Automobile Availability and Its Application in Transportation Studies

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ABSTRACT

The usefulness of personal automobile availability in travel behavior analyses as an alternative to the more familiar automobile-ownership approach is discussed. A measure of automobile availability for an individual based over a longer period of time (an average situation) rather than a person's actual access to the automobile at a specific time is offered. Four versions of the proposed definition of automobile availability are formulated and their performance is studied by examining the relationship between automobile availability and modal split. This is done by using data sets from Baltimore and the KONTIV data sets from Germany. Results of this analysis give preference to a simple three-level stratification [automobile (never/sometimes/always) available] in defining automobile availability for its apparent application in travel demand and policy analyses.

Until recently, the term "automobile availability" appeared in the literature just as a synonym for family automobile ownership. A forecast level of the family automobile ownership (0, 1, or 2+ automobiles) was a simple and natural input into the household-based trip generation models and an important explanatory variable for modal-split models.

However, in recent years interest in the variable "automobile availability," which describes an individual's access to a private automobile, has increased noticeably. In order to better understand transportation-related behavior it became necessary to focus on analyses oriented toward individuals within the household rather than on the household as a whole, because individual needs, options, and constraints are ultimately responsible for the travel choices made. Both individually oriented modal-split models and recent person-based trip generation models (1,2) required a compatible term: "individual automobile availability" rather than "household automobile ownership." Indeed, automobile availability, or its equivalent variable, automobile competition, appeared crucial for both modal choices (1, 3-7) and mobility analysis (1,2).

The usefulness of the automobile availability concept in transportation studies is examined with a primary focus on modal-split analysis. The following issues are addressed: (a) comparison between automobile availability and automobile ownership concepts and (b) comparison of alternative definitions and measurements of automobile availability with primary reference to the relationship between automobile availability and modal choices in different geographic contexts.

Two data sets are utilized in this study: the Baltimore Disaggregate Data Set from 1977 and the German data set called KONTIV, gathered in 1976. Only data records from German cities with more than 500,000 inhabitants (code 7) were considered for the KONTIV set, to make it comparable with the Baltimore set.

COMPARISON BETWEEN AUTOMOBILE AVAILABILITY AND AUTOMOBILE OWNERSHIP APPROACHES

For all household-oriented modeling approaches, an automobile ownership description (0, 1, or 2+ automobiles in the family) is a natural and simple one. For years, the forecast level of family automobile ownership has been commonly used as an input to the household-based trip generation models and as an important explanatory variable for modal-split models. However, a closer look at this problem from the point of view of an individual--the true decision maker and traveler--can raise some doubts about the adequacy of the term "automobile ownership" for travel behavior analyses and disaggregate travelchoice models.

First, it is apparent that any given level of family automobile ownership seldom means equal access to automobiles for all family members. For example, some will be primary users, whereas others will have to wait for the automobile until it is not needed for a more important activity. Also, not all family members may have a driver's license. A seemingly easy automobile-sharing arrangement among family members may often be significantly restricted if their activities outside the home are, for different reasons, temporarily or spatially inflexible.

Therefore, the total number of automobiles owned by a family may not be an absolutely objective description of high or low ownership level because it does not refer to the real need for an automobile by each family member. For example, family ownership of two automobiles (seemingly high) may not fully satisfy the needs of a family with four drivers if three of them are employed at different, widely dispersed locations. On the other hand, a low ownership level of one automobile will warrant unrestricted access to the automobile if there is only one driver in the household.

In addition, modal choices made by different family members depend primarily on the availability of private transportation to each individual family member rather than on the overall automobile ownership of the family. "Family modal choice" is virtually an undefinable term because the individual mode choices are often dramatically different among family members. Thus, the automobile availability description may be more suitable than the automobile ownership approach in describing the behavioral background of the modal-split choices, which are always closely related to automobile ownership and automobile availability issues.

Finally, the household-based automobile ownership concept encounters several problems when dynamic changes in the family "life cycle" (family size or number of employed members) are accounted for. Such changes contribute to the changing attitudes toward possessing a given number of automobiles. These changes are crucial considerations for long-range travel forecasts. Also there is difficulty in capturing such commonly observed trends relevant to the family automobile ownership issue as (a) decrease in the household size (fewer children and lower percentage of three-generation families), (b) increase in families with two or more breadwinners (increase in percentage of female employment), (c) increase in percentage of single-parent families, (d) increase in percentage of single persons, (e) increase in the average age of the population, and (f) increase in the percentage of women possessing a driver's license.

Because the automobile availability concept addresses the issue of access to an automobile at the individual level, it provides the potential for a more precise and better behaviorally based description of the complex relationship among a person's need for travel, travel opportunities, and actual travel itself. It should be stressed that any description of automobile availability should not ignore obvious family links and constraints, which may affect both access to the automobile and its actual use.

DEFINITIONS AND MEASUREMENTS OF AUTOMOBILE AVAILABILITY

Previous Studies

The majority of studies on automobile availability have based their measures on direct questions asked in household surveys, for example, "Was there an automobile available that you could have used for this trip?" Bailey (4) argues that this simple question can be difficult to interpret and is likely to be difficult for a respondent to answer quickly.

Therefore, in a number of studies, attempts have been made to overcome some of the problems and ambiguities by not asking the question about actual automobile availability at all (4). Instead, a number of assumptions had to be made regarding the priority of use of the automobile in potentially conflicting and nonconflicting situations. From these assumptions a judgment about actual automobile availability was made.

Gwilliam and Banister (8), for example, made the following assumptions: (a) an automobile was considered available for a particular trip when it was not in use and located at the point from which that trip was to begin, (b) availability of the automobile for passenger travel was excluded from the analysis, and (c) all trips measured as "automobile available" would be made by automobile.

Bailey and Layzell (9) postulated a clarification of the automobile availability concept. They compared the number of license holders and number of automobiles in the household, and defined the automobile as being available only if it remained unused for the duration of the period for which a particular traveler would be away from home.

It has to be emphasized that all the aforementioned definitions of automobile availability consistently attempted to represent actual access to an automobile by an individual at the analyzed specific period of time.

Proposed Definition of Automobile Availability

Stopher and Wilmot (7) developed individual-choice models of modal split by using a variable defined as "automobile competition." This variable was defined as the ratio of automobiles to licensed drivers and was a continuous measure of automobile availability. When the automobile competition variable was added to the multinomial logit model as a mode-specific variable for automobile driver, it added significant explanatory power to the work-trip model of mode choice.

Similar to Stopher and Wilmot's definition of automobile competition, the definition of automobile availability proposed here refers to the average situation over a longer period of time rather than just a survey day, which could be atypical (e.g., an automobile normally available for a given individual could be in for repair during the survey day; a person without an automobile can use a friend's automobile, etc.). Instead of delving into a complex system of dependencies to understand why an automobile is available for a given family member at certain times or directly asking the question about automobile availability in the household survey (which will never bring any clear-cut answers), it appears to be more beneficial and practical to investigate the general travel choices made by a person who has no access to the automobile as a driver, limited access, or unlimited access. The difference between the analysis presented in this paper and the one made by Stopher and Wilmot (7) is that the purpose of the automobile availability variable used here is to stratify the population into homogeneous groups that can be examined individually rather than using the automobile competition variable as an explanatory variable for multinomial logit (MNL) models.

The concept of automobile availability presented in this paper was originally proposed by Supernak et al. (5,6,10). The three-level choice described in this approach [automobile (never/sometimes/always) available] replaces a two-level choice [automobile (available/ not available) for a particular trip]. Automobile availability levels are described as follows (N_c = number of automobiles in the household and N_d = number of persons with a driver's license in the household):

	Automobile Availability	
Criterion	Drivers	Nondrivers
$N_c = 0$	Never	Never
$N_c > 0,\ N_d > N_c$	Sometimes	Never
$N_c > 0,\ N_d \leq N_c$	Always	Never

It should be noted that similar to previous work [e.g., that of Bailey (4)], the level of automobile availability refers to the availability to drive an automobile at any given time (not to being a passenger). Theoretically, any person can be a passenger in an automobile at any time (by hiring a taxi, for example). Also, any ridesharing arrangements are not limited to the same household.

Automobile Availability as an Element of a Person Category Travel-Demand Analysis

The concept of automobile availability was developed as part of an integrated modeling system based on homogeneous person categories. In particular, the result of the automobile availability model--a forecast share of the population with an automobile available (never/sometimes/always)--is the direct input into the person category trip generation model (1).

In developing this model, a multistage, multivariate analysis of factors influencing a person's travel behavior proposed that the most significant variables describing differences in travel behavior were age, employment status, and automobile availability. This analysis resulted in the formulation of eight homogeneous person categories as seen in Figure 1.

Age reflects obvious differences in demand for travel among (a) preemployment, (b) employment, and (c) postemployment stages in everyone's life. Employment status reflects a basic distinction between employed and nonemployed adults with respect to their demand for activities and travel. The former

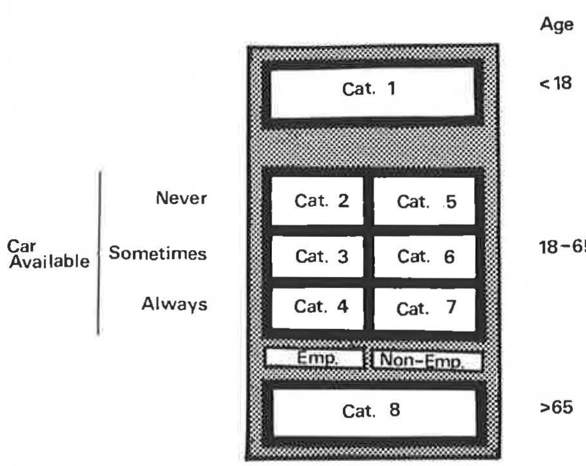

FIGURE 1 Description of the eight-person homogeneous categories.

group participates regularly in both obligatory and discretionary activities, whereas the latter participates primarily in discretionary outside-home activities. The third variable describes a person's ability to fulfill his or her travel needs through "purchasing" the services offered by the most convenient transportation mode: an automobile.

The aim of the person category automobile availability model is to describe the proportions $\alpha_2 : \alpha_3 : \alpha_4$ and $\alpha_5 : \alpha_6 : \alpha_7$, where α_i is the share of the population in category i. This is the only remaining element needed to forecast category percentages $\alpha_1, \alpha_2, \ldots, \alpha_8$ for the trip generation model. Shares of α_1 and α_8 are known from the demographic forecasts, whereas the split between the employed and nonemployed adults $(\alpha_2 + \alpha_3 + \alpha_4)/(\alpha_5 + \alpha_6 + \alpha_7)$ is known from the labor force and employment projections (which have to be made anyway for trip generation and trip distribution forecasting).

It should be noted that the level of automobile availability has to be described separately for employed $(\alpha_2 : \alpha_3 : \alpha_4)$ and nonemployed $(\alpha_5 : \alpha_6 : \alpha_7)$ adults because it can be reasonably expected that the need for an automobile is significantly differentiated between these two groups. Supernak has discussed the description of these shares briefly (6).

Modifications of Proposed Definition of Automobile Availability

The description of individual automobile availability proposed earlier is only one of many possible formulations. Although the situations "automobile never available" and "automobile always available" are clearly specified, there could be several alternative definitions of the situation "automobile sometimes available" to capture the difference between, say, one automobile shared by three drivers or three automobiles shared by four drivers. Therefore, three other descriptions of the situation "automobile sometimes available" are presented as modifications to the proposed definition of automobile availability.

Modification 1

Obligatory trips, which include work and school trips, usually must occur at a specific time of the day. Discretionary trips, which include personal business, shopping, and social-recreational trips, are more flexible and can be scheduled for more convenient times during the day. Because obligatory trips are on this rigid time schedule, they would usually be considered to have priority over discretionary trips. Therefore, in a household with less automobiles than drivers, the employed individuals may often have priority for the automobile to go to work.

Schoendorfer (11) proposed a modification of the automobile availability description that could account for the priority given to obligatory trips. The definition of the situation "automobile sometimes available" was revised by introducing a variable N_e, which is the number of employed persons in the household with a valid driver's license. The N_c variable (number of automobiles in the household) maintained the same definition that was used in the previous version.

If $N_e > N_c (N_c/N_e < 1)$, then some employed persons in that household may not always have unrestricted access to the automobile for their obligatory trips. If $N_e \leq N_c (N_c/N_e \geq 1)$, then the employed persons in this household may not need to compete for the automobile for obligatory trips or "always" have access to the automobile for these trips. Taking this into account, the original Category 3 (employed, automobile sometimes available), was divided into two groups, Categories 3A and 3B. Category 3A includes those individuals who may "sometimes" have access to the automobile for obligatory trips and Category 3B is those individuals who may "always" have access to the automobile for these trips.

Modification 2

Modification 2 examines in more detail Category 3A according to the actual ratio N_c/N_e. Although theoretically continuous, in reality this ratio is reduced to a relatively few discrete values resulting from possible combinations of number of automobiles, drivers, and employees in a household.

It was found that this ratio was often 1/3, 1/2, and 2/3. Based on this finding, the stratification of the segment of the population that is employed with an automobile sometimes available resulted in four ranges; $0 < x \leq 1/3$; $1/3 < x < 2/3$; $2/3 \leq x < 1$; and $x \geq 1$. The categories were named 3A.1, 3A.2, 3A.3, and 3B, respectively.

Modification 3

Modification 3 is an extension of the original description of automobile availability based on the ratio N_c/N_d to introduce more segments in the "automobile sometimes available" category $(0 < N_c/N_d < 1)$. The stratification of the segment of the population that is employed with an automobile sometimes available resulted in three groups, 3.1, 3.2, and 3.3, corresponding to N_c/N_d ranges $0 < x \leq 1/3$, $1/3 < x < 2/3$, and $2/3 \leq x < 1$, respectively.

COMPARISON OF ALTERNATIVE DEFINITIONS OF AUTOMOBILE AVAILABILITY

The aim in this section is to recommend the preferred version of automobile availability descriptions by comparing the proposed version and Modifications 1, 2, and 3. Data sets from Baltimore, Maryland, and German cities are utilized in order to (a) examine population representations within each automobile availability segment, (b) examine the consistency of category-specific modal-split characteristics for alternative descriptions of automobile availability, (c) compare modal-split characteristics of person categories between Baltimore and the German cities (this is done for the purpose of comparing automobile availability definitions only; the modal-split relationship will be investigated in greater detail in a separate paper), and (d) examine prospects for transferring category-specific modal shares from Germany to predict the use of the automobile and public transit modes in Baltimore.

Population Representations for Each Category

Table 1 shows the percentage of the population represented by each category. Most of the emphasis in this section is directed at Category 3 (age 18 to 65, employed, automobile sometimes available), which represents only about 20 percent of the population in both Baltimore and the German cities. Although this may be considered a small percentage of the entire population, it represents those who sometimes have an automobile available, a category that is not as clearly defined as situations in which an automobile is never or always available. However, when the individuals in Category 3 were reclassified according to Modifications 1, 2, and 3, it was recognized that this group was not as ambiguous as originally thought. In large German cities, for example, 74.6 percent of Category 3 fell into Category 3A.2 (N_c/N_e > 1/3 and < 2/3) for Modification 2 and 86.3 percent of Category 3 fell into Category 3.2 (N_c/N_d > 1/3 and < 2/3) for Modification 3. This suggests that because such a small segment of the population is represented by some of the other categories (Categories 3A.1 and 3A.2 in Modification 2 and Categories 3.1 and 3.3 in Modification 3), little accuracy is to be gained by the further stratification of Category 3, as was done in all modifications.

For Baltimore it is interesting to note that a larger percentage of the employed population has an automobile always available (23.6 percent of the population, or 46.8 percent of the work force). Almost half of the population represented by Category 3 always has an automobile available when availability is defined by the ratio of N_c/N_e as in Modification 1. This means that nearly 62 percent of the work force always has access to the automobile for obligatory trips. This suggests that the number of employees in a household directly affects the desired level of automobile availability within a household.

Automobile Availability and Modal Split in Baltimore and German Cities

The results summarizing modal-split characteristics are presented in Tables 2 and 3 for Baltimore and in Tables 4 and 5 for the German cities. The findings may be summarized as follows:

1. Independent of version, an increase in automobile availability results in consistent increases in shares for the automobile-driver mode and decreases in the automobile-passenger and public transit share. The walk share also decreases, although less consistently. This applies to both obligatory and discretionary trips for both data sets, although the overall differences in modal-split characteris-

TABLE 1 Category Representations for Alternative Descriptions of Automobile Availability

				Category Representations (%)			
				Entire Population		Category 3	
Age	Employment Status	Automobile Availability	Category[a]	Baltimore	German Cities	Baltimore	German Cities
Proposed Definition: N_c/N_d							
<18	N/A	N/A	1	20.5	15.0		
18-65	Employed	$N_c = 0$	2	10.2	20.9		
18-65	Employed	<1	3	16.6	20.5	100.0	100.0
18-65	Employed	≥ 1	4	23.6	18.2		
18-65	Nonemployed	$N_c = 0$	5	9.5	10.7		
18-65	Nonemployed	<1	6	6.9	4.0		
18-65	Nonemployed	≥ 1	7	6.8	2.5		
>65	N/A	N/A	8	5.9	8.2		
Modification 1[b]: N_c/N_e							
18-65	Employed	<1	3A	8.9	16.2	53.6	79.0
18-65	Employed	≥ 1	3B	7.7	4.3	46.4	21.0
Modification 2: N_c/N_e							
18-65	Employed	$>0; \leq 1/3$	3A.1	0.7	0.3	4.2	1.5
18-65	Employed	$>1/3; <2/3$	3A.2	4.7	15.3	28.3	74.6
18-65	Employed	$\geq 2/3; <1$	3A.3	3.5	0.6	21.1	2.9
18-65	Employed	≥ 1	3B	7.7	4.3	46.4	21.0
Modification 3: N_c/N_d							
18-65	Employed	$>0; \leq 1/3$	3.1	1.7	1.2	10.2	5.9
18-65	Employed	$>1/3; <2/3$	3.2	10.3	17.7	62.0	86.3
18-65	Employed	$\geq 2/3; <1$	3.3	4.6	1.6	27.7	7.8

Note: N_c = number of automobiles in the household; N_d = number of persons in household with a driver's license; N_e = number of employed persons in household with a driver's license; N/A = not applicable.

[a]Categories 1, 2, and 4 through 8 remain the same for all versions.
[b]For Modifications 1, 2, and 3, N_c is always greater than zero.

TABLE 2 Modal-Split Shares for Obligatory Trips in Baltimore for All Category Descriptions

						Mode-Split Shares (%)				
Age	Employment Status	Automobile Availability	Category[a]	α_{trav} (%)	Trip Rate (N)	Automobile Driver	Automobile Passenger	Public Transit	Walk	Other Modes
Proposed Definition: N_c/N_d										
<18	N/A	N/A	1	20.5	1.79	4.6	14.5	24.2	43.7	13.0
18-65	Employed	$N_c = 0$	2	10.2	1.75	2.4	30.7	49.2	14.6	3.1
18-65	Employed	<1	3	16.6	2.05	65.1	18.2	9.3	7.0	0.4
18-65	Employed	⩾1	4	23.6	2.00	88.1	6.2	1.8	2.7	1.2
18-65	Nonemployed	$N_c = 0$	5	9.5	0.34	0.0	15.2	30.4	54.3	0.0
18-65	Nonemployed	<1	6	6.9	0.50	46.9	28.6	8.2	16.3	0.0
18-65	Nonemployed	⩾1	7	6.8	0.37	66.7	8.3	5.6	11.1	8.3
>65	N/A	N/A	8	5.9	0.29	83.3	12.5	4.2	0.0	0.0
Modification 1[b]: N_c/N_e										
18-65	Employed	<1	3A	8.9	1.96	54.6	22.5	11.6	10.8	0.4
18-65	Employed	⩾1	3B	7.7	2.16	76.2	13.6	6.8	3.0	0.4
Modification 2: N_c/N_e										
18-65	Employed	>0; ⩽1/3	3A.1	0.7	1.60	37.5	25.0	12.5	25.0	0.0
18-65	Employed	>1/3; <2/3	3A.2	4.7	1.83	50.4	26.4	14.1	8.3	0.8
18-65	Employed	⩾2/3; <1	3A.3	3.5	1.98	58.6	16.2	12.1	13.1	0.0
18-65	Employed	⩾1	3B	7.7	2.16	76.2	13.6	6.8	3.0	0.4
Modification 3: N_c/N_d										
18-65	Employed	>0; ⩽1/3	3.1	1.7	1.83	50.0	25.0	11.4	13.6	0.0
18-65	Employed	>1/3; <2/3	3.2	10.3	1.99	58.6	21.0	11.7	8.3	0.3
18-65	Employed	⩾2/3; <1	3.3	4.6	2.27	82.0	10.7	4.0	2.7	0.7

Note: N_c = number of automobiles in the household; N_d = number of persons in household with a driver's license; N_e = number of employed persons in household with a driver's license; α_{trav} = percentage of travelers in each category of the population; N/A = not applicable.
[a]Categories 1, 2, and 4 through 8 remain the same for all versions.
[b]For Modifications 1, 2, and 3, N_c is always greater than zero.

TABLE 3 Modal-Split Shares for Discretionary Trips in Baltimore for All Category Descriptions

						Mode-Split Shares (%)				
Age	Employment Status	Automobile Availability	Category[a]	α_{trav} (%)	Trip Rate (N)	Automobile Driver	Automobile Passenger	Public Transit	Walk	Other Modes
Proposed: N_c/N_d										
<18	N/A	N/A	1	20.5	1.72	5.8	28.3	4.6	52.4	8.9
18-65	Employed	$N_c = 0$	2	10.2	1.14	0.0	24.8	21.8	46.1	7.3
18-65	Employed	<1	3	16.6	1.33	70.5	17.5	0.6	10.8	0.6
18-65	Employed	⩾1	4	23.6	1.64	83.0	7.5	1.3	7.3	0.9
18-65	Nonemployed	$N_c = 0$	5	9.5	2.70	1.1	33.5	11.0	50.8	3.6
18-65	Nonemployed	<1	6	6.9	2.91	50.5	27.0	2.8	16.5	3.2
18-65	Nonemployed	⩾1	7	6.8	3.33	73.4	22.0	0.3	4.0	0.3
>65	N/A	N/A	8	5.9	2.64	39.6	11.7	12.6	30.2	5.9
Modification 1[b]: N_c/N_e										
18-65	Employed	<1	3A	8.9	1.47	61.5	23.0	1.1	13.4	1.1
18-65	Employed	⩾1	3B	7.7	1.17	83.6	9.4	0.0	7.0	0.0
Modification 2: N_c/N_e										
18-65	Employed	>0; ⩽1/3	3A.1	0.7	1.60	25.0	43.8	6.2	25.0	0.0
18-65	Employed	>1/3; <2/3	3A.2	4.7	1.50	70.7	13.1	1.0	13.1	2.0
18-65	Employed	⩾2/3; <1	3A.3	3.5	1.22	57.4	29.5	0.0	13.1	0.0
18-65	Employed	⩾1	3B	7.7	1.17	83.6	9.4	0.0	7.0	0.0
Modification 3: N_c/N_d										
18-65	Employed	>0; ⩽1/3	3.1	1.7	1.25	36.7	33.3	3.3	26.7	0.0
18-65	Employed	>1/3; <2/3	3.2	10.3	1.35	73.6	14.7	0.5	10.2	1.0
18-65	Employed	⩾2/3; <1	3.3	4.6	1.33	75.0	18.2	0.0	6.8	0.0

Note: N_c = number of automobiles in the household; N_d = number of persons in household with a driver's license; N_e = number of employed persons in household with a driver's license; α_{trav} = percentage of travelers in each category of the population; N/A = not applicable.
[a]Categories 1, 2, and 4 through 8 remain the same for all versions.
[b]For Modifications 1, 2, and 3, N_c is always greater than zero.

TABLE 4 Modal-Split Shares for Obligatory Trips in German Cities (KONTIV Code 7) for All Category Descriptions

						Mode-Split Shares (%)				
Age	Employment Status	Automobile Availability	Category[a]	α_{trav} (%)	Trip Rate (N)	Auto-mobile Driver	Auto-mobile Passenger	Public Transit	Walk	Other Modes
Proposed: N_c/N_d										
<18	N/A	N/A	1	15.0	1.85	0.1	4.1	37.0	38.4	20.4
18-65	Employed	$N_c = 0$	2	20.9	1.52	4.7	9.1	46.6	32.6	7.0
18-65	Employed	<1	3	20.5	1.94	57.3	6.4	16.6	16.3	3.4
18-65	Employed	≥1	4	18.2	2.06	81.1	2.1	4.5	11.2	1.1
18-65	Nonemployed	$N_c = 0$	5	10.7	0.92	2.9	6.9	44.9	36.9	8.4
18-65	Nonemployed	<1	6	4.0	1.47	41.7	6.7	27.3	16.1	8.2
18-65	Nonemployed	≥1	7	2.5	1.49	71.4	1.6	8.3	15.7	3.0
>65	N/A	N/A	8	8.2	0.59	17.5	3.8	25.4	50.3	3.0
Modification 1[b]: N_c/N_e										
18-65	Employed	<1	3A	16.2	1.97	54.4	7.1	17.3	17.8	3.5
18-65	Employed	≥1	3B	4.3	1.80	69.5	3.8	13.2	10.2	3.3
Modification 2: N_c/N_e										
18-65	Employed	>0; ≤1/3	3A.1	0.3	2.22	44.9	8.2	20.4	22.4	4.1
18-65	Employed	>1/3; <2/3	3A.2	15.3	2.01	54.2	7.1	17.0	18.1	3.5
18-65	Employed	≥2/3; <1	3A.3	0.6	1.63	62.5	4.5	28.4	4.5	0.0
18-65	Employed	≥1	3B	4.3	1.80	69.5	3.8	13.2	10.2	3.3
Modification 3: N_c/N_d										
18-65	Employed	>0; ≤1/3	3.1	1.2	1.93	50.4	7.2	23.9	14.4	4.1
18-65	Employed	>1/3; <2/3	3.2	17.7	1.91	55.8	6.7	16.4	17.6	3.5
18-65	Employed	≥2/3; <1	3.3	1.6	1.88	78.0	2.8	13.6	4.9	0.7

Note: N_c = number of automobiles in the household; N_d = number of persons in household with a driver's license; N_e = number of employed persons in household with a driver's license; α_{trav} = percentage of travelers in each category of the population; N/A = not applicable.
[a]Categories 1, 2, and 4 through 8 remain the same for all versions.
[b]For Modifications 1, 2, and 3, N_c is always greater than zero.

TABLE 5 Modal-Split Shares for Discretionary Trips in German Cities (KONTIV Code 7) for All Category Descriptions

						Mode-Split Shares (%)				
Age	Employment Status	Automobile Availability	Category[a]	α_{trav} (%)	Trip Rate (N)	Auto-mobile Driver	Auto-mobile Passenger	Public Transit	Walk	Other Modes
Proposed: N_c/N_d										
<18	N/A	N/A	1	15.0	1.49	0.3	10.5	22.3	43.4	23.5
18-65	Employed	$N_c = 0$	2	20.9	1.51	3.7	11.5	22.6	52.5	9.7
18-65	Employed	<1	3	20.5	1.69	49.6	10.0	7.3	29.5	3.6
18-65	Employed	≥1	4	18.2	1.71	77.2	3.6	2.7	15.1	1.4
18-65	Nonemployed	$N_c = 0$	5	10.7	2.12	1.9	11.8	20.8	57.7	7.7
18-65	Nonemployed	<1	6	4.0	2.14	43.4	9.8	10.6	30.2	6.0
18-65	Nonemployed	≥1	7	2.5	2.25	65.7	0.7	4.4	24.1	5.1
>65	N/A	N/A	8	8.2	2.42	9.0	3.8	24.6	57.3	5.4
Modification 1[b]: N_c/N_e										
18-65	Employed	<1	3A	16.2	1.65	45.1	10.6	8.3	32.1	3.9
18-65	Employed	≥1	3B	4.3	1.81	65.4	7.6	3.7	20.5	2.8
Modification 2: N_c/N_e										
18-65	Employed	>0; ≤1/3	3A.1	0.3	0.68	53.3	13.3	0.0	26.7	6.7
18-65	Employed	>1/3; <2/3	3A.2	15.3	1.70	44.8	10.7	8.2	32.4	3.9
18-65	Employed	≥2/3; <1	3A.3	0.6	1.32	50.7	9.9	14.1	22.5	2.8
18-65	Employed	≥1	3B	4.3	1.81	65.4	7.6	3.7	20.5	2.8
Modification 3: N_c/N_d										
18-65	Employed	>0; ≤1/3	3.1	1.2	1.36	53.8	7.7	10.3	26.3	1.9
18-65	Employed	>1/3; <2/3	3.2	17.7	1.67	47.1	10.3	7.6	31.2	3.9
18-65	Employed	≥2/3; <1	3.3	1.6	1.87	69.8	8.4	2.8	16.1	2.8

Note: N_c = number of automobiles in the household; N_d = number of persons in household with a driver's license; N_e = number of employed persons in household with a driver's license; α_{trav} = percentage of travelers in each category of the population; N/A = not applicable.
[a]Categories 1, 2, and 4 through 8 remain the same for all versions.
[b]For Modifications 1, 2, and 3, N_c is always greater than zero.

tics between Baltimore and the German cities should be kept in mind.

2. The ratios N_c/N_d and N_c/N_e are higher in Baltimore than in the German cities. Both of these ratios were most often 1/2 for the German cities, whereas for Baltimore the N_c/N_d ratio shifts from 1/2 toward 2/3 and the N_c/N_e ratio is frequently 1. This offers much better ridesharing opportunities in Baltimore as compared with the German cities.

3. For Modifications 1 and 2 it is clear that preference is given to employed persons for their obligatory trips. In Modification 1, for example, Category 3B modal-split shares shift from Category 3 toward Category 4, indicating a tendency to make the automobile always available for obligatory trips for employed members. The modal shares are not exactly like Category 4, because those in Category 3B still may compete with other household members for the automobile when they make discretionary trips.

Transferability Tests

Simple transferability tests were performed to determine (a) how consistent the category-specific modal-split travel behavior is in Baltimore and the German cities and (b) which version of automobile availability description performs best for different population segments. The category-specific modal shares from Germany (β_{ij}^{Germ}) were "borrowed" to explain modal share j in Baltimore (β_j^{Balt}):

$$\beta_j^{Balt,pred} = \left(\sum_i \beta_{ij}^{Germ} \cdot N_i^{Balt} \cdot \alpha_i^{Balt}\right) \div \left(\sum_i N_i^{Balt} \cdot \alpha_i^{Balt}\right) \quad (1)$$

where

$\beta_j^{Balt,pred}$ = predicted share of mode j in Baltimore,

β_{ij}^{Germ} = actual share of mode j for person category i in the German cities,

N_i^{Balt} = actual trip rate per traveler belonging to Category i in Baltimore, and

α_i^{Balt} = actual share of the traveler Category i in Baltimore.

The errors were calculated as follows:

$$\text{Error} = (\beta_j^{Balt,pred} - \beta_j^{Balt,act})/\beta_j^{Balt,act} \quad (2)$$

where $\beta_j^{Balt,act}$ is the actual share of mode j in Baltimore.

The results of such an analysis are shown in Table 6. It may be seen that (a) transferability errors are small for the automobile-driver mode and much higher for the public transit mode; (b) errors are much smaller for "organized" obligatory trips than for more area-specific discretionary trips; (c) errors are much smaller for the employed segment than for the entire population; (d) Categories 1 and 8, not defined around the automobile availability variable, are least transferable; and (e) level-of-service variables are needed to explain the public transit share of the modal split, because the errors without these variables are too large, particularly for discretionary trips. [Note, however, that transfers of MNL models of mode choice may result in much higher errors if the model is transferred into a different urban environment; for example, the transfer of the Baltimore model to Twin Cities resulted in 500 percent error to the public transit share (12). Recent work by Supernak (13,pp. 533-559) shows a method for updating alternative specific constants of MNL models of mode choice by utilizing category-specific modal shares.]

It appears from Table 6 that no one version of automobile availability performs much better than any of the others. In most cases, the original proposed definition of automobile availability will be considered superior because of its simplicity as compared with the modified versions. Although further stratification of Category 3 has provided some interesting observations (e.g., that the higher the ratio of number of drivers to number of automobiles, or the number of employed drivers to the number of automobiles, the higher is the likelihood of driving the automobile), the small representations of each of the modified groups make these descriptions of automobile availability more cumbersome than they are worth.

Table 7 confirms the usefulness of categorization of the population according to such variables as

TABLE 6 Transferability Errors for Automobile-Driver and Public Transit Modes in Application of Category-Specific Modal Shares from German Cities to Baltimore

		Errors (%)					
		Obligatory Trips		Discretionary Trips		All Trips	
Version	Category	Automobile Driver	Public Transit	Automobile Driver	Public Transit	Automobile Driver	Public Transit
Proposed version	2-4	−8.65	+25.75	−13.48	+66.68	−11.03	+27.23
	2-7	−8.17	+31.61	−12.57	+107.55	−10.47	+63.17
	1-8	−11.75	+41.28	−19.41	+149.24	−15.79	+80.24
Modification							
1	2-4	−6.30	+22.44	−11.74	+60.03	−11.11	+12.82
	2-7	−5.94	+28.64	−11.46	+104.29	−10.53	+49.55
	1-8	−9.61	+39.46	−18.42	+147.08	−15.85	+70.80
2	2-4	−5.24	+25.80	−11.08	+63.20	−10.10	+11.35
	2-7	−4.93	+31.60	−11.04	+105.84	−13.84	+46.89
	1-8	−8.69	+41.21	−18.06	+148.10	−15.15	+68.51
3	2-4	−6.04	+24.72	−13.82	+61.12	−11.08	+7.45
	2-7	−5.69	+27.62	−12.79	+104.84	−10.51	+43.44
	1-8	−9.44	+38.89	−19.60	+147.45	−15.83	+66.12

TABLE 7 Analysis of Variance Results for All Trip Purposes

Factor	F^{calc} Auto-mobile Driver	Auto-mobile Passenger	Public Transit	Walk	Other Modes	$F^{0.01}$
2 Cities and 8 Categories						
Categories	33.65	3.27	10.41	8.80	7.77	6.99
Cities	4.30	41.22	11.38	7.25	9.02	12.25
2 Cities and 10 Categories[a]						
Categories	32.33	2.88	13.71	9.64	8.36	5.35
Cities	3.35	51.10	16.59	7.87	11.45	10.56

Note: Calculated F-values are shown and compared with $F^{0.01}$

[a]As defined in Modification 3.

automobile availability, employment status, and age (the factor "categories" is significant at the 1 percent level), for all modes except automobile passenger. When the analysis of variance is applied to the modified category description (Modification 3), the significance of area characteristics increases and the significance of category characteristics remains unchanged (see Table 7). Most significantly, this table confirms the usefulness of the automobile availability concept to analyze travel behavior, particularly modal split.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations may be stated:

1. The concept of automobile availability appears to be a valid alternative to the automobile ownership concept. An individual's access to the most convenient transportation mode, an automobile, is a primary factor in determining mode choice, particularly the share of the automobile-driven trips. The relationship between automobile availability and automobile use is strong, consistent, and very similar in Baltimore and certain large German cities.
2. This paper tested with success the automobile availability description based on average potential access of an individual to the automobile (never/sometimes/always) rather than actual access to the automobile for a given trip (available/not available). The recommended description is simple and easily applicable.
3. The proposed version of automobile availability was extended by a more detailed description of the situation "automobile sometimes available." Three modifications were considered. They consistently show that the higher the ratio of number of drivers to number of automobiles, or number of employed drivers to number of automobiles, the higher is the likelihood of driving the automobile. In families, priority for automobile use is commonly given to employed persons and their obligatory activities. The proposed version in its original form was preferred because of its simplicity.
4. The automobile availability issue deserves more studies, such as (a) an international comparison of the relationship between automobile availability and modal split, (b) explanatory variables for automobile availability levels, and (c) the potential for practical applications.

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Attribute Thresholds and Logit Mode-Choice Models

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ABSTRACT

The concept of thresholds has been mentioned in the transport choice literature from time to time. Few studies of mode choice have attempted to incorporate them into a modeling context, however. In this paper the concept of minimally perceived attribute differences is introduced into a logit choice model. For estimating the parameters of the model, maximum likelihood is employed and an experimental test is carried out on a sample of trip makers going to the Melbourne central business district. It was found that the average respondent required a 12-min (22 percent) difference in travel time or a 12-cent (32 percent) difference in travel cost before he would react to the variation in attribute ratings. The model is compared with a more traditional logit model with a linear additive measure of utility.

Transport planners have developed a variety of statistical techniques for analyzing mode choice (1-4). The common feature of all these models is that choice is seen as a function of the utility gained from each alternative. To calculate utility it was assumed that an alternative was characterized by a set of attributes that contribute to an index of total utility. A linear additive function was used to combine the attribute utilities into the index. In turn attribute utilities were assumed to be a continuous function of the satisfaction gained from each attribute. That is, every change in satisfaction, no matter how small, will influence the utility gained from an alternative and hence an individual's choice.

Evidence in the psychology (5,6), economics (7), and biology (8) literature suggests that people may be indifferent to changes in a stimulus unless it crosses a threshold of indifference. In the transport literature this suggestion has found support in several studies of the application of transport-choice models. Kovak and Demetsky (9) and Burns et al. (10) found that models that did not incorporate indifference thresholds tended to overestimate mode shift for small changes in attribute satisfaction. It was suggested that the inclusion of thresholds of indifference may overcome this problem because they would tend to dampen the effect of small changes in attribute satisfaction. In this paper the incorporation of such thresholds into logit choice models is investigated.

The paper is divided into six sections. The next section describes the incorporation of thresholds as used in a number of disciplines. The third section describes the incorporation of thresholds into logit choice models. The fourth section describes the data used in the study, and the fifth to seventh sections discuss the model estimation and compare model performance.

BACKGROUND

The existence of thresholds of acceptance has been discussed in many disciplines.

In psychology, sensory thresholds were suggested by Weber in 1830 (5). He introduced the concept of just noticeable differences and related their size to the magnitude of the stimulus. Fechner (6) extended Weber's law by relating the strength of the sensory process to the logarithm of the stimulus. Experimental studies that followed appeared to support Fechner's logarithm law and the existence of thresholds was accepted.

Similarly, economists analyze consumer choice of commodities by the application of indifference curves (5). In this approach it is considered that, in a choice between two commodities, the decision