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SOCIAL AND PSYCHOLOGICAL FACTORS IN URBAN TRANSPORT MODE CHOICE

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RESEARCH REPORT

NORTHWESTERN UNIVERSITY EVANSTON • ILLINOIS

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INTRODUCTION

Over the past twenty years, marked shifts in the utilization of urban transport technology have occurred. Except for trips to the central business district in the five to ten largest cities, the private automobile carries 80-90% of all work trip travel. The facts of these modal shifts are well-documented and survival of mass transit systems in almost every city have been threatened because of their inability to compete with the automobile. A basic question arises as to why this shift in modal preference has occurred. On the basis of traditional economics, such shifts were unpredictable, if not incomprehensible. Certainly the cost to own, operate, and park an automobile is far higher than the cost of using mass transit. Part of the answer seemed to be that travel time was a cost and the automobile generally had a significant advantage over mass transit. In effect, the logic of the argument ran that time was used as a basis of choice along with costs. Hence, early models of modal choice used diversion curves based upon travel time ratios.

All the planning models developed to predict modal split in urban transport have largely been based upon such aggregate and descriptive assumptions. The results have been only marginally satisfactory (1). As a consequence, it has become increasingly clear that the traditional assumptions underlying people's choice of alternative modes of urban transportation are not sufficient. Modal choice must involve a more complex process, essentially psychological in nature. Hence the only way to develop a truly predictive model of transport usage was to start with individual choice behavior.

This has led, in the past decade, to a new class of research which has developed along two parallel paths. One has been called disaggregate or behavioral models of mode choice. The other has involved the analysis of user preferences for urban transportation. The first involves the identification of objective or subjective variables that may be combined in a rational, analytic framework to describe the choice process and to predict the probability of modal choice. The second involves the determination of the subjective factors underlying transport preferences and developing rational scales of importance of these factors.

Although these two lines of research have proceeded quite independently, it is clear that they both ultimately converge. Present disaggregate models of mode choice use surrogate measures of subjective variables such as travel time and travel costs. User preference studies in defining and scaling the subjective measures underlying choice ought to provide the appropriate dimensions and units to be used in disaggregate mode choice models. It is the purpose of this paper to review the research in both these areas and to indicate how they can provide another dimension for urban transport planning and system design.

BEHAVIORAL MODELS OF MODE CHOICE

Research into the determinants of mode choice has, in recent years, resulted in a fundamental change in the approach to the modeling of travel behavior. These models are commonly referred to as disaggregate, stochastic, or behavioral models. They are disaggregate in the sense that the operational unit is not a geographic zone, but the individual traveler; they are stochastic in the sense that they predict the probability that the individual traveler will choose a given mode of transport; and they are behavioral in the sense that they are based upon hypotheses about the behavior of the individual.[1]

The aim in this paper is to review the behavioral hypotheses which have been used as a basis for the new generation of models, to examine their limitations and to discuss potential developments.

Behavioral Hypotheses

As an example of a behavioral hypothesis, consider the following. It may be hypothesized that an individual will base his decision to buy or not buy a new car on the following variables: the age of his present car, his income, and the level of his savings. Thus the model of his choice behavior would take the following form:

$$\text{Probability of buying car} = f \left\{ \begin{array}{l} \text{Age of car} \\ \text{Income} \\ \text{Level of Savings} \end{array} \right\}$$

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[1]For a complete treatment of the properties of disaggregate, stochastic, behavioral models, see Stopher, P. R. and Lisco, T. E.: "Modeling Travel Demand: A Disaggregate Behavioral Approach--Issues and Implications." Proceedings of the Transportation Research Forum, 1970, pp. 195-214.

Note that the functional form of the relationship has not been and, at this stage, need not be specified; nor has the relative importance of the three explanatory variables been considered. The important point to note is that the variables are selected, not because they are important policy variables nor because data on them happens to be available, but because they are, it is argued, the variables which the potential buyer considers.

Applying this logic to transport mode choice, the dependent variable becomes the probability that an individual traveler will choose a given mode of transport. The independent variables become those which are hypothesized by the analyst to influence that choice. The variables used by the more important analysts are detailed in Table 2.1 and, in general, may be described in three categories.

System Characteristics

The most generally used hypothesis argues that the individual traveler makes mode choice decisions on the basis of a comparison of the characteristics of the alternative modes and most models have included variables which reflect this comparison. The most frequently selected characteristics have been the times and costs of the journey by each mode, although the nature of the comparison has varied, some analysts preferring a difference formulation, others preferring a ratio form. System characteristic variables have been limited to times and costs for three major reasons. First, they are directly perceivable by the traveler who has to spend both time and money to undertake a

Table 2.1: Variables Used in Previous Studies

Variable	Lave	Lisco	Quarmby	Stopher	Thomas	Warner
Time	*	*	*	*	*	*
Cost	*	*	*	*	*	*
Comfort/Convenience	*				*	
Distance	@				*	*
Journey Purpose	n.a.	n.a.	n.a.	n.a.	n.a.	#
Journey Frequency						
Age/Sex	*	*			sex only	*
Demand for / Availability of } Car		*	*			*
Car Ownership	n.a.	n.a.			n.a.	n.a.
Size of Traveling Party						
Income	@	*			*	*
Other			*		*	

* indicates used as a variable

# indicates used to stratify sample

@ indicates used indirectly

journey, and it can thus be argued convincingly that they should form the basis of a model of travel choice behavior. Second, they are important policy variables which can be manipulated exogenously to change the mode split. Third, they are readily measurable.

Other system characteristics such as safety, comfort, and convenience have been considered and rejected either because they added nothing to the explanatory power of the model, or because they could not be measured. Quarmby seems to sum up the situation:

Apart from times and costs, "there are no other *quantifiable*[1] variables which express the characteristics of travel by each mode. Comfort, safety, and reliability may indeed be important factors. . . , but they cannot easily be quantified, and are more open to argument about differential perception than are any of the previous factors." (2)

At this point, it is sufficient to note that the early disaggregate modelers regarded such factors as unquantifiable; later in this paper we shall consider the validity of this conclusion.

User Characteristics

Many of the early modelers did recognize that the characteristics of the user and of the household to which he (or she) belongs may exert a strong influence on mode choice, the hypothesis being that travelers of different ages or sexes may react differently to the stimulus of times and costs. Some variables such as "car availability" have been

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[1]Our italics.

included on the grounds that they may also modify the reaction to the more basic variable and thus have a significant effect on the choice of mode.

The use of an income variable has been varied. In some models, it has been included directly as a dummy variable; some analysts have advocated the stratification of the sample, so that models may be built for each income group, yet others have argued that the effect of income will be combined with that of time or cost in the sense that the relative importances of time and cost will vary with income. Thus, composite variables, such as difference in time multiplied by income, have been constructed.

It is, by and large, true to say that models using only system and user characteristics of the type and in the manner outlined above were considered to be satisfactory by the analysts who constructed them, and it is not difficult to understand why this was so. The models were judged in terms of their ability to "explain" the phenomenon under consideration and of their capabilities for prediction. The explanatory powers of the early models were found to be high in the sense that they performed well under the statistical tests which were applied to them. Moreover, tests of prediction in which the models required to produce the observed mode split were very satisfactory. Quarmby's model was able to reproduce the existing mode split to an accuracy of within 0.3%; Stopher's model correctly predicted 74% of the observed car users and, when applied to Quarmby's data, correctly predicted 98% of the car users.

When the models performed so well, with a limited number of variables which were both hypothesized to be the prime causal factors and readily quantifiable, it is not surprising that the investigation of further variables was limited. Moreover, a model of mode choice is a planning tool and, thus, the restriction of variables to those which the planner can both measure, predict, and manipulate is a useful one.

At this point, however, it is appropriate to interject a note of caution. All the early models were built using data on commuting journeys. This was done partly because the accute peaking problems were largely the result of commuter traffic, and partly because the sample frame of commuters is readily accessible, either in a given workplace or in a given residential area. However, a commuter is a peculiar traveler in the sense that the journey to work is undertaken both more frequently and more regularly than any other journey. This feature of the commuting trip led to a suspicion that the results of modeling commuters may not be generalizable to other types of travelers. With this in mind, the British Ministry of Transport[1] commissioned a series of studies to investigate non-commuting trips. One study was to examine inter-city social and recreational travel; another intra-urban travel to recreational facilities; another shopping trips; and another to holiday resorts. As these are current studies, little can be said about their findings, but preliminary results indicate that variables of system characteristics do not have good explanatory power. For ex-

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[1]Now part of the Department of the Environment

ample, in the inter-city social and recreational travel study,[1] differences in times and costs perform poorly, while variables which perform well can be interpreted as variables reflecting the inconvenience of the rejected mode, such as walking and waiting times and the cost of access to the railway station. It seems likely that the system characteristics perform well in models of the commuting trip because the regularity and frequency with which the journey to work is undertaken means that the traveler is quite familiar with the times and costs of the modal alternatives. For a social or recreational journey, however, the traveler may be less familiar with the characteristics of the system and may thus base his mode choice decisions on other factors, such as comfort or convenience, or on his attitudes to the alternative modes of transport.

It may be argued, therefore, that a necessary prerequisite of modeling the non-commuting journey is a method of including in the model variables which reflect factors which were previously thought to be unquantifiable. This paper will consider two methods of achieving this end.

Proxy Variables

The first method to be considered is the use of proxy variables, i.e., variables which are not direct quantifications of the desired variables, but which reflect the effects of the desired variables. In other words, a quantifiable variable is found which is closely correlated

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[1]The Edinburgh-Glasgow Area Modal Split Study

with the unmeasurable variable. For example, it may be hypothesized that the state of cleanliness of public transport is a factor which influences a traveler's choice of mode, so that the dirtier the vehicle, the lower will be the probability that he will choose that mode. Since cleanliness is largely subjective, it is difficult to measure it directly, but a proxy variable can be derived by measuring the frequency with which the vehicle is cleaned. The assumption is that the state of cleanliness of the vehicle is closely correlated with the frequency of the cleaning operation. It will be clear that the proxy variable is not a perfect measure of the desired variable but, if the proxy is well chosen, it can be a close approximation.

A proxy variable has been used successfully in the Edinburgh-Glasgow Area Modal Split Study. It was hypothesized that the inconvenience of the railway alternative, in the sense that many travelers had to take a bus to and/or from the railway station, involving additional walks and waits, was an important factor influencing choice of mode. Thus a proxy variable for this inconvenience was constructed. The concept of a "journey unit" was evolved such that each stage of the journey, whether walking to a bus stop, waiting for a train, or riding a vehicle, was allocated one "journey unit." The result was that a suburb trip involving two buses and the train had a high "journey unit" score, whereas a car journey, by elimating waits and bus rides, achieved a low score. Moreover, the proxy variable was sufficiently flexible to differentiate between people who took one or two buses and those who took taxis or were driven to or from the station, thus eliminating some walks or waits.

This variable performed extremely well, being highly significant (in the statistical sense) in every model in which it appeared. It may be argued that it should take a different form. For example, the walks could be allocated two units on the grounds that walking is more inconvenient than riding in a vehicle, or waits could be allocated three units on the grounds that the lack of progress involved in a wait is more frustrating and inconvenient than either walking or riding. This is undoubtedly true, but the main conclusion is unassailable: that proxy variables can be used successfully to reflect the effects of "unquantifiable" variables.

Social Scaling of Attitudes

The use of proxy variables is subject, however, to certain limitations. Simply to construct a measure of comfort or convenience may not be enough since the effect of such factors on the traveler may be dependent upon his attitudes to these factors. If the traveler is unconcerned about safety, it is meaningless to utilize a measure of safety. The measurement of attitudes and the uses of social scaling techniques in the derivation of variables will now be considered.

USER PREFERENCES AND ATTITUDES FOR URBAN TRANSPORT

The results of the research on behavioral models of mode choice clearly indicate that the variables currently employed are rather loose indicants, rather than basic measures of the behavioral process. This leads rather naturally to a consideration of the scaling of the variables in subjective terms. The problem may be stated rather simply: How must units of cost and time as used in these models be measured such that they correspond to the ones humans subjectively use in their choice process? It would be nice if people valued time in fixed units such as minutes, but it is well known from various other areas of psychophysics that the relation between objective measures and subjective responses are generally nonlinear. This is not a new problem in psychology. Some kind of transformation is usually required to determine equal sensation units relative to any physical measure. This appears to be true for modal choice variables.

In the modal choice situation, it is clear that the individual is carrying out a series of simple trade-offs, usually among two alternatives. For the work trip, he would appear to be evaluating each mode on the basis of his perception of the characteristics of each relative to his own situation. A primary question then is what attributes of alternative transport systems does a traveler consider of primary importance? This question has been examined in two different ways. One has been to identify the abstract qualities of transportation of significance to users. In a series of studies done by Nash & Hille (3), a rating scale method was used. A large number of qualitative statements concerning travel were developed. A selected sample of residents of Baltimore and Philadelphia were asked to rate their importance on a seven point scale. The study was done for both work and non-work trip travel. On the assumption of a true interval scale, the scores were intercorrelated and factor analyzed. The factors that emerged as accounting for the largest proportion of the variance were: likelihood of repairs or breakdown, reliability of travel, speed, cost, independence, traffic congestion, age of vehicle, and capacity to carry family and friends. The attributes are clearly a mixture of physical and operational characteristics, as well as psychological and social elements.

A more recent study has been completed at Northwestern in which a categorical rating scale was developed. Here a set of 75 attributes of urban transport systems were identified and the importance of each was rated on a seven point scale by 200 respondents. Each item was scaled on the basis of Thurstone's law of comparative judgement. As may be recalled, the law assumes that the attitude continuum is distributed according to a normal law, hence intervals measured in normal deviates are equal units of psychological value. Operationally then, transformation of the proportions of response in each category on the rating scale to average values of normal deviates produces a true interval scale.

In this study, this procedure was followed and the assumption of normality for each item was tested. The interval scales thus derived were intercorrelated and factor analyzed. Six factors emerged that accounted for approximately half the total variance. These were:

1. Concern for social interaction or the way one is treated as a person while using the system.

2. Concern for the predictability of the outcome of using the system or the desire for minimum uncertainty or risk in achieving one's travel objective.

3. Individualization of the system or the desire to have a system adapted to and available for individual travel needs.

4. Desire for physical comfort in traveling.

5. Desire for feeling secure, safe, and independent when traveling.

6. Desire for the system to be accessible to the individual at his convenience.

What is important to people then, as a basis for making choices among transport alternatives, are the characteristics of each relative to their perceived merit on these dimensions. It would lead us to conclude that an individual valuation of transport alternatives are ordered on the basis of the system's adaptability to one's personal time and space demands for mobility and its capacity to protect the physical and psychological individuality of the user. These results, along with those of Nash & Hille, suggest quite clearly that modal choice decisions are increasingly based upon the differences in individualization of the systems as subjectively perceived by urban travelers. Combined with the physical limitations of mass transit systems meeting diffused O&D requirements, these results provide a means for explaining the continuing shift to automobiles in metropolitan regions. Unfortunately, such studies have not been done early enough to determine the magnitude of the shift in user values that has occurred over the past twenty years. Hence there is no way to predict or relate modal shift to changes in subjective values on the significant attributes.

A second class of study involves the measurement of attitudes toward the alternative modes. One would predict that behavior, in this case mode choice, should be correlated with attitudes toward the alternatives. One such study was that of Michaels (4) in which the method of summated ratings was used to measure attitudes toward two alternative highways between which drivers could choose. It was found that drivers did have stable attitudes toward two types of highways and that there was a significant correlation between attitude score and route choice (vs mode choice). Thus the attitude scale provided a measure of user preference for facilities and did predict choice behavior.

A more recent study also used the method of summated ratings to measure attitudes toward mass transit. Using standard techniques (Edwards, "Techniques of Attitude Measurement"), fifty-one items were developed and pretested and 34 were found to be discriminating. As is usually the case, those that were not discriminating were items that related to objective information or public policy issues. The final battery of twenty items was given to 103 residents of Chicago. Each item was rated on a seven point scale of agreement or disagreement.

The results indicated that the respondents did hold stable feelings about public transport. In addition, it was found that the attitudes were independent of frequency of travel but significantly related to age and employment status. Employed persons have less favorable attitudes toward transit than do unemployed, and younger people have less favorable attitudes than older people. Further, there was a significant decrease in favorable attitudes as a function of income. The more wealthy a person was, the more negative was his attitude toward transit. Since there is a high correlation between income and auto availability, this result indicates a shift in modal preference toward the automobile and would suggest that auto will more likely be used for urban travel as income rises. This is consistent with the findings in most urban transport studies. It is interesting also to note that in some recent work on behavioral mode split models, it was found that the estimated value of time to users decreased with their income. In essence, this result would indicate that time is used as an intervening variable and that as income rises, the qualitative aspects of the available modes become more important as determinants of choice. These aspects are, of course, more directly measured by attitudes than by objective variables such as time.

Another pilot study on modal preference was also carried out using the method of pair comparison. Here, a group of 25 respondents were given nine alternative modes of travel in all combinations by pairs. The scaling was done twice under two different sets of instructions. One was that the respondent was to make his choice on the basis of a work trip for which the cost of travel was the same regardless of mode used. In effect, this scaling was done with no economic constraints on choice. The alternatives were auto, bus, elevated rail transit, commuter railroad, bicycle, helicopter, subway, taxi, and walk. The results showed a clear ordering of preference that was statistically reliable. Helicopter, auto, and taxi were the three most preferred technologies and were closely grouped together. The distance between these and the mass transit modes which also grouped together was large and significant. The third group was bicycle and walk, which were considerably less preferred than mass transit modes.

In the second scaling, the instructions were modified to have the respondents consider the realities of costs and time in their judgement. This led to a significant reordering of preference. Rapid transit was the most preferred mode and was at a significantly greater distance from the automobile and bus which were grouped in the middle of the scale. The least preferred modes were those perceived to be most costly, i.e., taxi and helicopter. These results indicate two important conclusions. One is the rationality of preference under constraint where people will make subjective trade-offs in accordance with their economic condition. Second is that there is a latent preference structure which is distorted by economic and technological realities. But the latent preference structure reflects aspirations or desires. One would expect that people will try to realize their desired preferences and, as income rises or the costs of technology decrease, they will move in the direction of choice consistent with their latent preference structure. This hypothesis would seem to be borne out by the studies on attitudes previously discussed. Finally, the uncovering of a latent preference structure suggests a means of predicting changes in transport choice behavior under conditions of increasing income or implementation of new technology. In the latter case, if the qualitative attributes of such new technology are known, its subjective attractiveness relative to existing alternatives should be determinate. Its attractiveness can be placed on the same scale with the others and thus provide an indication of its potential utilization. This can provide a far better basis for investment decisions in new systems development than current methods of decision making in civilian technological innovation.

SUMMARY AND CONCLUSIONS

There has been, over the past few years, an increasing emphasis in transport planning and analysis on the individual as the unit of analysis for predicting transport requirements. The assumption underlying this research has been that travel reflects the end result of a choice process by individuals. The most obvious observable behavior reflecting this process is the choice of mode of transportation for the work trip. A series of models of this choice process have been developed which attempt to predict the probability that the individual will choose between automobile and transit. These models combine both operational functions of the two alternative systems and certain demographic and socioeconomic descriptors of the users.

These models are quite successful in predicting mode choice in work trip travel. Even though all the variables used are objective observables rather than subjective ones, they consistently predict modal split. More importantly, however, these models are the first ones in transport planning to make the individual traveler the basic unit of measurement. Consequently, they have inherent in them the capacity to synthesize trip generation directly without the unjustifiable assumptions of uniformity of zones that are the basis of most current planning models.

In addition to the work on behavioral models of mode choice, another line of research has proceeded in which traditional methods of psychometric measurement have been applied to urban transport. These have involved a variety of attitudinal and preference studies. Their main thrust has been to scale the attitudes toward alternative modes and to scale the attributes of transport systems of importance to the users. The results are fairly consistent in indicating that for urban transportation there is a consistent and significantly more favorable attitude toward automobiles than mass transit. These attitudes and preferences are conditioned by the economic status of the individual. The higher the income, the greater is the distance between transit and automobile on the attitude continuum. Conversely, although people appear to have an ideal preference for transport technology, this is markedly modified by their economic situation with their actual choice being highly economically determined.

In addition to modal preference studies, research has proceeded in the determination of the characteristics of transport systems that indicate that performance reliability, adaptability to individual requirements, costs, and comfort are the primary attributes of importance to users.

Both the lines of research in modal choice behavior and attitudinal measurement indicate that there are stable elements in and rational processes underlying individual behavior relative to transportation. People do evaluate alternative transport technology relative to their subjective expectations and experiences. These evaluations involve sealing the characteristics on psychological continua which appear to follow traditional psychometric scaling laws. The research in both areas indicate that the subjective scales of the variables of importance are non-linearly related to objective measures of these same variables. Furthermore, this research provides evidence that in the choice process, users are able and do make a series of trade-offs based upon their physical, social, and economic situation. Both of these operations appear to be the underlying determinants of modal choice in urban areas.

Finally, it is becoming increasingly clear that to construct a general behavioral model of mode choice, the subjective scales of travel times, costs, and comfort must replace the objective measures currently being used. The psychological scaling methods offer a means for accomplishing this transformation.

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