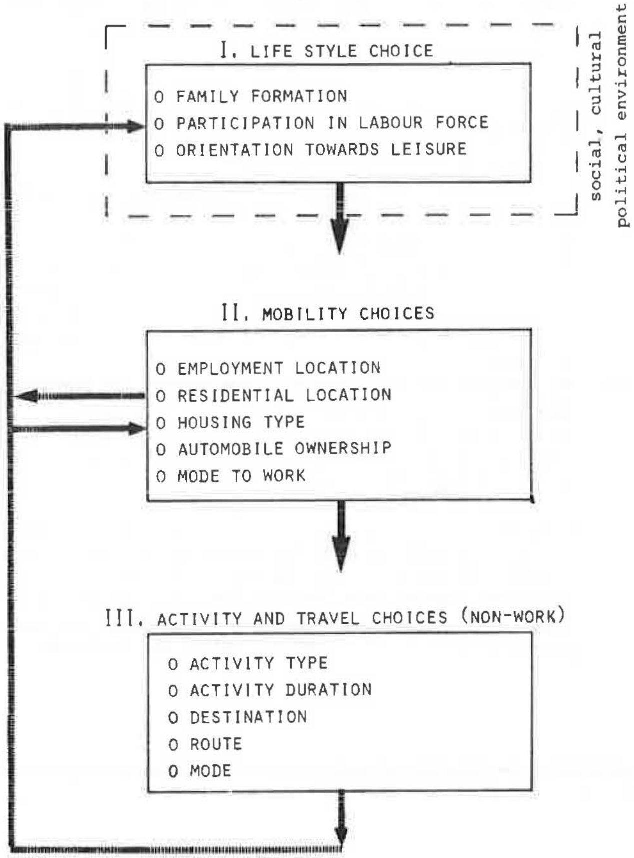
The shifting focus of travel-demand analysis to individual or household behavior has drawn attention to the problem of cross-sectional differences in individuals' tastes. A number of pragmatic solutions have been used over the past few years to account for taste differences. Generally, the approach entails the use of market segmentation, which creates some homogeneous groups that are likely to behave in a similar manner under changing conditions. Yet it seems that in many of these efforts there is a lack of a theoretical basis.

This paper presents an attempt to use a segmentation that is based on the concept of lifestyle. Life-style segmentation, as defined in this paper, offers a theoretical basis for differentiating between behavioral groups. It is integrated in the framework of the choice hierarchy that distinguishes between short- and long-run decisions in travel behavior. Although there still exists a serious gap between the conceptual definition of life-style and its empirical definition, an attempt to apply the concept is presented.

The concept of life-style is widely used in market research as a basis for segmentation (1,2). It is also regaining ground among sociologists who suggest that life-style differentiating among groups has greater behavioral relevance than differentiation along social or economic classes (3,4).

A segmentation based on life-style is compared with alternative market-segmentation schemes based on socioeconomic characteristics. The performance of a mode and destination choice model for shopping trips is used to evaluate the alternative schemes. The results of this analysis indicate that life-style segmentation is an improved approach compared with the others tested in this research.

Figure 1. Extended choice hierarchy.



GENERAL

Market Segmentation in Travel Behavior

The widely used method for accounting for systematic taste variations is the segmentation of the population into groups that are assumed to be homogeneous with respect to the behavioral aspect under study. The choice of variables to be used as a basis for segmentation depends mainly on their power in improving the performance of a well-specified model in the specific context it is to be used. Most importantly, the behavioral relevance of the segmentation basis needs to be considered. Segmentation along an irrelevant dimension will result in inaccurate prediction results. Only variables for which there are sound theoretical grounds for their explanatory power of a particular choice situation can be used successfully. The variable used must also have a limited number of distinct values that are relevant to the behavior under study, so as to generate a manageable number of segments.

The variety of experimentations with market segmentation carried out to date can be classified along three dimensions: the nature of the variable used, its mathematical form, and the applicability of the segmentation to varying situations. Most often, demographic and socioeconomic variables as well as choice constraints are used as a basis for segmentation. The first type includes attributes such as age, income, etc. (5-7). The second type differentiates between groups that face different constraints (or lack of them) such as modal availability (5,8). The third type of variable used is attitudinal or perceptual data (9).

The second dimension is the form in which the variables are used. The segmentation can be based on the values of the variables directly, either in a unidimensional or multidimensional form, or, alternatively, the variables may be transformed into a composite variable that serves as the basis for segmentation. An example of the first type is given by Ben-Akiva and Lerman (7), who have used a simple combination of life cycle and occupation. The second type was used by Golob and Burns (8), Dobson and Tischer (9), and Tardiff (10), who have used composite variables like principal components.

The third dimension is a conceptual one; it distinguishes between choice-specific and generic segmentation. Most applications of market segmentation have, justifiably, chosen as a basis variables that are sensitive to the specific behavioral choice the model deals with (e.g., automobile ownership for mode choice, life cycle and occupation for automobile ownership choice, etc.). Yet, conceptually as well as practically, a generic segmentation, one which is applicable to the whole range of travel-behavior models, is very attractive. Although a generic basis may lose its sensitivity to some specific choice situation, it can be practical for a wide range of applications.

There is general agreement that market segmentation is a useful technique to capture taste differences between population groups. As to segmentation basis, no single approach has been shown to be universally superior (5). The choice of segmentation basis thus depends on context and needs. One of the advantages of the technique is that it also provides a method for incorporating attitudinal data, as a basis for segmentation, in disaggregate revealed-preference models. To date, such information is not explicitly treated by disaggregate models.

Life-Style as a Segmentation Basis

Life-style is defined as the pattern of behavior that conforms to the individual's orientation toward the three major roles of a household member, a worker, and a consumer of leisure, and to the constrained resources available. A detailed discussion of the nature of these life decisions and the definitions of life-style is given elsewhere (11).

The choice of a life-style is a long-term one. Probably a person makes that choice only a few times in the course of life. By using the concept of a choice hierarchy that distinguishes between the mobility (long-term) and travel (short-term) decisions, as suggested by Ben-Akiva (12), it is suggested to add the choice of life-style (very long-term decisions) as an upper block in this hierarchy, as illustrated in Figure 1. The longer-term decision, that of choosing a life-style, constitutes a choice of the type or pattern of activities one aspires to engage in. It is the outcome of this choice that is the motivation for the observed mobility and travel.

If it is possible to identify life-style groups, i.e., groups that share similar patterns of behavior as defined above, then these groups can serve as market segments. They have the advantage that they share not only a common value on some socioeconomic variable but also similar motivations for travel.

METHODOLOGY

Two stages of analysis were employed in testing the hypotheses about the relevance of the life-style concept. First, a method for identifying life-style groups was developed. In the second stage, the life-style groups were tested as market segments in travel-behavior choice models.

Identifying Life-Style Groups

Given the above definition, life-style groups could presumably be identified by clustering of individuals or households for which we can observe similar patterns of life-style choices. However, in most available data sets, the orientation toward leisure is not measured.

Therefore, it becomes necessary to identify life-style groups by the use of proxy variables from which inferences on the choice of life-style can be made. A basic premise of this research is that the concept is to be developed within the commonly available urban transportation surveys (i.e., home interview survey).

It is assumed that membership in life-style groups can be estimated from an array of socioeconomic and demographic characteristics of a household. The choices noted in the definition of life-style are identified by surrogate variables that, as closely as possible, imply or indicate the individual's patterns of life-style aspirations.

The socioeconomic and demographic variables that were used to define life-style groups include the following:

1. Household structure
   a. Age of head of household (AGE)
   b. Presence of children under 6 years old (CHLDPR)
   c. Presence of children between 6 and 18 years old (JCHLD)
   d. Household size (HHSIZE)
   e. Number of adults in household (ADULTS)
2. Labor force participation
   a. Proportion of household income earned by male head of household (PRNC1)
   b. Proportion of household income earned by female head of household (PRNC2)
   c. Household annual income (INCOME)
   d. Employment status of male head of household (EMP1)
   e. Employment status of female head of household [full employment (FEMP2) and part-time employment (EMP2)]
3. Orientation toward leisure
   a. Level of education, highest in household (EDUCATION)
   b. Number of white-collar male employees (WCOL1)

The data set used in this analysis is the Baltimore travel-demand data set collected in 1977. It contained detailed one-day trip reports for some 965 households.

These variables, which serve as indicators of life-styles, were used to identify groups of households that share similar life-styles. The statistical method employed is cluster analysis (K-means method). Cluster analysis is an exploratory tool that enables the analyst to search for different structures that may exist in the data. Although cluster analysis can generate any desired output, and therefore should be used with much caution (13), its use can provide valuable insights into a population structure by varying the specification and the relative weight assigned to each variable. More details on the use of cluster analysis in this research are given elsewhere (11,14).

Use of Travel-Demand Model to Test Segmentation Schemes

Two approaches were employed to test the relevance of life-style segmentation. The first is the incorporation of interaction variables in the specification of the utility function. That is, some of the variables assumed to be of different value or importance to different life-style groups appear in the model as life-style-specific variables. The second approach involves the separate estimation of models for each market segment. Here the assumption is that all parameters vary across the life-style groups and therefore will assume different values in the estimation procedure.

The model is of a logit form that predicts the choice probability of a particular mode and destination combination. The choice set includes three modes--automobile, walk, and transit--as other modes constituted negligible numbers in the sample. The possible destinations included all traffic zones that have shopping facilities, although, for the purpose of estimation only, a sample destination was assigned to each individual, including the home zone, the central business district (CBD), the zone actually chosen, and a random sample of three or four zones.

RESULTS

Cluster-Analysis Output

As cluster analysis is an experimental technique, a large number of alternative outputs were produced and evaluated. From these, the clustering schemes described in Tables 1 and 2 provide two intuitively acceptable divisions among life-style groups in the current data set.

Scheme A

Under scheme A, five clusters were created based on 521 observations, each represented by 20 variables. The cluster means for each variable are presented in Table 1. In this scheme, two variables that describe time allocation to activities (home activities and services) were included for each of the heads of the household. In other schemes, time allocation was excluded because it may be viewed as part of the dependent variable.

The differences among the clusters can be characterized along a number of dimensions. For example, both cluster 1 and 2 are the upper-income groups, yet they vary in household size, the latter having children only in a small percentage of the sample. Also, the female spouse in cluster 2 is contributing significantly more than in any other cluster to the household income and, consequently, also spends the least time at home. Cluster 2 also includes the highest level of education and the largest share of time allocated to services for the household by the male head.

Cluster 1 includes the large household headed by middle-aged, educated persons. Women in this group rarely participate in the earning, yet the household income is relatively high and most of the male workers hold white-collar occupations.

Cluster 2 consists of very small households headed by middle-aged adults. It is impossible to infer from the data whether cluster 2 members were childless throughout their life or whether they are households with older children who have already left. Judging by income and education, clusters 1 and 2 probably belong to the same socioeconomic class, yet they differ in the females' work status and activity pattern and hence in life-style.

Cluster 3 is characterized primarily by its low income, low level of education, and its very low share of white-collar workers. The demographic information indicates that a third of this group are elderly households, and we tend to assume that actually two distinct household sizes constitute

Table 1. Clustering scheme A: mean values of input variables.

Cluster No.	No.	Percentage of Sample	HHSIZE	ADULTS	Age of Head Distribution (%)			CHLDPR	JCHLD	PRNC1	PRNC2	Education Level Distribution (%)			
					18-44	45-65	65+					1	2	3	4
1	161	31	5.16	2.9	0	99	1	100	93	2.32	3.13	2	35	46	17
2	75	14	2.47	2.3	21	71	8	13	11	3.47	1.61	13	37	27	23
3	71	14	3.11	2.1	10	59	31	49	39	1.97	2.70	100	0	0	0
4	108	21	3.87	2.0	100	0	0	92	49	2.00	3.07	4	42	45	9
5	106	20	2.58	2.5	0	70	30	8	1	2.28	3.49	1	49	42	8
Total	521	100	3.70	2.5	25	63	12	60	46	2.36	2.92	17	35	36	12
P-value			0.999	0.999	0.999	0.999		0.999	0.999	0.999	0.999	0.999	0.999	0.999	

Table 2. Mean values of variables by cluster: scheme B'.

Cluster No.	No.	Percentage of Sample	HHSIZE	ADULTS	Age of Head Distribution (%)			CHLDPR	JCHLD	PRNC1	PRNC2	Education Level Distribution (%)			
					18-34	35-64	65+					1	2	3	4
1	120	23	4.73	2.97	0	98	2	79	69	2.33	3.38	0	0	81	19
2	86	17	2.49	2.28	24	70	6	17	12	3.52	1.76	20	34	27	19
3	108	21	3.95	2.03	100	0	0	94	52	1.93	3.15	9	41	42	8
4	108	21	4.75	2.75	0	99	1	91	81	2.25	3.09	23	69	0	8
5	99	19	2.15	2.09	2	45	53	4	2	2.01	3.01	37	35	23	5
Total	521	100	3.71	2.45	25	63	12	60	46	2.36	2.93	17	35	36	12
P-value			0.999	0.999	0.999	0.999		0.999	0.999	0.999	0.999	0.999	0.999	0.999	

this group: elderly without children and middle-aged with children. The dimension that discriminates this group is obviously economic and educational, so this group can probably be labeled the low-socioeconomic class, which in terms of life-style is a group on which the economic constraint is most binding. It is also typified by a very low share of household services performed by the male head.

Cluster 5 is similar to cluster 3 in its age composition yet differs significantly in its economic and educational status and presence of children. Again, it is impossible to determine whether this is a lifelong childlessness or whether it is late-life childlessness.

Cluster 4 is distinguished from the others mainly by its young household composition. One can speculate that this group is the younger version of cluster 1, where the differences in household size, income, and participation in the labor force can mostly be attributed to the age difference.

In summary, we suggest that all but cluster 3 are groups of similar socioeconomic status that vary along demographic and activity dimensions to constitute different life-style groups. Cluster 3 forms a separate group because of its economic constraints but could probably include some distinct life-styles within it, which vary along similar lines that distinguish the rest of the clusters.

Scheme B'

Clusters 1 and 2 constitute the upper socioeconomic classes as judged by their income and educational levels. They are dissimilar in their demographic characteristics and employment status. Cluster 1 consists of middle-aged households (35-64 years old) and very large households. By contrast, cluster 2 consists of much smaller households and one-quarter of its members are young (less than 34 years old). The difference in employment and occupation status is also noticeable. Cluster 1 male members are primarily employed in white-collar jobs and a very small number of that cluster's female heads of households participate in the full-time labor force. This life-style group may be characterized as the family-oriented economically active group that, by virtue of being family-oriented, only the male head of household works outside the house while the female head is not committed to an out-of-home economic activity. This can be viewed as the traditional form of life-style for the family-oriented households, which contrasts with some emerging new forms of life-styles. Family orientation combined with dual participation in the labor force, which traditionally was observed only in the working classes, is today more prevailing in economically well-to-do households. In cluster 2, 95 percent of the female heads of households work full-time.

Cluster 2 is more heterogeneous than cluster 1. It probably captured both white- and blue-collar workers who have high incomes and whose female spouses work full-time. Hence, it could probably be broken down to at least two distinct groups. The first group is probably the newly emerging life-style of families headed by two career-oriented or other white-collar employees, many of whom do not have children. The second group is probably the households of the upper working class, where both heads work and hence have a relatively high income.

Cluster 3 is a younger group, mostly with young children and with very low rates of women participating in the labor force. It is thus assumed to be a younger version of cluster 1 members, for which the attainment of income and educational levels are a matter of time. It also includes a high proportion of blue-collar workers who will eventually belong to cluster 2 or 4. It is obvious that, in this case, life cycle is the dominant discriminatory dimension, and this group, regardless of economic status, can be defined as the young, family-oriented childbearing households.

Cluster 4 is similar in its demographic characteristics to cluster 1, but its members differ in socioeconomic attributes, where cluster 4 members constitute a lower-income, lower-educational level class. Women participation in the labor force in

INCOME ($)	Home 1	Home 2	Leisure 1	Leisure 2	Service 1	Service 2	EMP1	WCOL1
24 726	61	79			1.66	2.93	37	52
25 133	65	63			2.01	1.87	72	49
10 176	77	87			0.96	1.88	24	6
17 337	59	81			1.59	3.09	81	50
20 316	77	90			1.70	2.13	49	53
20 373	67	80			1.61	2.50	52	45
0.999	0.999	0.999			0.58	0.25	0.999	0.999

INCOME ($)	EMP1	WCOL1	FEMP2	EMP2
29 749	45	68	11	27
24 465	69	44	95	0
16 810	81	48	15	13
18 097	40	31	23	12
11 823	27	30	0	8
20 373	52	45	26	13
0.999	0.999	0.999	0.999	0.999

cluster 4 is higher in the full-employment category and lower in the part-time category, which indicates that there are more working-class households earning less for their work and working despite the high incidence of the presence of young children. This group, in reference to the life-style choice, includes those households that have chosen to establish a family with children and who have chosen, in most cases by default, to participate in lower-paying jobs in the labor market. Holding lower-paying jobs requires for this group's members that more than one family member will participate in the labor force.

Cluster 5 includes most of the elderly households of the sample, but almost half of it are middle-aged households. This cluster is distinct from the others by its low income and education levels, small household size (and almost no households with children), and very low levels of participation in the labor force. This cluster, it is assumed, captured both the retired low-income elderly and the poor middle-aged households. Thus, it is a cluster based on both socioeconomic and demographic attributes. A refinement of this cluster would probably reveal the retired people as one life-style group and the other as a group who have made a decision not to participate regularly in the labor force and not to have children. Their life-style can be characterized as that of living through life rather inactively. However, time limitation prevented us from this refinement at the current stage.

In summary, this scheme is discriminatory along a mixture of dimensions: purely socioeconomic, employment status, and age. It is thus probably closer to a life-style classification, which allows similar values on some attributes and discriminates on others, rather than to a socioeconomically based discrimination. Yet it is obvious that some groups are still quite heterogeneous, and the differentiation among them can only be obtained by increasing the number of clusters, which will result in identification of smaller but more distinct life-style groups.

Travel-Demand Models

For testing the viability of the life-style segmentation, a choice situation was desired, which was assumed to be sensitive to life-style differences and that had also been modeled before, so that the model specification is relatively known. Given the data available, that situation was the mode and destination choice for shopping trips, which was previously modeled by Adler and Ben-Akiva (15).

Two model structures were estimated. One is a three-mode model, in which the hypothesis that certain attributes of the utility function are affected by the membership in a particular life-style group was tested. The second structure included only the automobile and walk modes. For this model, the life-style-based segmentation was compared with a pooled sample and with other market segmentation schemes.

The variables used in the various models are defined in Table 3, and most of them are self-explanatory. Walk time was defined only for interzonal trips, because in the intrazonal trips we concluded that assigning a constant trip length involves a large error and would result in inconsistent coefficients. Thus, intrazonal walk time is captured by a constant term (INZWDM).

In the three-mode model, accounting for taste variation was obtained through the incorporation of life-style group-specific variables in the model. The hypothesis that certain variables interact with the various life-styles was tested by defining these as group specific (denoted by numbers 1 through 5 for the five life-style groups). The estimated coefficients and summary statistics of the three-mode case with and without the life-style-specific variables are presented in Tables 4 and 5. Although the improvement in the model performance (as evaluated by the log-likelihood ratio) could be attributed simply to the addition of relevant explanatory variables, the contribution of this analysis is in demonstrating the differences of some of the estimated coefficients across life-style groups. Specifically, the difference in the out-of-vehicle travel time for automobile (OVTTA) between groups 1 and 2 indicates, for example, a different evaluation of time for these, despite the fact that their average income is similar ($24 726 and $25 133, respectively). Such a difference may be attributed to the fact that these groups vary mainly in the presence of children, which is very low in group 2, and in the employment rate of the female head, which is very high in that group. (This result must be qualified because of the relatively low t-statistic for the OVTTA of group 2.)

The weight assigned to walk time also varies considerably between the life-style groups where group 3, which is the poorest, least educated, and least holding white-collar occupations, has the lowest negative value, and group 4, which is the youngest and has the highest employment rate, accounts for the highest negative value.

Th LNRET variable accounts for the size of the shopping opportunities at the destination. The variance in the coefficients among the groups should indicate varying preferences for shopping at large shopping concentrations, where group 1 is least sensitive to size. The sensitivity of group 4 may be explained by the fact that the members of this group make the least trips alone (i.e., 56 percent of the trips are accompanied by at least one family member). If that member is a child, it is plausible that many shopping opportunities in proximity will be more attractive than few opportunities.

The last attribute assumed to be different among life-style groups is the dummy for intrazonal desti-

Table 3. Variable names and definitions.

No.	Variable	Definition
1	IVTTA	In-vehicle travel time for automobile, minutes, one way
2	IVTTTR	In-vehicle travel time for transit, minutes, one way
3	OVTTA	Out-of-vehicle travel time for automobile, minutes, one way
4	OVTTTR	Out-of-vehicle travel time for transit, minutes, one way
5	ACSTI	Out-of-pocket travel cost for automobile, one way, dollars, divided by annual income
6	COSTIN	Out-of-pocket travel cost, all modes, one way, dollars, divided by annual income
7	WLKTT	Walk-trip time for interzonal trips, 0 for intrazonal trips
8	LNRET	Natural LOG of retail employment in destination zone
9	RTDNS	Retail employment divided by total employment at destination zone
10	AUTOCON	Constant: 1 if automobile alternative, 0 otherwise
11	WLKCON	Constant: 1 if walk alternative, 0 otherwise
12	CBDDUM	Constant: 1 if CBD destination, 0 otherwise
13	INZDUM	Constant: 1 if trip destination equal to origin zone, 0 otherwise
14	INZWDM	Dummy for intrazonal walk trip: 1 if intrazonal walk trip, 0 otherwise
15	AAVAPR	Automobile availablity divided by number of adults in household for automobile alternatives
16	AAVWPR	Automobile availability divided by number of adults in household for walk alternatives
17	DRESW	Dummy for residential zone origin for walk alternatives: 1 if origin in zone of residence, 0 otherwise
18	SUBWLK	Dummy for walk alternatives in suburbs: 1 if origin in suburb, 0 otherwise
19	EMPAUTO	Dummy for employment status for automobile alternatives: 1 if fully employed, 0 otherwise

Table 4. Comparison of three-mode model with and without interaction of life-style.

	Without Life-Style Variables		With Life-Style Variables	
Variable	Estimated Coefficient	t-Statistic	Estimated Coefficient	t-Statistic
IVTTA	-0.167	-8.29	-0.173	-8.26
IVTTTR	-0.054	-1.39	-0.069	-1.72
OVTTA	-0.572	-4.70	-	-
OVTTTR	-0.108	-1.60	-0.102	-1.67
WLKCON	-0.644	0.73	0.531	0.59
AUTOCON	2.200	2.43	1.964	2.12
INZDUM	-3.070	-12.33	-	-
INZWDM	0.543	0.10	0.087	0.15
EMPAUTO	0.741	1.78	0.692	1.60
COSTIN	-7522	-1.20	-6169	-0.96
ORESW	1.953	3.81	1.970	3.74
SUBWLK	-1.000	-2.26	-1.089	-2.40
AAVAPR	3.046	2.83	3.838	3.40
AAVWPR	2.888	2.78	3.750	3.41
CBDDUM	-0.851	-1.85	-0.933	-1.86
RETDENS	0.967	2.55	0.972	2.49
LNRET	0.410	5.65	-	-
WLKTT	-0.074	-5.10	-	-
OVTTA1			-1.078	-3.42
OVTTA2			-0.242	-1.91
OVTTA3			-0.426	-1.04
OVTTA4			-1.028	-2.52
OVTTA5			-0.970	-2.64
WLKTT1			-0.096	-3.64
WLKTT2			-0.113	-1.71
WLKTT3			-0.031	-2.02
WLKTT4			-0.136	-3.46
WLKTT5			-0.115	-3.48
LNRET1			0.286	2.74
LNRET2			0.425	2.44
LNRET3			0.368	1.62
LNRET4			0.712	4.69
LNRET5			0.456	2.83
INZDUM1			-3.792	-9.26
INZDUM2			-2.682	-5.76
INZDUM3			-2.385	-4.40
INZDUM4			-3.023	-7.73
INZDUM5			-2.974	-7.15

nation compared with the other alternatives. (Note that by including the intrazonal destination in the choice set for all observations, this and the CBD destination are disproportionately represented in the sample and therefore have biased coefficients.) With all coefficients highly significant, we find a range of coefficients that vary from -3.79 for group 1 to -2.38 for group 3. The fact that the latter is the group with the lowest automobile-ownership level and the lowest coefficient for walk time explains, in part, its low negative value for the intrazonal shopping trip.

Table 5. Summary statistics for Table 4.

Item	Without Life-Style Variables	With Life-Style Variables
L^*0	973.427	973.427
$L^*\theta$	434.6	412.75
ρ^2	0.554	0.576
Adjusted ρ^2	0.530	0.531

In summary, this analysis demonstrates that the values of the coefficients estimated in a model can be disaggregated into very different values by interacting the variables with group indicators that are a priori assumed to be behaviorally different. The effect of this disaggregation on the remaining variables must also be noted. The improved accounting for the distractions to walk trips by separating the walk-time variables results in the reduction of the magnitude of the walk constant, as more of the variance is explained by the interaction variables. Similar effects are visible in the case of the intrazonal walk dummy and the out-of-pocket cost variable (the latter is statistically insignificant). The observed differences in the estimated coefficients lead to the conclusion that the life-style groups are behaviorally relevant and that by using knowledge of life-style membership, the performance of the model is improved.

By using the market-segmentation approach, these schemes were evaluated. First, the life-style segmentation for the estimated model coefficients and some statistical properties of the models are presented in Tables 6 and 7. The pooled model included the total sample (344 trips), while models 1 to 5 correspond to each of the life-style groups presented in Table 2.

This set of models performs better than the pooled model, as evaluated by the value of the log-likelihood function: -342.8 as compared with -400.5 for the pooled model. The segmented models are performing better than the pooled model at a significance level of 0.001 (chi-square value of 115.3 with 54 df).

The life-style segmentation scheme was compared with two other segmentation schemes. The two were chosen from the variety of available schemes on the basis of the type of data they employ (i.e., available socioeconomic data), so as to be comparable with the life-style segmentation.

In the income-based segmentation, five income groups were defined and models were separately estimated for each. The estimated coefficients and summary statistics are shown in Tables 8 and 9. For the set of five models, the total value of the log-likelihood function is -373.9 as compared with -342.8 for the life-style segmentation. Note that a slight variation is due to the difference of one in the sample size (345 versus 344 cases).

The second segmentation scheme, which is a more elaborate one, is based on life cycle and occupation. This scheme was previously employed in a model of automobile ownership and mode of travel to work by Ben-Akiva and Lerman (7). The five segments are defined in Tables 10 and 11 with the list of estimated coefficients and summary statistics. This set

Table 6. Estimated coefficients for pooled sample and life-style segments.

			Life-Style Segment									
	Pooled Model		1		2		3		4		5	
Variable	Estimated Coefficient	t-Statistic	Estimated Coefficient	t-Statistic	Estimated Coefficient	t-Statistic	Estimated Coefficient	t-Statistic	Estimated Coefficient	t-Statistic	Estimated Coefficient	t-Statistic
IVTTA	-0.172	-8.13	-0.247	-4.32	-0.056	-1.28	-0.152	-3.43	-0.266	-5.42	-0.149	-2.12
OVTTA	-0.493	-3.90	-0.832	-2.02	-0.110	-0.57	-1.655	-1.96	-1.631	-2.31	-1.891	-1.72
SUBWLK	-1.043	-2.40	-3.303	-1.92	2.268	1.33	-2.546	-2.03	1.25	0.72	-0.320	-0.33
INZWDM	0.708	1.29	-2.415	-0.67	-7.798	-1.47	0.689	0.44	4.636	2.99	-0.462	-0.36
INZDUM	-3.161	-12.34	-4.484	-6.69	-1.995	-3.570	-2.901	-5.54	-3.742	-6.34	-3.943	-4.53
AAVAPR	0.135	0.21	-4.152	-2.19	2.582	0.89	0.140	0.01	3.718	1.52	0.449	0.37
AUTOCON	1.619	2.23	2.566	0.58	-6.534	-1.10	2.571	1.25	6.682	3.09	1.009	0.60
ACSTI	-6668.26	-1.00	1183	0.07	-49 043	-2.07	-6966	-0.51	9852	0.99	-16 633	-0.84
LNRET	0.403	5.47	0.401	2.84	0.231	1.25	0.637	3.82	0.114	0.679	0.761	3.18
RTDNS	0.889	2.28	1.023	1.10	0.836	0.80	1.323	1.45	1.89	2.2	-0.44	-0.04
WLKTT	-0.065	-4.58	-0.402	-1.47	-0.555	-1.23	-0.109	-2.19	0.013	0.86	-0.128	-3.04
ORESW	2.328	4.31	5.451	2.33	3.243	1.65	3.187	2.47	3.024	2.13	1.97	1.63
EMPAUTO	0.599	1.42	0.973	0.727	2.000	1.30	-0.398	-0.38	0.498	0.43	-1.107	-1.15
CBDDUM	-1.476	-2.63	-0.203	-0.09	-1.158	-0.85	-[a]	-[a]	-[a]	-[a]	-3.726	-2.54

Note: The number of observations is as follows: pooled = 344, 1 = 50, 2 = 83, 3 = 82, 4 = 77, and 5 = 52.
[a]Variable excluded.

Table 7. Summary statistics for Table 6.

		Life-Style Segment				
Item	Pooled Model	1	2	3	4	5
$L^*(0)$	751.580	182.291	111.793	179.252	170.52	107.874
$L^*(\theta)$	400.462	70.102	66.667	84.418	72.361	49.345
ρ^2	0.467	0.62	0.40	0.53	0.58	0.54

Table 8. Estimated coefficients for models based on income segmentation and pooled model.

	Pooled Model		1		2		3		4		5	
Variable	Estimated Coefficient	t-Statistic	Estimated Coefficient	t-Statistic	Estimated Coefficient	t-Statistic	Estimated Coefficient	t-Statistic	Estimated Coefficient	t-Statistic	Estimated Coefficient	t-Statistic
IVTTA	-0.173	-8.17	-0.389	-1.74	-0.122	-2.39	-0.168	-4.29	-0.130	-1.93	-0.194	-4.54
OVTTA	-0.496	-3.91	-1.365	-1.55	-0.354	-1.37	-[a]	-[a]	-1.016	-2.04	-0.315	-1.14
SUBWLK	-1.052	-2.42	-[a]	-[a]	0.499	0.41	-1.499	-1.97	-0.897	-0.71	-[a]	-[a]
INZWDM	0.691	1.26	0.033	0.02	-2.522	-0.96	3.694	3.31	-4.379	-1.76	3.465	1.07
INZDUM	-3.147	-12.33	-4.182	-3.25	-2.717	-4.82	-3.460	-6.86	-2.394	-4.35	-3.970	-6.73
AAVAPR	0.126	0.20	0.561	0.31	6.631	2.47	-0.646	-0.58	-2.155	-1.55	-3.760	-1.37
AUTOCON	1.629	2.24	1.166	0.63	-3.822	-1.37	3.891	2.84	0.241	0.10	9.620	2.07
ACSTI	-6449	-0.97	-48 398.8	-0.67	-20 961.9	-1.29	-10 989.7	-0.95	-27 802.0	-0.87	-6140.63	-0.40
LNRET	0.407	5.53	0.769	1.54	0.529	2.76	0.236	2.05	0.303	1.87	0.268	1.95
RTDNS	0.893	2.29	1.361	0.77	1.769	1.83	2.684	3.93	0.427	0.55	0.578	0.63
WLKTT	-0.065	-4.59	-0.131	-3.03	-0.195	-1.89	-0.001	-0.08	-0.332	-1.86	-0.021	-0.37
ORESW	2.333	4.31	-[a]	-[a]	3.758	2.69	1.577	1.70	-[a]	-[a]	5.821	2.83
EMPAUTO	0.609	1.44	0.612	0.54	-2.958	-2.29	0.799	1.03	-[a]	-[a]	1.248	0.74
CBDDUM	-1.482	0.2165	-3.883	-2.24	-1.417	-0.87	-[a]	-[a]	1.257	0.64	-0.862	-0.46

Notes: For income segmentation, 1 = low income and 5 = high income.
The number of observations is as follows: pooled = 345, 1 = 38, 2 = 68, 3 = 102, 4 = 58, and 5 = 79.
[a]Variable excluded.

Table 9. Summary statistics for Table 8.

Item	Pooled Model	1	2	3	4	5
$L^*(0)$	753.785	74.2404	150.219	223.517	130.679	175.13
$L^*(\theta)$	401.312	25.427	71.982	123.095	67.569	85.865
ρ^2	0.468	0.658	0.521	0.449	0.483	0.510

Note: For income segmentation, 1 = low income and 5 = high income.

Table 10. Estimated coefficients for life-cycle and occupation segments and pooled model.

Variable	Pooled Model Estimated Coefficient	Pooled Model t-Statistic	1[a] Estimated Coefficient	1[a] t-Statistic	2[b] Estimated Coefficient	2[b] t-Statistic	3[c] Estimated Coefficient	3[c] t-Statistic	4[d] Estimated Coefficient	4[d] t-Statistic	5[e] Estimated Coefficient	5[e] t-Statistic
IVTTA	-0.173	-8.17	-0.142	-4.14	-0.240	-4.08	-0.225	-3.24	-0.057	-1.04	-0.261	-4.63
OVTTA	-0.496	-3.91	-1.356	-2.56	-0.315	-1.10	-0.153	-0.88	-0.660	-2.02	-2.00	-1.80
SUBWLK	-1.052	-2.42	-0.768	0.88	-0.937	-0.77	-0.949	-0.78	-0.465	0.37	-2.54	-1.95
INZWDM	0.691	1.26	1.169	0.76	3.950	3.29	-2.33	-1.28	-5.222	-2.11	0.242	0.14
INZDUM	-3.147	-12.33	-3.660	-7.45	-3.442	-5.72	-3.08	-4.75	-2.169	-3.39	-4.039	-5.30
AAVAPR	0.126	0.20	-0.614	-0.50	-1.223	-0.73	-0.742	-0.42	3.968	1.42	2.712	1.33
AUTOCON	1.629	2.24	3.164	1.70	7.586	3.45	0.910	0.42	-5.388	-1.86	-0.230	-0.09
ACSTI	-6449	-0.97	-12 493	-1.05	-398	-0.02	-2545	-0.11	-31 563	-1.59	10 120	0.96
LNRET	0.407	5.53	0.487	3.89	0.431	2.08	0.426	2.09	0.569	2.61	0.295	1.70
RTDNS	0.893	2.29	1.403	2.11	1.007	1.03	1.219	1.05	0.294	0.29	0.215	0.18
WLKTT	-0.065	-4.59	-0.100	-1.90	0.009	0.71	-0.114	-2.49	-0.409	-2.64	-0.083	-2.00
ORESW	2.333	4.31	3.144	2.52	1.627	1.10	4.442	2.35	2.530	1.96	-0.412	-0.222
EMPAUTO	0.609	1.44	1.683	1.48	-1.42	-1.11	-0.030	-0.03	-1.307	-1.04	1.843	1.40
CBDDUM	-1.482	0.2165	-[f]	-[f]	-2.41	-1.59	-1.892	-1.77	-[f]	-[f]	-0.742	-0.51

Note: The number of observations is as follows: pooled = 345, 1 = 113, 2 = 68, 3 = 52, 4 = 51, and 5 = 56.

[a]Young white-collar with and without children.
[b]Young blue-collar with children.
[c]Old white-collar without children.
[d]Old blue-collar without children.
[e]Old blue- and white-collar with children.
[f]Variable excluded.

Table 11. Summary statistics for Table 10.

Item	Pooled Model	1	2	3	4	5
$L^*(0)$	753.777	251.066	146.088	124.485	108.624	123.515
$L^*(\theta)$	401.312	116.551	70.9242	66.729	54.3713	57.2442
ρ^2	0.468	0.536	0.515	0.464	0.499	0.537

Note: Segments 1 through 5 correspond to footnotes a through e in Table 10.

Table 12. Summary statistics of alternative market-segmentation schemes.

Scheme	ρ^2	Log-Likelihood Difference (versus pooled)
Pooled	0.47	
Income segmentation	0.50	54.8
Life-cycle and occupation segmentation	0.51	71.8
Life-style segmentation		
A	0.58[a]	43.7
B′	0.54	115.3

[a]Compared with 0.55 for the pooled three-mode model.

of models resulted in a total log-likelihood value of -365.8 as compared with -342.8 for the life-style segmentation. Thus, the life-style segmentation performs significantly better than the income and life-cycle/occupation segmentations. The summary statistics are presented in Table 12.

In assessing the individual life-style-based models shown in Tables 6 and 7, one notices that they vary in their explanatory power as evaluated by the ρ^2 statistic. The range is from $\rho^2 = 0.62$ for model 1 to $\rho^2 = 0.40$ for model 2. Recall that segment 2 is that of a relatively high socioeconomic class that is distinguished from segment 1 mainly by the high rate of females' full employment and small one-household size. It was speculated above that segment 2 includes at least two distinct groups that vary in life-style and in tastes. Consequently, constraining the model coefficients to be identical for these two (or more) groups results in a relatively low explanatory power.

Most cofficients have the expected sign, and those that do not have very low t-statistics. Overall, the problem of sample size becomes obvious here, as each segment is based on less than 100 observations and 14 coefficients are estimated, the standard errors for most being relatively large.

CONCLUSION

The results shown in this research have demonstrated that the life-style concept, as operationalized here, does provide an improved discrimination between market segments when compared with income or life-cycle/occupation-based segmentations. But it can be argued that the operationalization presented here is merely a more complex form of presenting socioeconomic characteristics, and the improvement in the model's performance could be attributed to the fact that more variables are taken into account.

Such arguments are refuted because the theoretical concept of life-style developed in this research does extend our conceptualization of travel-behavior decisionmaking. It suggests a sound theory of the relation between long- and short-range choices made by individuals. It also conforms with efforts carried out in other social sciences to improve the differentiation among behavioral groups (3,16). Hence, this work is a step in the direction of identifying an array of variables that reflect, through some interaction, the chosen life-style of groups of individuals, and they are not merely a combination of some available variables.

The operationalization presented here still lags after the theoretical concept. Further research is being done in an effort to improve the ability to distinguish between life-styles emerging in Western society today. Specifically, it is now necessary to identify variables that are more indicative of life-style and to attempt to identify life-style segments within a relatively homogeneous socioeconomic sample.

ACKNOWLEDGMENT

The paper is based primarily on research done at the Massachusetts Institute of Technology (MIT) and supported by a grant from the U.S. Environmental Protection Agency. We wish to thank Marvin L. Manheim and Steve Lerman of MIT and David Segal of Harvard

University for their useful comments and suggestions.

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Publication of this paper sponsored by Committee on Passenger Travel Demand Forecasting.