CAR AVAILABILITY VERSUS CAR OWNERSHIP MODELING: THEORETICAL DISCUSSION AND EMPIRICAL FINDINGS

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1. INTRODUCTION

Car ownership forecasting is one of the major components of travel demand modeling. First, it "bridges the gap" between the land use models and the sequence of travel demand models. Second, the level of ownership/availability of a private automobile has a direct impact on both the trip generation and the modal split sub-models: a higher car ownership level is associated with greater overall mobility and, undestandably, a higher percentage of auto trips. The consistency of these relationships has been confirmed by numerous transportation studies and research works over the last two decades. A close interrelationship between car ownership, trip generation and modal split was the reason why they were considered as a joint model in some research works, e.g., [1,2] (car ownership and trip generation) or [3,4] (car ownership and modal split).

Not surprisingly, the disaggregate car ownership models are specified at the household level of data aggregation. The main objective of these models is to predict the proportions of households owning 0/1/2+ cars. This information often constitutes a direct input into a household-based trip generation model (although it can be utilized directly, e.g., for estimation of the overall number of cars). A common analysis unit of "household" assures a full compatibility of both models: car ownership and trip generation. However, modal split models are normally specified at the "person" level of data aggregation.

Some of the recent works, e.g., [3,5,6,7,8] have improved our overall understanding of the complex nature and interdependence of human choices: where to live, how many cars to possess, how often to travel, how far, by what mode of transportation, etc. They raised questions about the proper analysis unit for disaggregate models, stability of behavioral patterns, situational constraints, etc., and generally, created an atmosphere of reevaluation of some, even the most commonly accepted, concepts, assumptions and modeling approaches.

In particular, it can be postulated that the subsequent travel demand submodels: car availability/ownership, trip generation and modal split should: a) be conceived as a multi-model unit, b) utilize the same analysis unit in order to assure their compatibility, and c) refer to the choices made by an individual rather than a household, since only the first unit is the truly behavioral, decision making one [9].

In order to realize this postulate, a person category trip generation model was developed for Polish cities [9] and originally presented at the PTRC Summer Annual Meeting in 1979 [10]. Another version of the person category trip generation model was proposed for American cities [11]. Both models are also discussed in another paper prepared for the World Conference on Transport Research [12].

Consequently, a new concept of individual auto availability [9,13] replaced the "traditional" concept of family auto ownership to assure compatibility of the following three modeling stages related to homogeneous categories of persons: car availability, trip generation and modal split. The concept of auto availability refers to the "real" level of access to the automobile for every family member instead of dealing with the overall family's car ownership level.

This paper compares the concepts of car ownership with car availability. The following aspects are considered: a) theoretical discussion, b) analysis of empirical findings from Baltimore, Maryland, U.S.A., c) implications of both modeling approaches on the entire methodology of travel demand modeling, and d) final conclusions and recommendations for practical applications.

2. CAR OWNERSHIP VERSUS CAR AVAILABILITY MODELING: A COMPARISON OF CONCEPTS

2.1 Problems with the car ownership concept

The term "auto availability" very seldom appears in the literature, e.g. [14], particularly if one excludes works where this term is just a synonym for "family car ownership". For all household-oriented modeling approaches, a car ownership description (0/1/2+ cars in the family) is such a natural and simple one that any attempt to "improve" it seems an unnecessary complication of the problem. 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 "auto ownership" for disaggregate modeling purposes.

First, it can be noticed that any given level of family auto ownership seldom means an equal access to the automobile by all family members. Not all of them may have a drivers licence, some will be primary users while others will have to wait for the car until it is not needed for a "more important" activity, etc. A seemingly easy car sharing arrangement among family members may often be significantly restricted if their outside home activities are, for different reasons, temporarily and/or spatially inflexible.

Second, the total number of cars owned by a family may not be an "absolutely" objective description of "high" or "low" ownership level since it does not refer to the "real need for a car" by each family member. For example, family ownership of two cars -- seemingly high -- may not fully satisfy the needs of, say, four drivers among the family members, three of whom are employed at different, widely dispersed locations. On the other hand, a "low" ownership of one car will warrant an unrestricted access to the car for the only driver in the household.

Finally, modal choices made by different family members depend primarily on the individual availability of private transportation of each family member rather than on the overall car ownership of the family. The "family modal choice" is a virtually undefinable term since the individual mode choices are often dramatically differentiated among family members. Thus, car availability rather than car ownership description may also be more suitable to reflect the behavioral background of the modal split choices which are always closely related to car ownership/availability issues.

In recent years more and more researchers dealing with disaggregate car ownership modeling recognized -- among other "external" factors — the problem of family's heterogeneity and a need to distinguish between different household types, structures, etc., in order to explain differences in a family's requirements for car ownership. Different stratifications, mostly due to "life cycle" or "life style" have been proposed, e.g. [3,15,16]. Goodwin and Mogridge [6] even proposed a fully dynamic model of car ownership growth which focused on the process whereby a household chooses to own one or more cars. Hopkin [17] postulated that more attention should be focused on social factors influencing car ownership.

These and other works significantly increased our understanding of human behavior in respect to many transportation related choices, among them the decision to purchase one or more cars. However, reference to the family as the analysis unit seems to have some "organic" problems which may "always" be difficult to overcome. The dynamic changes inside each family, which contribute to the changing attitudes toward possessing a given number of cars, are not only difficult to describe (if one wants to consider all relevant factors) but even more difficult to forecast.

There are also obvious limitations in the "family life cycle" approaches. A "manageable" number of 8-10 groups differentiated by a family's "stage of life" often does not clearly refer to such seemingly important characteristics as: family size, number of employed members, etc. There will also be difficulty in capturing such commonly observed trends relevant to the family car ownership issue as: a) decrease in the household size (fewer children, lower percentage of three-generation families); b) increase in families with two or more breadwinners (increase in percentage of women professionally active); c) increase in the percentage of single-parent families; d) increase in the percentage of single persons; e) increase in the average age of the population; f) increase in the percentage of women possessing drivers licence, etc.

It will be unreasonable, of course, to expect that the car availability approach can automatically solve all these problems. First of all, there will be no "escape" from references to household constraints, interrelationships, etc. Yet, at this level of analysis it should be easier to follow Brög's recommendation that "future transportation planning models must deal more specifically with the 'actors', as well as with the reasons which influence persons to behave as they do". [5].

2.2 Introduction of the car availability concept

As an alternative to car ownership concept, the following description of the individual car availability is proposed (Table 1).

Table 1. Description of auto availability levels

Criterion	Car Available: Drivers	Car Available: Non-drivers
$N_c = 0$	never	never
$N_c > 0,\ N_d > N_c$	sometimes	never
$N_c > 0,\ N_d \leq N_c$	always	never

Where N_c = number of cars in the household

N_d = number of persons with the drivers licence in the household

It should be noted that the level of auto availability refers to the ability to drive a car at any given time (not to being a passenger). Theoretically, any person can be a passenger in a car at any time (by hiring a taxi, for example).

The proposed description of individual auto availability is, or course, only one of many possible formulations. For example, there could be a more detailed description of the situation "car sometimes available" to describe the difference between, say, car shared by three drivers and three cars shared by four drivers. Also, there is no direct distinction between "non-availability" of the car because of: a) the lack of drivers licence, and b) the lack of a car in the family. However, the relatively simple description of car availability proposed in this paper has proven to be quite adequate and sufficient for American conditions.

The concept of car availability can be conveniently utilized for both travel demand modeling and policy analysis. This can be briefly illustrated by the following sequence of questions referring to a "person" as an analysis unit:

a) Why does a given person (or homogeneous person category C_i) desire to have a given level of auto availability (affected by: geographic location, needs for activities, purchasing ability, etc.)?

b) How will this person behave after achieving the desired level of auto availability (affects: trip generation, modal split, trip distribution)?

c) How can one change a person's: a) attitude toward car availability, and/or b) travel behavior (affected by: policy)?

The concept of car availability can also be used for an interpretation of the overall car ownership of a family. The following factors seem to influence the number of cars owned by a family: a) the individual needs of every family member for access to the car (obligatory/discretionary type of outside-home activities, geographic location of the residence and most common destination points), b) limitations in a car ridesharing among family members, c) overall family ability to purchase, insure, maintain etc. the desired number of cars, d) parking availability (at home and at the most visited destination points), and e) the overall car usefulness in a given area (driving conditions, availability/accessibility of public transportation, prospects for walking, biking, etc.).

3. CAR OWNERSHIP/AVAILABILITY MODELING: A "NEED" CONCEPT VS "PURCHASING ABILITY" CONCEPT

Generally, in order to explain the differences in family car ownership (or in individual availability of the private automobile) one can choose between two main approaches. The first one will try to explain the level of auto ownership/availability by the household/individual purchasing ability, represented by household income. The second approach will relate to the "objective" need for the private automobile of every family member living in a given geographic location (area type: urban versus suburban, distance from the center, availability/accessibility to public transportation, etc.)

The first approach was (and still is) a very popular one in the theory of car ownership. For example, the British RHTM [18] brings the following explanation of the level of family car ownership:

$$P_t(1+) = \frac{S(1+)}{1+e^{-a_1(t)}\, Y_t^{-b_1(t)}} \quad (1)$$

$$P_t(2+/1+) = \frac{S(2+/1+)}{1+e^{-a_2(t) - b_2(t)Y_t}} \quad (2)$$

where $P_t(1+)$ = proportion of households with income Y_t owning one or more cars

$P_t(2+/1+)$ = proportion of households with income Y_t who, given that they own one car, own 2 or more cars

$S(1+)$; $S(2+/1+)$ = saturation levels for $P_t(1+)$ and $P_t(2+/1+)$

$a_1(t)$, $b_1(t)$, $a_2(t)$, $b_2(t)$ = model coefficients

The change in the model's structure, by replacing Y_t by Y_t/P_t^c (where P_t^c is a car price index), did not change the general philosophy of the model, i.e. that the level of auto ownership primarily depends on the household's purchasing ability. Income was utilized as a primary explanatory variable in many other models developed in Europe and America, e.g. [4,1].

The alternative approach will refer to a "real need" for private transportation rather than to the affordability concept. One of the factors influencing the desired level of auto availability/ownership is the location of the residence. For example, inhabitants of far suburbs, with no access or limited access to public transportation must have a high level of auto availability/ownership for their "normal" everyday activities. On the other hand, inhabitants of dense central areas may often prefer to do without a car even if they can afford one (or more) because of parking problems, a convenient public transportation system,etc. Clearly, the long-range decisions (where to live), the medium-range ones (how many cars to possess), and the short-range ones (what mode of transportation to use) become a set of strongly interrelated choices for each family - as demonstrated by Ben Akiva and Lerman [3].

This interrelationship seems to be more easily explainable by the "need approach" rather than the "car affordability" concept. Some observations from American cities support this point. For example, the high-income area of East Mid-Manhattan, New York City (with monthly apartment rents of $1,000 - $2,000) should have an exceptionally high level of auto ownership. Because of parking problems at home and at most destination points, overall difficulty with driving in New York City, a good taxi system, and a relatively efficient subway/bus service,this level is instead relatively low.

On the other hand,in low-income sections in many large metropolitan areas in North America, often there is a relatively high level of auto ownership/availability. The cars used there are often second-hand and inexpensive. Since there are still relatively low gasoline prices in the U.S.A., often unsatisfactory levels of public transportation service, a high availability of inexpensive used cars and an extensive auto repair industry - this situation is understandable. Living in these areas requires at least a minimal level of auto ownership/availability.

This observation would suggest that the location land use variables (such as population density, accessibility to public transportation, etc.) should be more appropriate to explain differences in car ownership/availability than variables which refer to economic affordability (such as income or disposable income). However, it is clear that variables such as income, population density, distance from the city center, and public transit accessibility are often highly interrelated.

Therefore, it would be desirable to search for a primary variable which could best explain differences in auto availability of homogeneous groups of persons (and in family car ownership). This was the main aim of the empirical analysis performed for the Baltimore Metropolitan Area reported later in this paper.

4. THE INTERRELATIONSHIP BETWEEN THE CAR AVAILABILITY AND TRIP GENERATION MODELS

As mentioned before, the car availability model is closely connected with the person category trip generation model proposed for American cities [11]. Both models distinguish the following eight homogeneous person categories (Fig. 1).

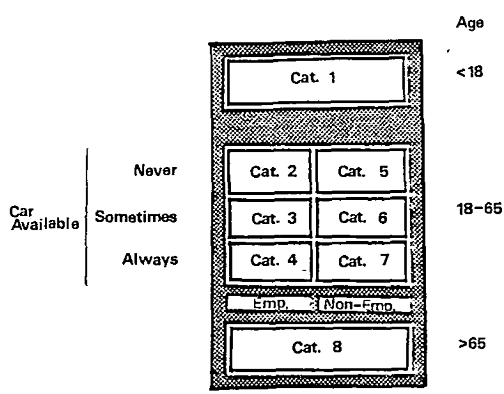

Fig. 1. Description of the eight person categories

The final description of person categories was a result of a multistage, multivariate analysis of factors influencing a person's travel behavior. As seen in Fig. 1, the most significant variables describing differences in travel behavior are: age, employment status, and auto availability. Age reflects obvious differences in demand for travel among: a) pre-employment, b) employment, and c) post-employment stages in everyone's life. Employment status reflects a basic distinction between employed and non-employed adults due to their demand for activities and travels. The former group participates in both obligatory and discretionary activities while the latter one participates only in discretionary outside-home activities. The third variable refers to the supply side: it describes the person's ability to fulfill his/her travel needs through "self-supplying" the services offered by the most convenient transportation mode: a car.

The aim of the person category car 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 percentage of category "i" in the population. This is the only remaining element needed to forecast category percentages $\alpha_1, \alpha_2, \ldots, \alpha_8$ for the trip generation model. Percentages of α_1 and α_8 are known from the demographic forecasts, while the split between the adult employed and non-employed $\frac{\alpha_2 + \alpha_3 + \alpha_4}{\alpha_5 + \alpha_6 + \alpha_7}$ is (or should be) known from the labor force/employment projection (which has to be made anyway for trip generation/distribution forecasting).

It should be noted that the level of auto availability is described separately for employed ($\alpha_2 : \alpha_3 : \alpha_4$) and non-employed ($\alpha_5 : \alpha_6 : \alpha_7$) adults because it can be reasonably expected that the need for a car is significantly differentiated between these two groups.

5. FACTORS INFLUENCING CAR AVAILABILITY LEVEL: EMPIRICAL FINDINGS FROM BALTIMORE, MARYLAND

5.1 Search for a primary explanatory variable

The Baltimore Disaggregate Data Set, gathered by the Federal Highway Administration in 1977, was used for testing the interrelationships between the level of family car ownership/individual car availability and such explanatory variables as: family income, population density, distance to the CBD and public transport accessibility. The Baltimore Metropolitan Area was split into three sub-areas: A - central, B - urban fringe, and C - suburbs.

A regular relationship was found between the car availability level (measured by proportions $\alpha_2 : \alpha_3 : \alpha_4$ for employed adults and $\alpha_5 : \alpha_6 : \alpha_7$ for non-employed adults) and the residential population density (see Fig. 2).

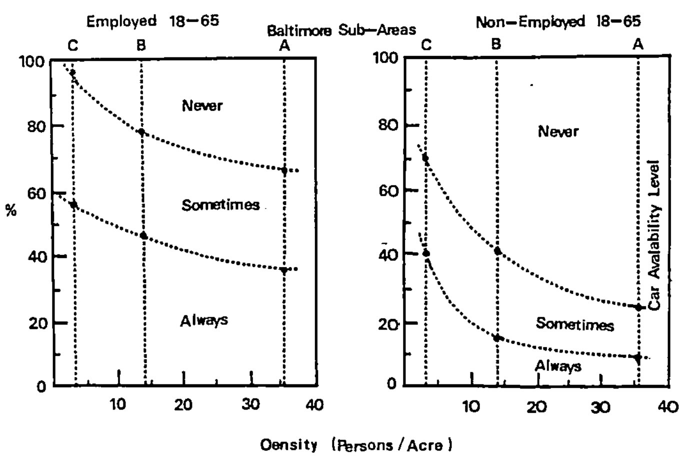

Fig. 2. The relationship between auto availability and population density

This relationship clearly shows that the need for car availability is much higher for employed persons than for non-employed ones. Thus, the overall employment level strongly influences the demand for cars. The level of auto availability is significantly higher in less dense areas than in the more dense ones. Both regularities agree with the expectation and theoretical discussion made earlier in this paper.

The relationships between income and car availability/ownership level were also investigated. They were found to be far less regular than the respective relationships between the residential density and car availability/ownership. These findings could support the idea that the desired level of auto availability/ownership depends primarily on the "real" need for private transportation of all family members rather than on the family's level of purchasing ability.

Two more variables were also tested as explanatory variables. They were: the "distance from the CBD" and "public transit accessibility." "Distance from the city center" reproduced, to some extent, the relationship between the population density and auto availability, but it was too simplistic in nature to be recommended for modeling purposes.

The relationship between "public transit accessibility" and "car availability" is always interesting since it touches on two questions of primary importance in transportation planning:

a) Is a high level of auto availability/ownership a result of an inadequate, unaccessible transit service?

b) Should we expect a significant reduction in the car availability/ownership level if an attractive, more accessible public transit system is offered.

However, the Baltimore study did not analyze the overall attractiveness of public transportation but rather focused only on the transit accessibility level, measured by the distance to the nearest stop. Therefore, any more general conclusions about the influence of the "public transit attractiveness" on the desired level of auto availability cannot yet be made.

The empirical findings from Baltimore did, indeed, confirm the expected relationship: "more accessible transit → lower overall level of auto availability." But the relationship was far "weaker" than the one found between auto availability and population density. For example, only 22% of employed persons for whom public transportation was accessible within 0.1 mile (160 m), had a "car never available," while 44% of them had a "car always available." It is worth mentioning that a relatively small influence of the transit level of service on the level of car ownership was earlier reported by Ben Akiva and Lerman [3], who analyzed this problem in much greater detail (using a data set from Washington, DC).

Since conventional public transportation is offered mostly in the high density areas, the variables "population density" and "public transit accessibility" are often strongly interrelated. The Baltimore findings, however, suggest that "population density" rather than "transit accessibility" should be seen as the primary variable in order to explain the desired level of auto availability for employed and non-employed persons. They also suggest that the overall success of conventional public transportation may strongly depend on the area's population density. Except for heavily loaded corridors leading to the main employment centers, conventional public transit may not be either effective or justifiable to serve the low density areas.

5.2 Interrelationship between the car availability level and mobility

The variable "car availability" was found to be one of the three significant variables in the person category trip generation model [11,12]. It can be expected that a higher level of auto availability should produce greater opportunity for traveling which should result in higher trip rates. On the other hand, a higher level of auto availability may also be caused by a higher need for a person's outside-home activities and, consequently, travels. This interrelationship was confirmed by data from Baltimore (Fig. 3).

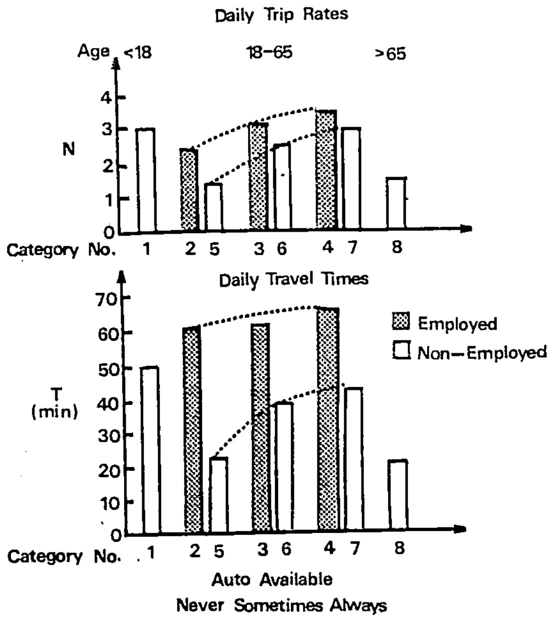

Fig. 3. Relationship between auto availability and mobility

It can be seen that the auto availability level affects both daily trip rates N and time spent traveling T. In both cases the mobility of non-employed persons is affected by the level of auto availability to a much higher degree than is the mobility of employed persons. This is because the level of auto availability influences primarily discretionary trips (shopping, personal business, social-recreational) rather than the obligatory ones (work, education).

It should be noted that a similar type of interrelationship has been reported in many studies performed at the household level. A higher family car ownership contributed significantly to a higher overall mobility of the household. In some cases, however, this relationship was not particularly regular since the overall mobility was primarily affected by the family size. The concept of the individual car availability and mobility makes their interrelationship a more direct and truly behavioral one, with a clear reference to the "actors" making travel choices.

5.3 Interrelationship between the car availability level and modal split

It can be logically expected that there should be a strong interrelationship between a person's auto availability level and his/her modal split. As before, in the case of mobility, there is an interplay of cause and effect. A higher level of auto availability is a direct reason for a higher percentage of car trips. On the other hand, a need for more frequent use of a car may be the reason for an increase in the car availability level in the first place, say, from a situation: "car sometimes available" to the situation: "car always available".

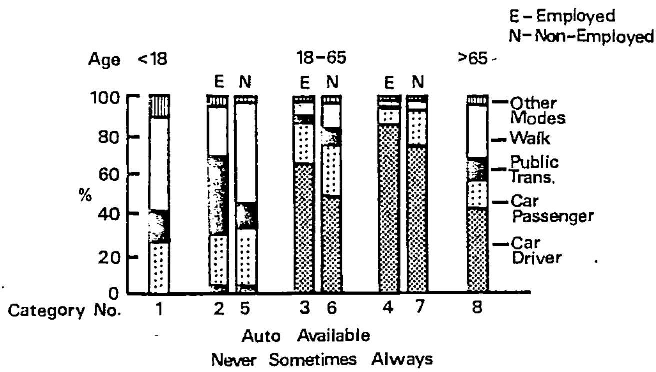

Fig. 4. Relationship between auto availability and modal split

Figure 4 shows that the interrelationship between the car availability level and the use of a car is a very direct and strong one. The convenience of having a car always available results in a clear modal preference: the use of public transit is only marginal, and driving a car covers 90% of the trips made by employed persons and more than 75% of the trips made by non-employed persons. Understandably, the situation "car never available" practically eliminates driving a car and opens a "chance" for alternative ways of traveling: public transportation, walking, biking etc.

These alternative modes of traveling may be neither feasible nor convenient in low density areas, which condition thus automatically imposes a certain level of auto availability.

6. THE USEFULNESS OF THE CONCEPT OF PERSONAL CAR AVAILABILITY

The concept of personal auto availability has several advantages which are discussed below. In many cases, the usefulness of this modeling concept is much more visible when the car availability model is seen as an inseparable part of the combination of models: car availability - trip generation - modal split.

6.1 Descriptive ability of the model

At the personal level, the model is able to capture the following commonly observed regularities in car availability/ownership:

a) Employed persons require a higher level for both auto availability and use than non-employed persons.

b) The level of auto availability is higher for persons of 18-65 than for either young people (<18) or older people (>65). The main reason for lower auto availability among younger persons is the lack of drivers licences; while for the elderly, it is health problems as well as lack of drivers licences.

The model is able to interpret the actual number of cars possessed by a family as a function of:

a) number of employed members, which increases both need for more cars and family's purchasing ability;

b) number of licenced drivers: another car may be needed if the competition for car use increases and "real" car availability decreases.

The model is able to illustrate the following differences between city subareas, represented by their population densities:

a) Locational differences: Less dense areas are, normally, not only further away from the center city but also from many other potential destinations (work places, banks, entertainment, etc.). Longer travel distances and more diverse destinations increase the need for a faster and more convenient mode of transportation: a car. Due to stronger spatial and temporal constraints, car sharing among family members can become more difficult.

b) Differences in wealth, income, life style, social status, race. All these characteristics are, normally, highly correlated with population density. The family's purchasing ability -- which should be represented by "cummulative wealth" rather than by "income" -- seems to have more influence on type of housing, specific neighborhood location and standard of living (which, among other factors, is represented by the quality of the car(s)), rather than on the number of cars possessed.

c) Public transit availability/accessibility level. Public transit service in the high-density areas can often appear as the most convenient transportation mode (more lines available, short walking and waiting time, majority of potential destination points accessible by transit etc.). In low density areas a car may still be needed since public transportation may not yet satisfy all transportation needs.

d) Driving and parking convenience. The advantage of private automobile use (convenience, flexibility, speed etc.) disappears in very dense areas where finding a parking space can be a serious problem, both at the residence and at many destinations. In the suburban areas, on the other hand, there is often enough room for parking even three cars per household.

The model is also able to explain the well-known difference in both population densities and auto availabilities between cities, e.g. between California cities vs. old, dense Pennsylvania cities.

6.2 Model dynamics: ability to illustrate major trends

At the personal level of analysis the model is able to capture the following, recently observed trends and their impacts on the level of auto ownership/availability:

a) increasing percentage of older persons in the population;
b) changes in percentage of children;
c) increasing percentage of employed women;
d) changes in unemployment rate;
e) increasing number of single parents families;
f) increasing number of single adults, etc.

All these elements are difficult to analyze using the concept of household car ownership.

At the household level the model reflects the relationships between the family's decision about where to live and the decision about how many cars to own to satisfy all family members' needs. These decisions depend on the "stage of life," family size, income, number of employed members and the social status of the family. This relationship makes the model dynamic and sensitive to changes in all characteristics listed above. For example, a young family will not move into the suburbs before they can afford to buy/rent a house/condominium and 1-2 cars.

The model can capture the following trends observed in several metropolitan areas, which influence the overall car availability/ownership level:

a) the exodus from the dense center to the less dense suburbs -- as a result of the social, environmental and economic factors -- and the increased need for automobiles as a result of this process;

b) the dynamics of the development of a given metropolitan area: increase in the total population, migrations, etc. (in most cases the new developments will be further away from the center, because the closer land is already used).

The model can also illustrate the following differences existing between cities:

a) growing cities versus declining cities

b) "sprawling" cities versus cities with a predominantly "dense" development

c) indirectly, also, between cities with different levels of public transportation service

6.3 Interdependence of travel choices and its reflection in modeling methodology

There is an interdependence between the long range decisions (where to live and where to work), medium range ones (how many cars to possess and what modes to use for obligatory activities), and short range ones (frequency, destination mode, time of day and route). This was convincingly presented in [3]. In that study, separate models were developed for seven different household groups defined by the households' "lifecycle" and the occupation of the primary worker in the household.

The concept of analyzing personal rather than household choices appears to be a valid alternative approach for describing this interrelationship. The set of choices always relates to a homogeneous group of persons. There is also a direct interdependence between the person's needs for activities and the travel itself (frequency, mode, time etc.). For example, an employed person, living in a far suburb, needs to have a car always available for his/her obligatory and discretionary activities, and, consequently utilizes this car extensively (see Fig. 2, 3 and 4).

Even if all the family members make identical choices (e.g., where to live), the personal level of data aggregation can conveniently assign the same choices to each family member. The reverse process, however, is more complicated. Although the long range decisions (where to live and how many cars to possess) are definable at the household level, the short range decisions (trip frequency, mode, time, route) are practically undefinable at the household level. As a rule, a family lives together but does not travel together.

Consequently, a sequence of sub-models built at the person level of data aggregation makes all modeling stages fully compatible, and all interrelationships more direct and easy to describe.

6.4 An interplay: transportation demand vs supply

The concept of auto availability creates new opportunities to observe and describe a dynamic interplay between transportation demand and supply. Auto availability level appears as an important element of transportation supply, more specifically, self-supply. For example, if a person lives in an area where public transportation (supply side) is not available and the feasibility of walking is limited (long distances), he/she will have to self-supply him-/herself with a private mode of transportation, preferably a car. The level of self-supply (measured by the car availability level) will depend on how "crucial" this need is (demand side). This need is defined by: a) a need for person's out of home activities (obligatory and discretionary), and b) area type (served by public transportation or not, etc.).

The demand and supply sides influence each other in a dynamic process. The supply of public transportation and the "self-supply" of private automobiles "compete" with each other to meet the travel demand. The system is in equilibrium if the demand is met by an adequate (for a given area type) combination of transit supply and auto self-supply. The system will be "undersupplied" if in a dense area an inadequate supply of public transportation cannot be complemented by an appropriate self-supply of cars because of the parking problem, etc. The immediate result will be a transportation substandard, which in the long run can result in either: a) the necessity of providing a new, appropriate service from the public transportation system, or b) an exodus from the city center into lower density areas where car self-supply is unrestricted.

The system may be "oversupplied" if conventional public transportation is provided in low density areas. Decrease in the auto availability level may be rather small ("car still needed"). The long run result may be either: a) a low-patronage transit operation (which can lead to the closing of the system); or b) a relatively successful "park and ride" scheme for commuters who travel to major employment centers.

6.5 Transportation and non-transportation policies.

The above discussion leads directly into transportation policy issues, particularly transit promoting policies. The author of this paper believes that many policy analysis issues can be addressed more directly at the person level of data aggregation. Car availability issues and other person-related characteristics make analysis better defined and more precise. For example, the following questions can be formulated: "How will a person category C_i modify his/her attitude/behavior if policy P_j is implemented?" "Will the person C_i change his/her residence place/auto availability level/trip frequency/modal split, etc.?" Many of these potential changes will be strongly interrelated with each other and that will make the analysis more consistent, precise and sensitive.

The problem of transportation policy analysis deserves much more attention and study. Some preliminary thoughts referring to American conditions can be offered as a result of empirical findings from Baltimore. First, certain transit-promoting policies have clear limitations. If a generally "right" policy is applied in the "wrong" place (e.g. low density area) its effectiveness may be doubtful. Second, the success of the transit promoting policy may often not be necessarily the result of the attractiveness of the transit service, but rather, the result of making cars unattractive or even totally non-usable in certain areas (parking restrictions, car-free zones etc.).

One more observation can be made about the potential impact of "non-transportation" policies on transportation choices. These policies seem to be of great importance to the transportation problem, although are often overlooked or underestimated. The interrelationship between car availability and population density indicates an existence of strong links between travel demand and land use characteristics (which is also very important at the trip generation and distribution stages). Location of new developments, types of housing (e.g. houses versus apartments, etc.) strongly depend on the local land use policy and may be significantly influenced by such factors as: national and local economy (interest rates, credits etc.), tax policy, etc.

This analysis shows that the forecasting of zonal population — "standard" information for trip generation/distribution models -- also affects car availability, and the modal split stage of the travel demand forecast. Therefore, the forecast of the population distribution should be made very carefully.

It should be noted that the housing decisions may not be very strongly affected by the area's accessibility to public transportation [5] or "closeness to work" [19]. This second study shows that this criterion of the choice of housing place was ranked much below such factors as "safe neighborhood", "closeness to school", "closeness to a park", etc. [19].

6.6 Concept of saturation levels

Saturation levels are often utilized in transportation analysis and modeling concepts. For example, family car ownership saturation levels S(1+) and S(2+/1+) are utilized in the British RHMT model, [18] cited in this paper.

The problem with the saturation description is that it is not an "absolute" level. Car ownership saturation levels have to be constantly updated and are different for, say, England and U.S.A., urban and rural areas, etc.

The car availability concept conveniently utilizes an absolute saturation level: "car always available". Even if the number of cars N_c is larger than number of licenced drivers N_d in the family, the transportation effect is the same as in the case $N_d = N_c$ (one can drive only one car at the same time).

Furthermore, the group of travelers with "car always available" should have the convenience of using the car only as often as needed. Therefore, both trip rates and the percentage of car trips for this category could also refer to "saturation levels" since this should be the highest level of transportation self-supply and convenience (if the use of car is not restricted, etc.). Figures 3 and 4 seem to confirm this.

6.7 Advantages at the application stage

The car availability model is only an initial stage of the sequence of behavioral models which also include both trip generation and modal split submodels. Although very simple, the models seem to capture a lot of major factors influencing travel behavior, interdependences, and policy issues:

both transportation and "non-transportation" ones.

At any stage these models require limited amounts of "routine" data. For the car availability model, for example, there is no need to predict the "average zonal income," a variable commonly used in many car ownership models. This information may be more difficult to predict than the zonal car ownership itself (e.g., effect of inflation, etc.).

The forecasting ability of the income-based car ownership models can also be questionable. By observing different cities in the world we can see an increase in auto ownership which seems to be faster than what the increase in the average family's income would suggest. The "density concept" seems to explain this phenomenon better since most new urban developments are being made in low density areas, which require relatively high level of auto availability.

7. CONCLUSIONS AND RECOMMENDATIONS. A NEED FOR FUTURE RESEARCH

In conclusion, the concept of car availability can be treated as a valid alternative to the car ownership concept. The car availability model should be considered together with the person category trip generation model and a "personally oriented" modal split model. Together, these have the following potentials:

a) they are behaviorally more sound since the analysis unit is always identical with the decision making one: "a homogeneous group of persons";

b) they can more easily describe and interpret several relationships such as "transportation ↔ land use", "demand ↔ supply", etc.;

c) they can be a more precise tool for transportation policy analysis;

d) they have several advantages in practical application (small data requirements, simple concept, etc.);

e) they do not have several shortcomings present in household-based approaches (problems with family structure description, difficulty with stratification, problems with zonal income predictions, etc.).

The future research should concentrate on the following problems:

a) The consistency of the basic relationships found valid for Baltimore (e.g. car availability as a function of population density) should be tested by data sets from other metropolitan areas. If successful, a more formal description of this relationship can be attempted.

b) A uniform methodology should be developed to assure a full comparability of the term "population density". As the "total density" may be often a vague characteristic, strongly affected by "empty spaces" (vacant land, lakes, parks, etc.), the recommended descriptions could be either "net density" (persons per acre of developed land) or "residential density" (persons per acre of residential area). More studies about the preferred form are needed.

c) The model is primarily developed to describe the level of auto availability for employed and non-employed persons - the information directly needed for trip generation model. However, some other potential uses could also include an estimation of: 1) total number of cars; 2) total number of cars being used; and 3) total number of cars being used in the system at a given time, e.g. during the peak hour (by utilizing -- among other information -- the hourly trip histograms of homogeneous group of persons [10]).

d) In the long run, an ultimate objective should be a set of behavioral models that consistently utilizes a homogeneous group of persons as an analysis unit. One of them is the car availability model. This should produce a dynamic, operational model for the travel demand ↔ land use interactions which will be useful for forecasts and policy analysis.

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