TRANSPORTATION CENTER

Consumer Oriented Transportation Service Planning
Report 5
Models of Consumer Travel Choice Behavior:
Technical Report

WESTERN UNIVERSITY EVANSTON • ILLINOIS

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By

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CONSUMER-ORIENTED TRANSPORTATION SERVICE GROUP

The COTS group is an interdisciplinary research team associated with the Transportation Center at Northwestern University. Its goals are the advancement and application of consumer behavior, market research, and transportation demand analysis to provide transportation managers, regulators, and planners with techniques to understand and predict consumer response to transportation strategies.

The COTS group consists of faculty associates and graduate assistants involved in a series of funded and unfunded research investigating consumer response to transportation and communications strategies. Although the administrative structure varies by project, research responsibility is shared jointly by the faculty associates. The administrative structure for this project is Frank S. Koppelman and Alice M. Tybout, joint principal investigators, and John R. Hauser, faculty associate.

ACKNOWLEDGEMENTS

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Supplemental support and cooperation was provided by the City of Evanston under the direction of Edward A. Martin, City Manager, and Dennis Dawson, Assistant to the City Manager.

REPORT SERIES

This is Report 5 in the series Consumer-Oriented Transportation Service Planning which describes the development of models of consumer response to local transportation services. The reports in the series are:

1. Consumer Analysis and Strategies, Final Report
2. Consumer Views of Transportation Service in Evanston: A Report Based on Focus Group Interviews
3. The Development and Implementation of a Questionnaire to Determine Consumer Wants and Needs
    A. Final Surveys and Developmental Surveys, Appendix to Report 3
4. Preliminary Analysis of the Survey
5. Models of Consumer Travel Choice Behavior

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MODELS OF CONSUMER TRAVEL CHOICE BEHAVIOR

1. INTRODUCTION

Transportation planners require an improved understanding of consumer travel choice behavior in order to plan and design transportation services that better meet consumer needs. The primary goal of the consumer oriented transportation service planning research is to draw upon state-of-the-art knowledge in travel demand forecasting, consumer behavior theory and marketing research techniques, to develop practical methods to assist transportation planners to understand and respond to consumer needs and desires for travel services. The integration of the knowledge from these disciplines leads to methods of consumer oriented transportation service planning (COTSP). The COTSP research provides transportation planners and managers with important diagnostic information about travel behavior. This information can be used as a guide to formulate strategies that can influence consumers' travel behavior.

The research reported here, and in other reports in this series, was conducted in Evanston, Illinois, in cooperation with the City Manager's Office. Evanston is a northern suburb adjacent to the city of Chicago, with a population of approximately 80,000. The Evanston public transit system includes: a rapid transit line which serves Evanston and connects with the Chicago rapid transit system, a commuter railroad which runs through Evanston to downtown Chicago, extensive local bus services, and bus service to neighboring suburbs.

The transit problems of Evanston are typical of many suburban cities. Significant excess capacity exists on the local public transit system, especially during off-peak hours and an annual subsidy of $300,000 is required to maintain the transit system. The City of Evanston provides a good context for this research because of the range of services available and its similarity to numerous other suburban communities in the United States.

The consumer oriented transportation service planning research is described in a series of five reports. The first report in the series provides an overview of the research and describes the application of the consumer oriented approach to the development and evaluation of alternative strategies to improve public transportation services. The second report describes the use of focus groups to identify the desires and needs for local public transportation services in Evanston. Focus group interviews provide useful insight into the consumer's travel choice decision process. The focus group results provided qualitative input into the design of consumer surveys. The third report describes the development, testing, refinement, and implementation of consumer surveys to measure transportation perceptions, opinions, attribute importances, knowledge, availability, and behavior. Report 4 presents a preliminary analysis of data collected for trips to downtown Evanston. It evaluates the representativeness of the respondents and the degree of completion of returned surveys. A reduced set of data is identified for more detailed analysis.

This report, the fifth in the series, provides the details of the analyses of data describing travel to downtown Evanston. These analyses demonstrate the effectiveness of the consumer oriented approach in representing the travel behavior decision process.

The results of the COTSP research can be summarized as follows:

- models of mode preference and choice can be estimated on the basis of perceptual and feelings measures,
- factors which describe general service, safety, convenience/accessibility, and psychological comfort are important in influencing mode preferences,
- mode-related feelings are important in influencing mode preferences,
- the proposed sequential preference - choice structure compares satisfactorily to the more commonly used revealed preference choice models,
- automobile availability is an important determinant of travel choice behavior,
- market segments based on common demographic characteristics do not appear to significantly improve preference analysis or prediction but classification by age and education levels improves choice analysis and prediction.

The principal objectives of this report are to:

(i) Fully document the development of the perception, preference and choice models described in the first report in this series, and

(ii) provide technical details for the various procedures (factor analysis, logit models), and tests (modified Friedman T-test, segmentation test, information measure) employed in this research.

Organization of the Report

This report is organized in sections which describe (2) theory and models, (3) perception of modes, (4) feelings about modes, (5) confirmation of the theoretical model, (6) preferences for travel modes, (7) choice of travel mode, (8) market segmentation, and (9) summary.

2. THEORY AND MODELS OF MODE CHOICE BEHAVIOR

Theoretical Model Structure

The disaggregate travel demand models, developed in the early 1970's and widely used today, concentrate on observed system and demographic characteristics. As a result, they do not provide an understanding of the behavioral process underlying travel decision making, and therefore, cannot reflect the wide range of strategies that can be designed to influence consumer travel behavior.

In recent years, several transportation researchers have demonstrated the importance of including perceptual variables, in addition to system characteristics such as travel-time and cost, in travel mode choice models (Nicolaidis, 1975; Prashker, 1977; Spear, 1974). However, it is necessary to draw on models from psychology, consumer behavior; and marketing in order to develop an understanding of the relationship between system characteristics, perceptions, feelings, preference and choice. Report No. 1 in this series proposes a model of these inter-relationships, reproduced here as Figure 2-1. The components of this model, and the practical implications, are described in Report No. 1. The model provides a basis for developing a broad range of strategies, in addition to traditional service modification strategies, to influence consumer travel choice decisions.

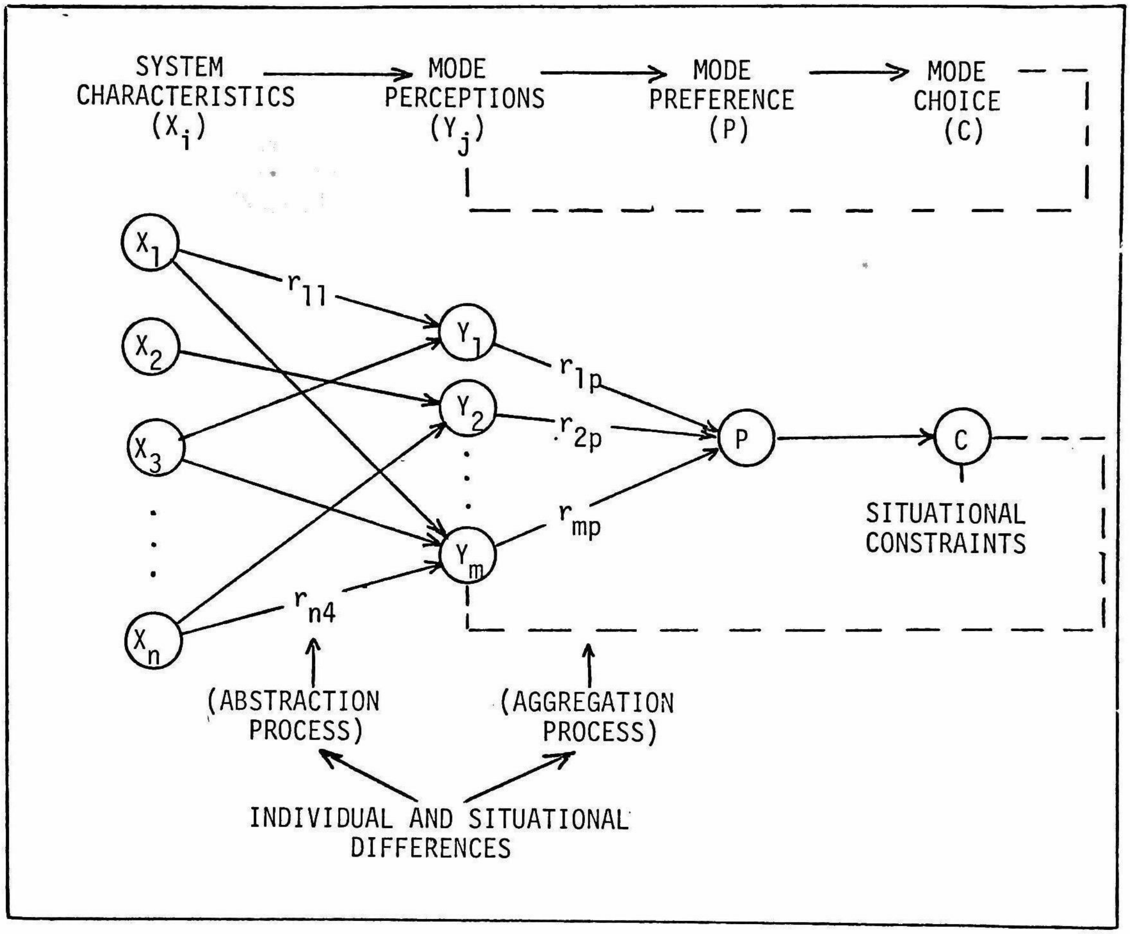

FIGURE 2-1: A MODEL OF CONSUMER TRANSPORTATION BEHAVIOR

(Reproduced from: COTSP - Report 1)

Application of Theoretical Structure

Consumers are often presented with the need to choose one of a set of available alternatives. This choice situation naturally arises in the selection of a residence; mode of travel to work; destination for a shopping, recreational, or other trip; etc. The focus of this tudy is to analyze and describe the consumer choice process for choice of mode for trips to a suburban central business area. Enhanced understanding of this process will provide city planners and public transportation operators with a basis for designing and evaluating strategies to influence travel mode choice behavior.

The major objective of the COTSP research is to examine the relationships between consumers' mode perceptions, feelings, preference, and choice as a basis for developing strategies to modify consumers' choice. We also examine the adequacy of the model in determining the relative strengths of the relationships between reported system characteristics, perceptions, preference, choice. Future research is planned to deal with the direct measurement of the relationships between physical characteristics and perceptions.

Report No. 1 in this series suggests that the conceptual model (Figure 2-1) be operationalized by developing component models of perceptions, feelings, preference and choice, as illustrated in Figure 2-2. Sections 3 and 4 of this report describe in detail the operationalization of the perceptions and feelings measures, using factor analysis. The factor analyses yield factor scores (see Appendix A) for each perception and feelings dimension.

These factor scores are used as explanatory variables in a preference model which relates a weighted sum of the perceptions and feelings to each

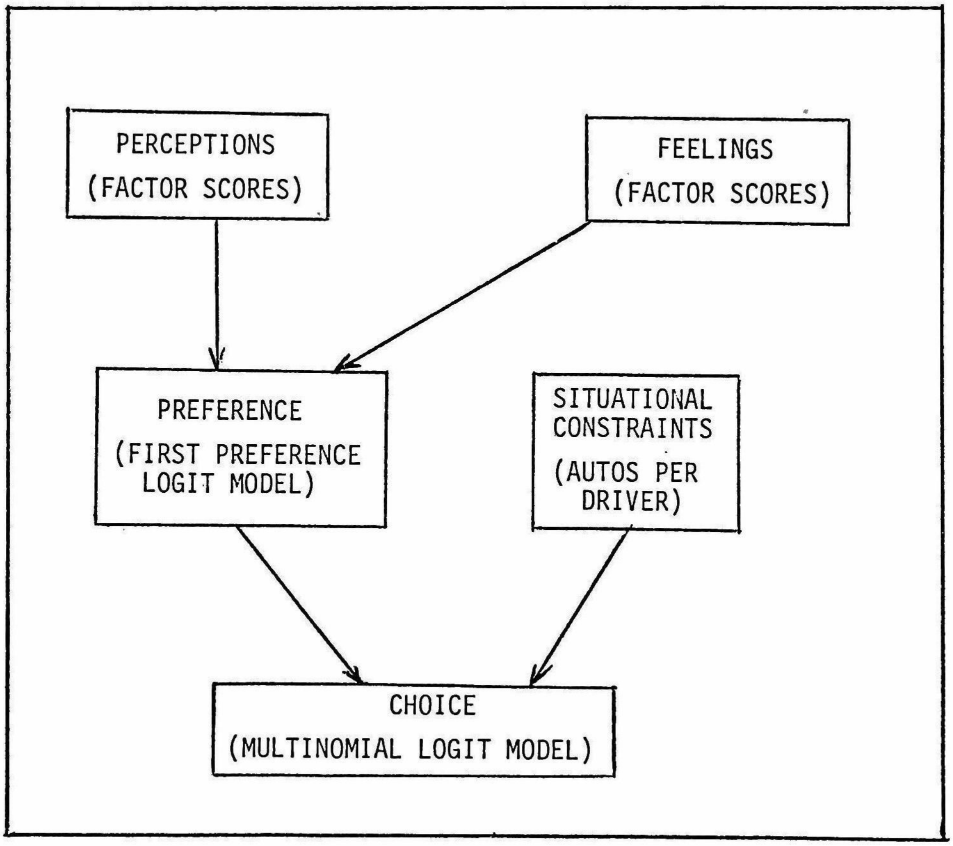

FIGURE 2-2: MODEL COMPONENTS
(Reproduced from: COTSP - Report 1)

consumer's preference for each mode. This preference model is a multinominal logit model which uses first preference as the dependent variable (McFadden, 1973; Koppelman and Hauser, 1978). A preference index is formulated as the weighted (by preference model parameters) sum of perceptions and feelings. Finally, the preference index and the situational constraint (autos per driver) are used as explanatory variables in a multinominal logit model which uses choice as the dependent variable.

This simplified representation is part of a more complex market process which describes interaction among individuals, information diffusion, changes in behavior based on experience, differences between market segments, etc. (Lovelock, 1975; Hartgen and Tanner, 1970; Hauser and Koppelman, 1977). Nonetheless, the simplified representation included in Figure 2-2 (reproduced from Report No. 1) provides a useful framework for the analysis of mode choice behavior.

Overview Description of Component Models

The model components shown in Figure 2-2 are described in detail in the sections which follow. However, to place these models in perspective a brief overview is presented here.

Perceptions of transportation modes (Section 3) are measured by twenty-five attributes identified by review of the literature, qualitative research, and questionnaire pretesting (see Report No. 3 in this series). Factor analysis is used to reduce these transportation service attributes to a smaller set of underlying cognitive dimensions. This provides a simpler perceptual structure which more closely approximates the consumers' use of information in decision making.

Feelings about modes (Section 4) are investigated to determine whether psychological or perceptual factors other than evaluations of mode attributes influence transportation preference and choice. A variety of non-attribute perceptions of travel alternatives were measured (i.e. affect, personal normative beliefs, social normative beliefs, extraneous events). These measures are factor analyzed to develop an aggregate measure of feeling toward each mode.

The overall model structure is examined for consistency (Section 5) by analysis of the relationships between system characteristics, perceptions, feelings, preference, situational constraints, and choice.

First preference logit models (Section 6) are used to estimate the importance weights which relate perceptions and feelings to preferences. The estimated importance weights are used to compute a preference index for each individual for each mode. Multinominal logit choice models (Section 7) are used to estimate the influence of the preference index and situational constraints (automobile availability) in determining choice behavior. The effect of market segmentation on preference and choice is examined in Section 8. Details of results, as well as procedures and tests employed in this research, are provided in Appendices, as follows:

Appendix A - Common Factor Analysis
Appendix B - Factor Loadings for Mode Perceptions
Appendix c - Factor Loadings for Mode Feelings
Appendix D - Information Measure
Appendix E - Modified Friedman Test
Appendix F - First Preference Model Segmentation Analysis
Appendix G - Chi-Square Test of Market Segments
Appendix H - Choice Model Segmentation Analysis

3. PERCEPTION OF MODES

A central hypothesis of this study is that individuals choose among alternatives based on their perceptions of these alternatives rather than engineering or other objectively measured characteristics. That is, perceptions of modal attributes (system characteristics) serve as mediating variables between objective measures and preferences. Because formation of perceptions is influenced by both measured (age, income) and unmeasured (experience, psychological make-up) individual characteristics, as well as modal attributes, the perceptions of alternatives are expected to differ among individuals.

Consideration of consumer perceptions rather than direct (engineering) measures of alternatives also allows us to include attributes or characteristics for which direct (engineering) measures do not exist or are difficult to obtain. Furthermore, differences between consumer perceptions of alternatives and engineering characterizations can be accounted for. The usefulness of incorporating non-engineering measures in models of travel choice behavior has been demonstrated in studies by Spear, 1974; Nicolaidis, 1975; Dobson and Kehoe, 1975; Prashker, 1977; and Koppelman and Hauser, 1978. Differences between perceptions among individuals and/or differences between perceived and engineering measures have been identified by Burnett, 1973, 78; Dobson and Tischer, 1976; Koppelman et al, 1977, and Miklius and Casavant, 1975.

Focus groups, open-ended surveys and other qualitative measurement techniques identify elemental or fundamental attributes (defined below) which consumers use to describe a particular product or service. Two alternative models of consumer perceptions of different modes are discussed here. These are fundamental attributes, which represent service characteristics by an extensive list of attributes and factor analysis, which identifies a reduced set of cognitive dimensions. The primary characteristics of these perceptual models are described below.*

Fundamental Attributes is the simplest and most obvious method of representing consumer perceptions. Consumer ratings of an exhaustive list of attributes are employed in this model. These scales provide a complete description of consumer perceptions and are easy to use because no further data collection or analysis is required. Use of the complete list assumes that no further reduction is possible without loss of important information and that the individual simultaneously evaluates a long list of attributes in formulating preferences among alternatives. A number of problems arise in the use of fundamental attributes. First, a complete list of attributes often includes a large number of partially redundant scales. Second, the sheer size of the list can provide too much information for a manager to readily analyze and, perhaps, thereby prevent insightful analysis. Third, redundancy in attributes leads to multi-collinearity which makes the estimated coefficients in preference and choice models unreliable and difficult to interpret.

Perceptions of fundamental attributes are measured by the ratings for each attribute for each modal alternative. These ratings provide a basis for assessing the relative strengths and weaknesses of each mode. Table 3-1 reports the average and standard deviation of ratings for three existing modes for twenty-five attributes, after standardization of scales across modes for each individual.

The objective of this standardization procedure is the elimination of biases in the way in which different individuals use the same scale.

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*Alternative methods of identifying cognitive dimensions, non-metric scaling and discriminant analysis, have been excluded from these analyses as an earlier study by Koppelman and Hauser, 1978, showed these methods to be inferior in terms of interpretability and predictive ability.

TABLE 3-1

AVERAGE AND STANDARD DEVIATION OF STANDARDIZED ATTRIBUTE RATINGS FOR THREE EXISTING MODES

		Bus	Walk	Car
1.	On time	-.12 (.96)	.08 (1.03)	1.13 (.64)
2.	No trip scheduling necessary	-.78 (.65)	-.48 (.83)	-.07 (.94)
3.	Relaxing	.07 (.85)	-.03 (1.00)	.27 (.78)
4.	Correct temperature	.31 (.72)	-.15 (.80)	.80 (.60)
5.	No worry of assault	.76 (.75)	.38 (.86)	1.06 (.49)
6.	Can come and go as I wish	-.47 (.89)	.67 (.74)	.83 (.72)
7.	Inexpensive	.56 (.82)	1.10 (.59)	-.59 (.79)
8.	Errands take little time	-.28 (.88)	-.36 (.89)	.81 (.67)
9.	No worry about injury	.98 (.63)	.68 (.77)	.71 (.69)
10.	Know how to get around	.73 (.85)	1.04 (.53)	.99 (.54)
11.	Little effort involved	.26 (.84)	-.21 (1.02)	.64 (.80)
12.	Available when needed	-.20 (.91)	.91 (.68)	.56 (.91)
13.	Not made uncomfortable by others	.91 (.60)	1.01 (.54)	.90 (.60)
14.	No problems in bad weather	.01 (.89)	-.73 (.82)	.30 (.88)
15.	Pleasant drivers or other personnel	.43 (.64)	.43 (.60)	.41 (.66)
16.	Get to destination quickly	-.09 (.85)	-.50 (1.07)	.84 (.53)
17.	Protected from smoking	.09 (.77)	.65 (.65)	.75 (.60)
18.	Safe at night	-.02 (.79)	-.51 (.99)	.68 (.63)
19.	Not annoyed by others	.74 (.57)	.81 (.57)	.57 (.78)
20.	No long waits	-.03 (.85)	.77 (.73)	.75 (.66)
21.	Easily carry packages	-.19 (.85)	-.57 (.84)	1.03 (.57)
22.	Easy to travel with small children	-.01 (.69)	-.37 (.76)	.75 (.62)
23.	Not tiring	.44 (.72)	-.30 (.98)	.82 (.62)
24.	Easy getting in and out	.56 (.70)	--- ---*	.82 (.56)
25.	Easy walk access	.79 (.70)	--- ---*	.96 (.58)

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*Not rated for walk mode. However, for ease of interpretation, these variables were set to arbitrary (high) values before factor analysis.

This is achieved in the following way:

$$t_{im\ell} = \frac{d_{im\ell} - \overline{d}_i}{\sigma_i} \tag{3-1}$$

where $t_{im\ell}$ = individual i's standardized rating for mode m on attribute ℓ

$d_{im\ell}$ = individual i's "raw" rating for mode m on attribute ℓ

$\overline{d}_i$ = the mean rating of all modes (m = 1,...,M) on all attributes (ℓ = 1,...L), for individual i

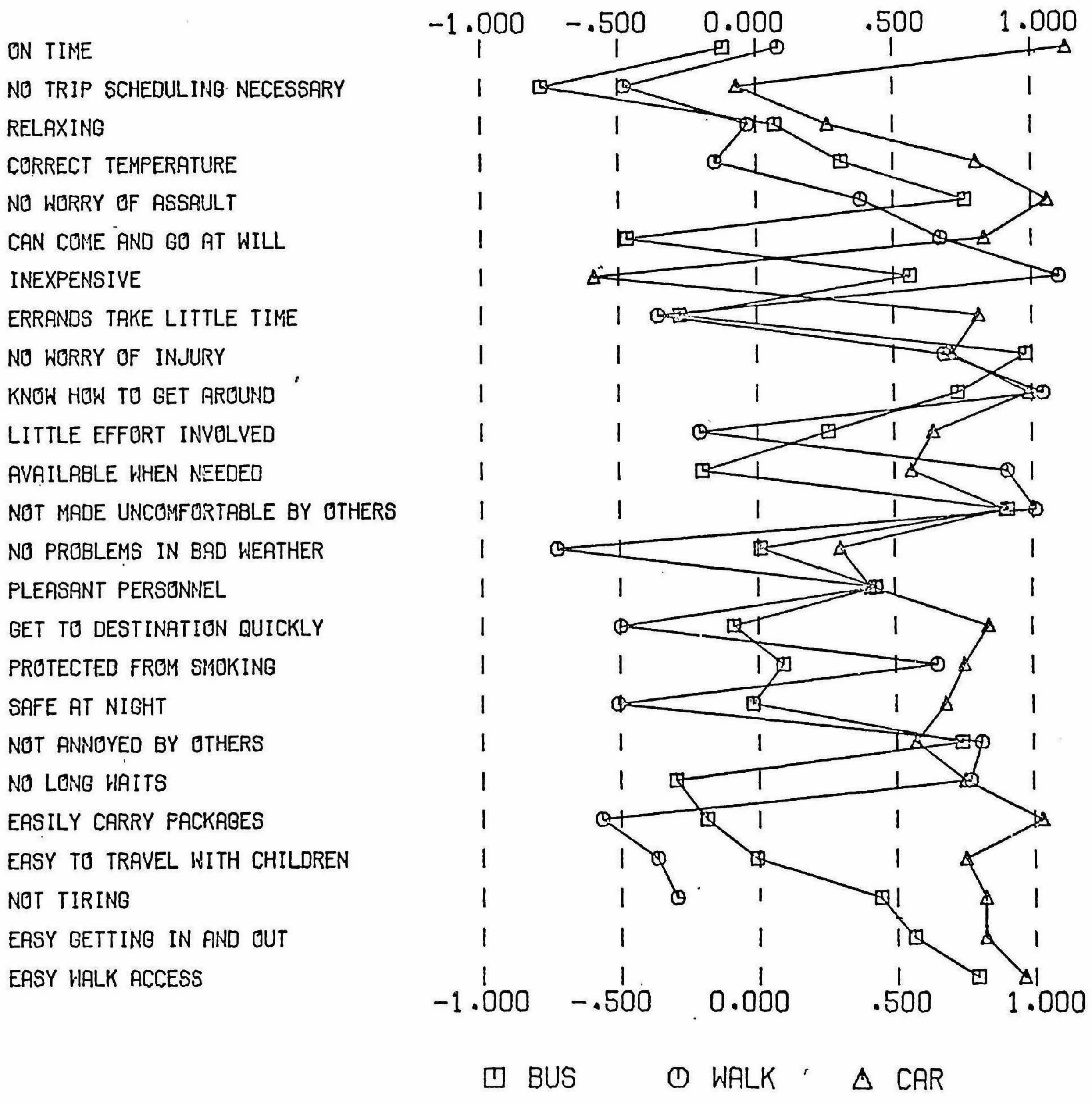
σ_i = standard deviation of the raw ratings provided by individual i, across all modes and attributes

Thus the $t_{im\ell}$ have a mean of zero and standard deviation of 1, for each individual in the sample. The scores on statements which were negatively worded on the original questionnaire are subsequently reversed in sign so that higher values are associated with more positive perceptions.

Figure 3-1 plots the average standardized ratings of each mode for each attribute. The automobile has the highest average ratings for all of the attributes considered except "low cost," "safe from injury," "availability." and "not annoyed/made uncomfortable by others." The low ratings

FIGURE 3-1

AVERAGE ATTRIBUTE RATINGS - THREE MODES



for automobile are expected except for the scales "not annoyed/ made uncomfortable by others." These scales were expected to identify irritation, fear, or other discomfort of people traveling with strangers on public vehicles. The results suggest that the irritation of auto users with "others" includes other drivers and pedestrians. Apparently these irritations are greater than those of sharing public transit vehicles for the local trip to downtown Evanston. The variation in ratings shown in Table 3-1 indicates more agreement about some attributes than about others. Standard deviations vary from 0.53 to 1.07. These variations are high relative to the average values and confirm the disparity of ratings across individuals. Report 4 in this series details differences in average attribute ratings by individuals who currently use different modes. Generally, individuals using bus or walk rate that mode more positively than other individuals while most individuals rate auto similarly. This is consistent with the findings of others (Dobson and Tischer, 1976).

Information on fundamental attributes is cumbersome and difficult for the manager to interpret even when the number of stimuli (modes) is small, (see Figure 3-1). Furthermore, research by Bruner et al (1956) indicates that consumers identify a relatively small number of basic dimensions to reduce cognitive strain in evaluating products or services.

Factor Analysis assumes that such underlying cognitive dimensions exist. Common factor analysis assumes that consumer ratings of attributes include a common component which represents these cognitive dimensions, an attribute specific component, and some measurement error. The common components or cognitive dimensions can be found by factor analysis of the attribute ratings across modes and individuals. The structure of consumer perceptions and the names of the common dimensions are determined by examining the correlations (factor loadings) between the fundamental attributes and the dimensions uncovered by the analysis. (Appendix A provides a brief introduction to Common Factor Analysis).

The factor loadings give insight into individual perceptual structure (that is, the way individuals relate fundamental attributes to cognitive dimensions). Factor analysis also develops measures to indicate how the various modes are perceived by consumers. Estimates of consumer's perceptions of the modes along the common dimensions, factor scores, are computed from each individual's standardized fundamental attribute ratings.

The primary advantage of factor analysis relative to fundamental attributes is that it identifies a simpler perceptual structure which provides clearer insight into how consumers perceive alternatives.

Common factor analysis of 24 fundamental attribute ratings for existing local transport modes was undertaken in two through six dimensions.* The variance explained, identification of cognitive dimensions, and relationship between fundamental attributes and cognitive dimensions are presented in figures 3-2 and 3-3 and table 3-2. These data indicate that solutions in three, four, or five dimensions may be suitable for representation of the consumer's perception structure (dimension beyond five are not identifiable). These solutions explain 45 to 55 percent of the variance in fundamental attributes (figure 3-2). The identification of the different factor structures is illustrated in figure 3-3. Factor analysis in two dimensions produces general service (on time, reliable, safe, etc.) and convenience/accessibility (available when needed, within walking distance, etc.). Increasing the

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*Twenty-four of the twenty-five attributes shown in Figure 3-1 are included in the factor analyses. "Inexpensive" was eliminated as it does not represent a service characteristic. This variable is considered for inclusion in model development (see sections 6 and 7).

Figure 3-2

Cumulative Percent Variance Explained

Factor Analysis of 24 Attribute Ratings

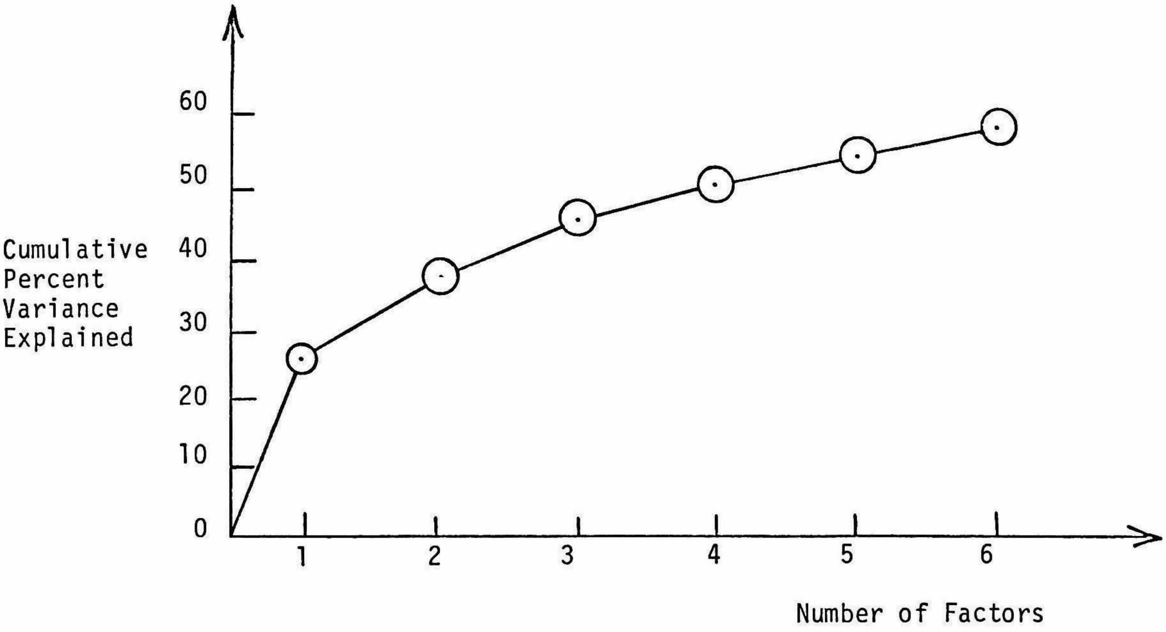
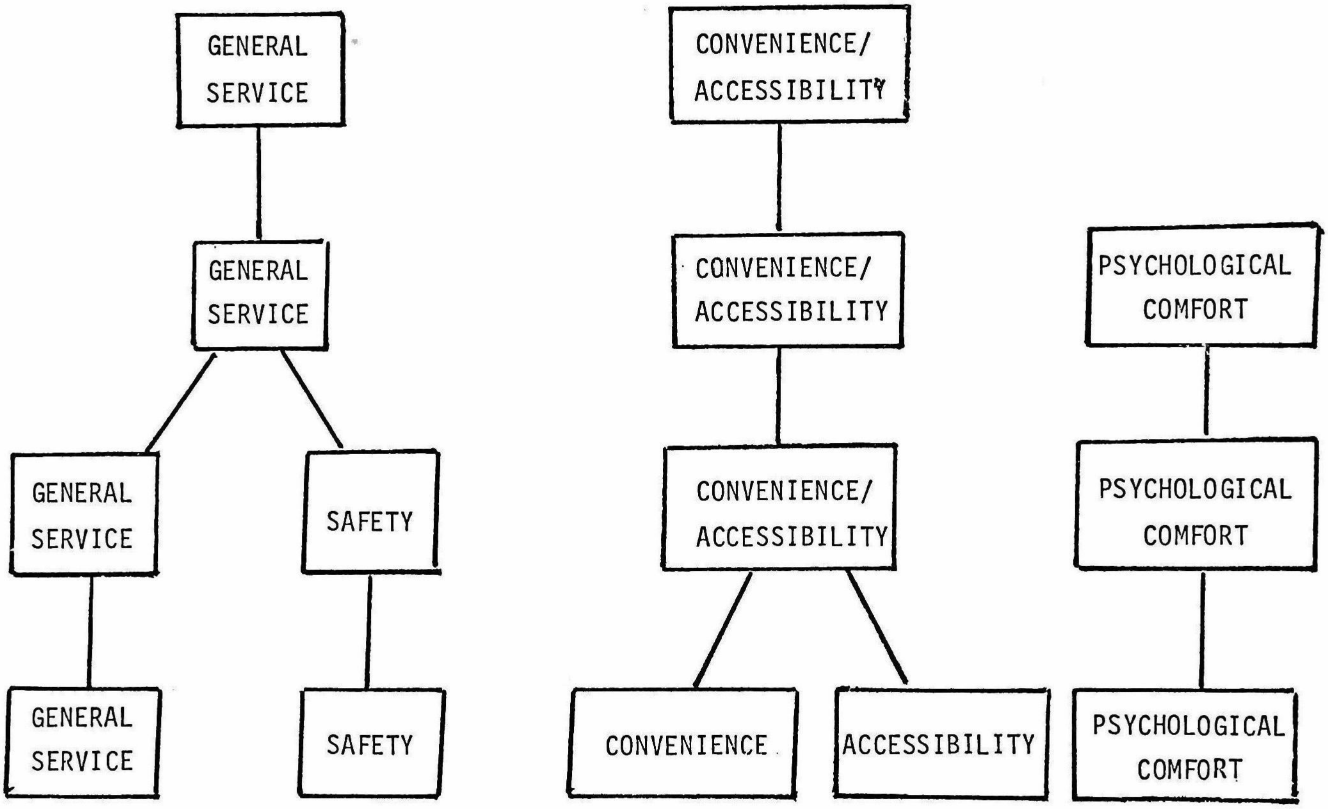


FIGURE 3-3

IDENTIFICATION OF COGNITIVE DIMENSIONS FOR EXISTING MODES

IN TWO THROUGH FIVE DIMENSIONS



factor analysis to three dimensions uncovers a new dimension which we characterize as psychological comfort (not annoyed/bothered by others). Adding a fourth dimension separates out safety from other measures of general service. Adding a fifth dimension separates convenience and accessibility. Additional dimensions are not strongly associated with any of the fundamental attributes.

The relationship between the cognitive dimensions and fundamental attributes is presented in Table 3-2. The attributes of "no trip scheduling necessary," "know how to get around" (by that mode), "pleasant drivers and other personnel," and "protected from smoking" do not load heavily on any dimensions in the two through five dimensional solutions. The two dimensional solution also excludes the attributes of "not made uncomfortable/annoyed by others" and "worry about injury". The three factor solution produces three distinct and identifiable dimensions. Although the four and five dimensional solutions identify additional dimensions, they also produce some joint loadings (i.e., attributes which load heavily on more than one dimension). Based on these results it is reasonable to consider the three, four, or five dimensional factor spaces to represent the underlying cognitive perception structure.*

Each of these perceptual structures can be used to describe average perceptions of the existing modes. Maps of average perceptions in three, four and five dimensions are presented in Figures 3-4 through 3-6. The three dimensional map (Figure 3-4) reveals large differences in perception of modes along the general service and convenience/accessibility dimensions and smaller differences between modes for the psychological comfort dimension.

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*The factor loadings matrices for factor solutions in two through five dimensions are presented in Appendix B.

TABLE 3-2

RELATIONSHIP BETWEEN FUNDAMENTAL ATTRIBUTES AND COGNITIVE DIMENSIONS

IN TWO TO FIVE DIMENSIONS

FUNDAMENTAL ATTRIBUTES	2 DIMENSIONS	3 DIMENSIONS	4 DIMENSIONS	5 DIMENSIONS
NOT MADE UNCOMFORTABLE	*	PSYCHOLOGICAL COMFORT	PSYCHOLOGICAL COMFORT	PSYCHOLOGICAL COMFORT
NOT ANNOYED BY OTHERS	*			
NO WORRY ABOUT INJURY	*		SAFETY	
NO WORRY OF ASSAULT	GENERAL SERVICE	GENERAL SERVICE		SAFETY
SAFE AT NIGHT			GENERAL SERVICE	GENERAL SERVICE
RELAXING				
CORRECT TEMPERATURE				
ERRANDS TAKE LITTLE TIME				
LITTLE EFFORT INVOLVED				
BAD WEATHER NO PROBLEM				
QUICK				
EASILY CARRY PACKAGES				
EASY TRAVEL WITH CHILD				
NOT TIRING				
ON TIME				CONVENIENCE
COME 'N GO	CONVENIENCE/ ACCESSIBILITY	CONVENIENCE/ ACCESSIBILITY	CONVENIENCE/ ACCESSIBILITY	
AVAILABLE WHEN NEEDED				
NO LONG WAITS				
EASY GETTING IN AND OUT				ACCESSIBILITY
EASY WALK ACCESS				
NO SCHEDULING NEEDED	*	*	*	*
KNOW HOW TO GET AROUND	*	*	*	*
PLEASANT PERSONNEL	*	*	*	*
PROTECTED FROM SMOKING	*	*	*	*

* DOES NOT LOAD ON ANY DIMENSION

FIGURE 3-4

AVERAGE MODE PERCEPTIONS
3-FACTOR SPACE

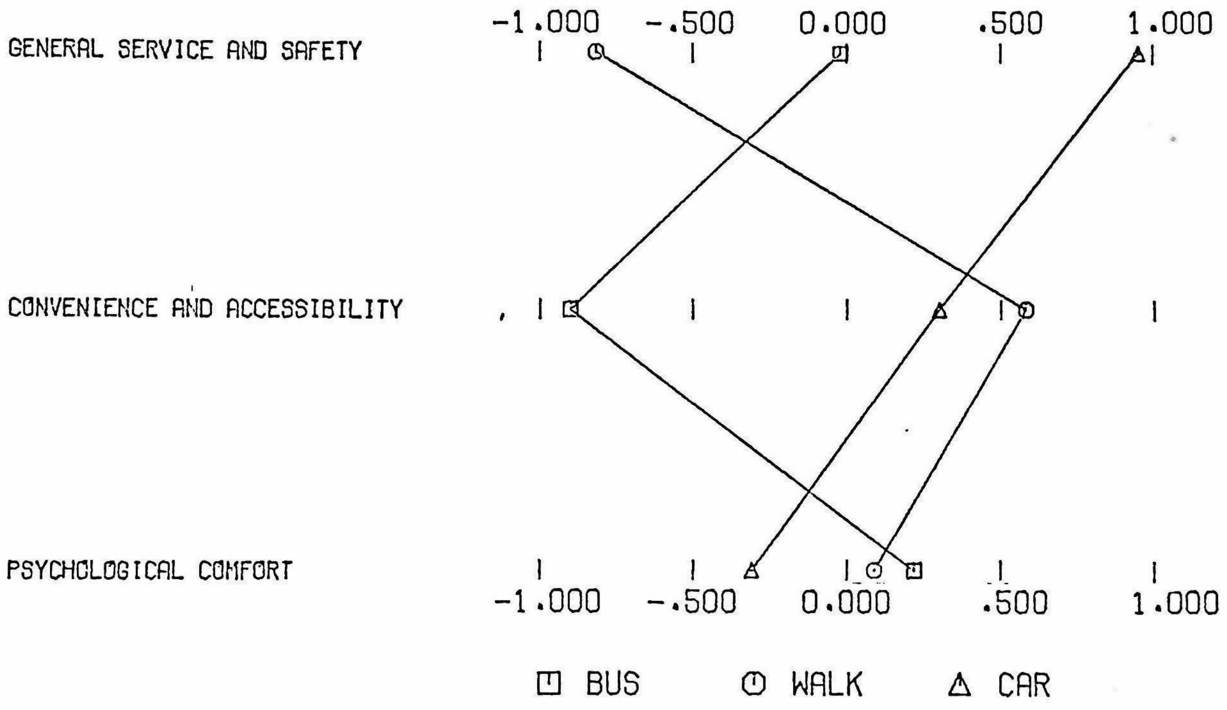


FIGURE 3-5

AVERAGE MODE PERCEPTIONS
4-FACTOR SPACE

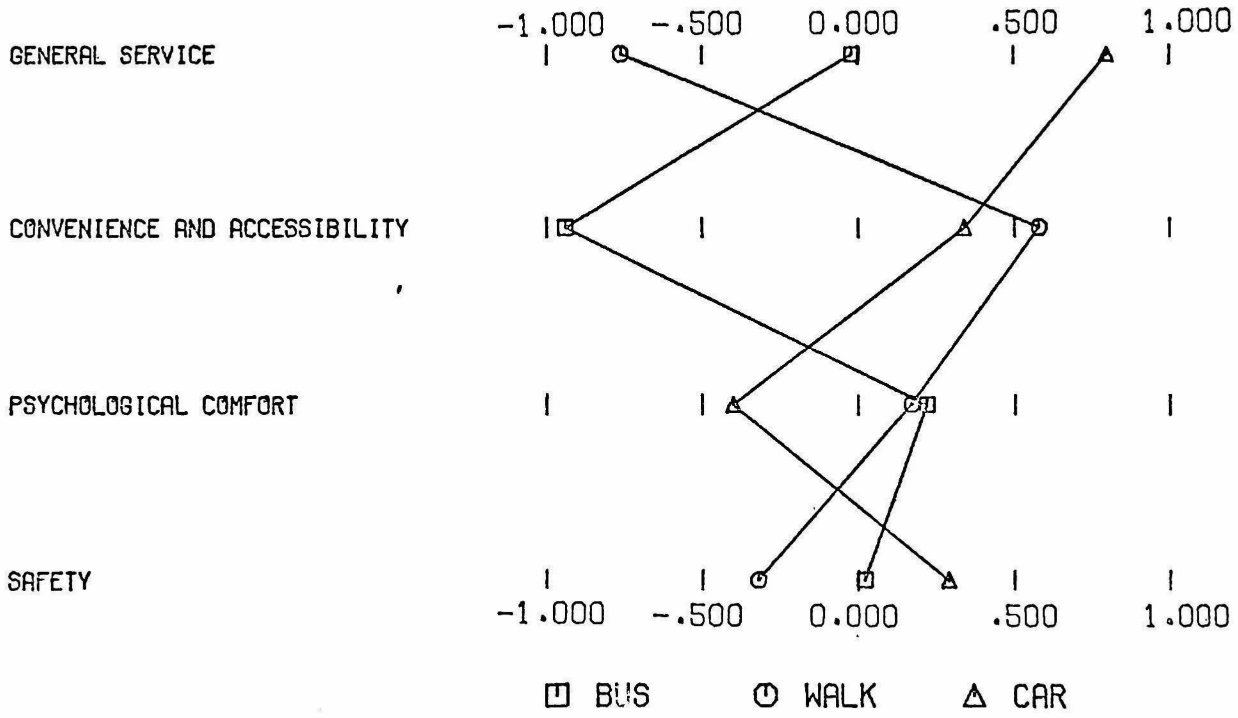
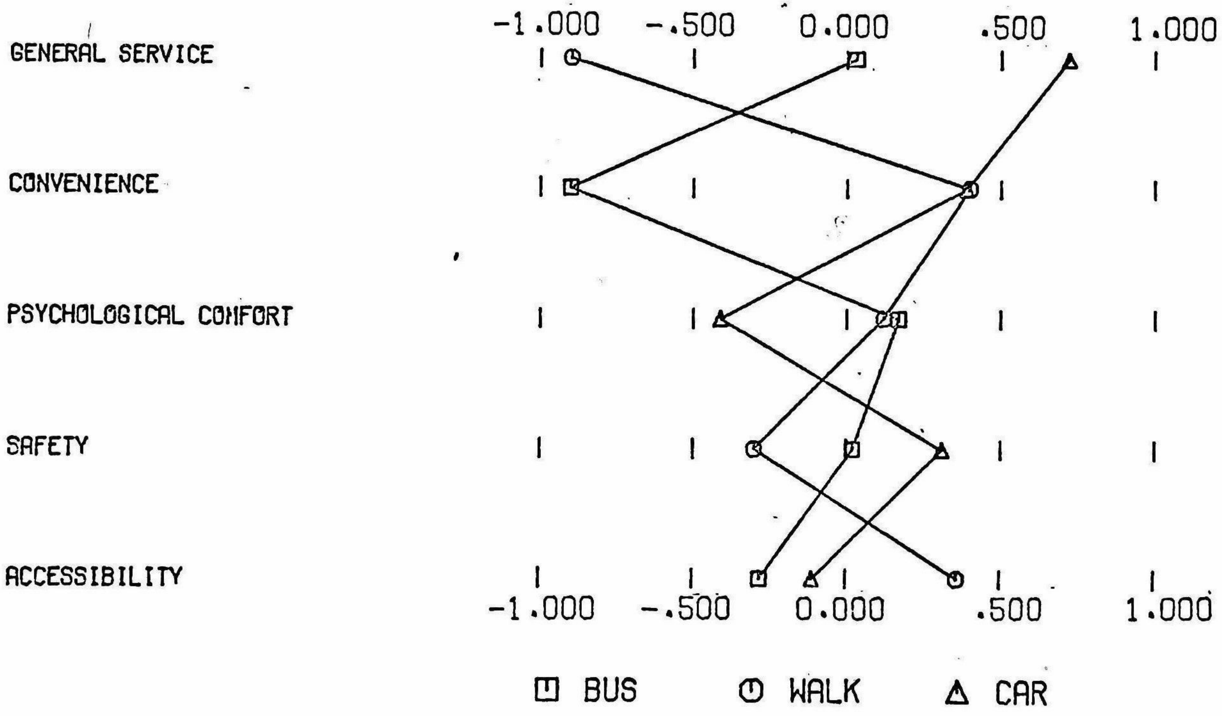


FIGURE 3-6

AVERAGE MODE PERCEPTIONS
5-FACTOR SPACE



The low average rating of car with respect to psychological comfort suggests that car users are expressing a negative response to the strain associated with driving an automobile.

The safety factor identified in the four dimensional space places car ahead of bus, and bus ahead of walk. The other dimensions are unaffected by the addition of the fourth dimension. The five dimensional map leaves the dimension of general service, psychological comfort and safety unchanged but disaggregates convenience and accessibility into two dimensions. The convenience scale shows walk and car much closer than on the joint convenience/ accessibility scale and the accessibility scale indicates car accessibility to be lower than walk access (which is defined to be very high).

Thus, the analysis of perceptions identifies three alternative structures to reduce the ratings of fundamental attributes to underlying sets of cognitive dimensions. The reduced perceptual maps are easier to work with and understand than the fundamental attribute map (Figure 3-1) which presents too much data to readily synthesize. They also identify a small number of dimensions which trip makers use in evaluating alternative travel modes. Of these three candidate perceptual structures, the three dimensional space is selected based on ease of interpretation and, as shown in section 6, ability to explain and predict individual preferences.

4. FEELINGS ABOUT TRANSPORTATION MODES

Historically, transportation researchers have employed only one psychological dimension, namely beliefs (or perceptions) about the attributes of the object (e.g., perceptions of the comfort or convenience of transportation modes), in explaining consumers' travel behavior. However, theory and research findings in social psychology indicate that other psychological dimensions might be important determinants of travel behavior.

An individual's attitude towards an object is influenced not only by his/her beliefs about the characteristics of that object but also by his/her liking/disliking of the object, or affect, (Ostrom, 1969). Fishbein (1972) argued that an individual's attitude towards an object is not the only explanatory variable with respect to behavior. He found that social normative beliefs, i.e., an individual's perceptions of what others want him to do, are important in explaining behavior. Similarly, Swartz and Tessler (1972) have demonstrated that an individual's perceptions of what he ought to do, or personal normative beliefs, also influence behavior. Wicker (1971) found level of commitment, i.e., how easily an unanticipated event influences behavior, to be the most important explanatory variable in a study of church-related behavior.

In order to investigate whether any of the above mentioned variables influence transportation mode preference and choice, respondents were requested to express their feelings about transportation modes by responding to 27 statements on a 5 point Likert scale ranging from strongly disagree to strongly agree. Of the 500 respondents in this data set, 356 responded to all 27 statements. The responses for each individual were standardized (see earlier description) across the 27 scales, and the missing values for the 87 respondents who completed at least two-thirds of this section of the questionnaire were filled with the average response for that statement across all individuals. This yielded a sample size of 443.

The statements, their mean scores and standard deviation (after individual standardization) are shown in Table 4-1. High algebraic values indicate agreement with a particular statement. A number of interesting observations may be made from these results. Respondents on average express positive feelings toward car (positive enjoyment, not depressed), less positive feelings toward walk and relatively neutral feelings toward bus. They indicate a high degree of sensitivity to major increases in gasoline prices (fewer car trips, more walk trips) but little sensitivity toward changes in bus fares. On the other hand, they would react positively toward improved bus service (more frequent service). As with attribute ratings, there is a large variation among respondents for these questions (standard deviation ranging from .59 to .99).

Since each of the beliefs (e.g., social-normative) was measured by a relatively small number of statements per mode, analysis by mode and individual would produce unstable factors. Therefore, these measures were factor analyzed together to develop a composite measure of feelings towards each of the three modes.* These combined indices provide measures of general feeling toward each mode. Common factor analysis with iterations and varimax rotation was used for three through five dimensions. Although we were implicitly seeking a three-dimensional solution (one factor for each mode) as noted above, the higher order solutions were obtained to see if they yielded any useful insight.

The factor loadings matrices for three to five dimensions are presented in Appendix C. The results of these analyses are summarized in Figures 4-1 and 4-2 and Table 4-2. Figure 4-1 shows the cumulative percent of the total variance explained. This figure indicates that the 3-dimensional solution accounts for approximately 37% of the total variance.

Figure 4-2 shows the effect of increasing dimensionality on the factor structure. The three factor solution identifies a feeling (or disposition) towards each of the three existing local modes of bus, walk and car. The four factor solution uncovers a further dimension which represents carpool receptivity (willingness to consider the carpool mode). The five factor

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*Current research by the COTSP group is attempting to explicitly measure the cognitive dimensions discussed above.

Figure 4-1

Cumulative Percent Variance Explained:

Factor Analysis of 27 Feelings Statements

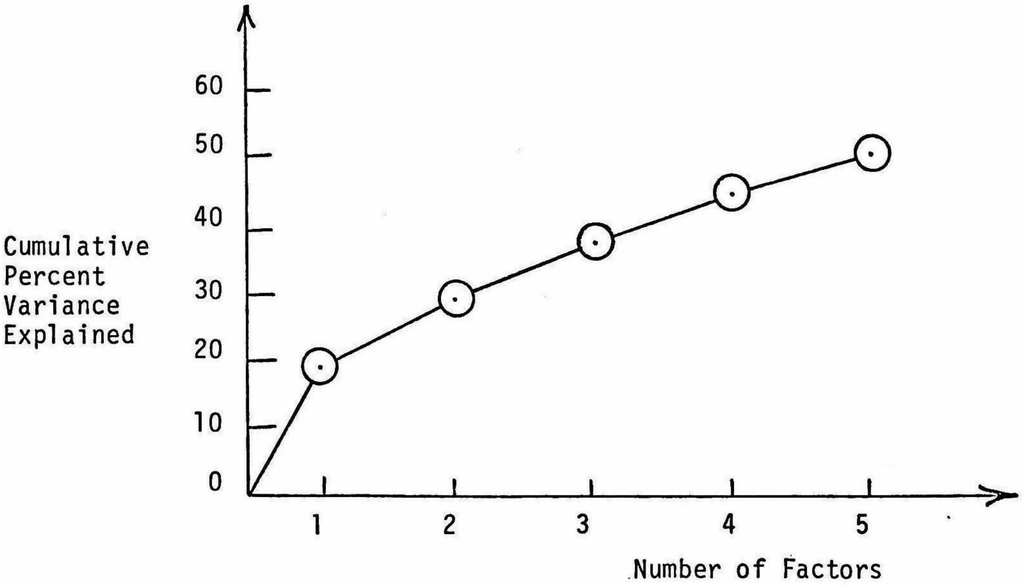

FIGURE 4-2

IDENTIFICATION OF FEELING DIMENSIONS

IN THREE THROUGH FIVE DIMENSIONS

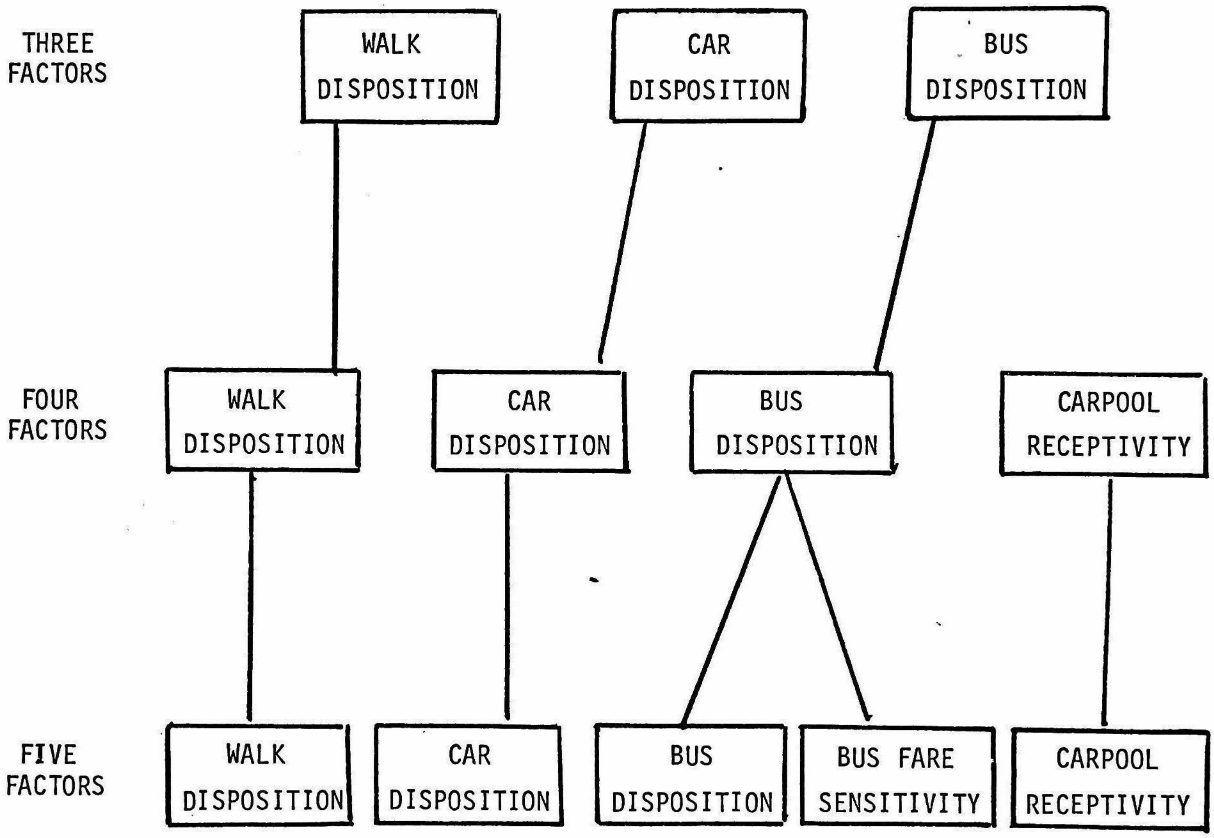

TABLE 4-2

RELATIONSHIP BETWEEN FEELINGS AND FACTORS IN THREE TO FIVE DIMENSIONS

FEELING DESCRIPTION	3 DIMENSIONS	4 DIMENSIONS	5 DIMENSIONS
ENJOY TRAVEL BY FOOT	WALK DISPOSITION	WALK DISPOSITION	WALK DISPOSITION
DEPRESSING TO TRAVEL BY FOOT			
OUGHT TO TRAVEL BY FOOT			
IF GAS PRICE DOUBLED, MORE WALK TRIPS			
PEERS SURPRISED IF WALKED A LOT			
OUGHT TO TRAVEL BY CAR		*	*
WOULD TRAVEL BY BUS EVEN IF LONG WALK	*	*	BUS DISPOSITION
ENJOY TRAVEL BY BUS	BUS DISPOSITION	BUS DISPOSITION	
DEPRESSING TO TRAVEL BY BUS			
PEERS SURPRISED IF RIDE BUS REGULARLY			
IF BUS FARES LOWER, MORE BUS TRIPS		*	BUS SERVICE SENSITIVITY
IF BUS FARES LOWER, FEWER CAR TRIPS		*	
ENJOY TRAVEL BY CAR	CAR DISPOSITION	CAR DISPOSITION	CAR DISPOSITION
DEPRESSING TO TRAVEL BY CAR			
WOULD TRAVEL BY CAR REGARDLESS OF COST	*		*
WILLING TO CAR POOL SOME TRIPS	*	CARPOOL DISPOSITION	CARPOOL DISPOSITION
IF GAS PRICE DOUBLED, MORE CAR POOL TRIPS	*		
PEERS SURPRISED IF DROVE CAR REGULARLY	*	*	*
IF WEATHER BAD, FEWER CAR TRIPS	*	*	*
IF WEATHER BAD, FEWER BUS TRIPS	*	*	*
IF WEATHER BAD, FEWER WALK TRIPS	*	*	*
IF GAS PRICE DOUBLED, MORE CAR TRIPS	*	*	*
IF GAS PRICE DOUBLED, FEWER CAR ALONE TRIPS	*	*	*
IF BUS MORE OFTEN, MORE BUS TRIPS	*	*	*
IF PARKING COST DOUBLED WOULD WALK	*	*	*
DIFFERENT FROM BUS RIDERS	*	*	*
OUGHT TO TRAVEL BY BUS	*	*	*

* DOES NOT LOAD ON ANY DIMENSION

solution disaggregates bus fare sensitivity from other aspects of bus disposition. Table 4-2 summarizes the factor loadings for each of the three, four and five dimensional solutions, by indicating which statements load highly on each factor as well as which statements do not load on any dimension.

As noted above, we were seeking a three factor solution, in which each dimension would represent a general feeling or bias towards each of the modal alternatives. The results reported here show that in more than three dimensions a non-mode-specific factor is identified, and that the three dimensional solution accounts for a reasonable proportion of the variance in the data. A factor score for each mode and individual was computed from the factor score coefficients for the three dimensional solution. These scores are tested for explanatory ability with respect to mode preference in section 6.

5. CONFIRMATION OF THEORETICAL MODEL

The models of individual behavior which are estimated in this research are developed within the conceptual framework illustrated in Figures 2-1 and 2-2. In this section, we examine our data to determine whether it is consistent with the conceptual model. We do this by examining the correlations between variables which describe system characteristics, perceptions, feelings, constraints, and choice (see Table 5-1). These correlations are computed between pairs of variables which are defined for a single mode or for all modes. That is, the correlation between autos per driver and other variables is defined across the car mode only. Similarly, correlations for bus seat availability are defined for the bus mode only. Formally, the correlations in Table 5-1 are computed by the following formula:

$$r_{st} = \frac{\sum_i \sum_k (X_{isk} - \overline{X}_{s(t)}) (X_{itk} - \overline{X}_{t(s)})\delta_{stk}}{[\sum_i \sum_k (X_{isk} - \overline{X}_{s(t)})^2 \delta_{stk}] [\sum_i \sum_k (X_{itk} - \overline{X}_{t(s)})^2 \delta_{stk}]}$$

where X_{ijk} = value of variable j for alternative k for individual i

δ_{stk} = 1 if both variables s and t are defined for alternative k

= 0 otherwise

$\overline{X}_{s(t)}$ = mean value of variable s across those alternatives for which both variables s and t are defined.

In addition to providing support for the conceptual model, as discussed below, the correlations provide other useful insights. For example, cost is positively and significantly correlated with general service, preference, and choice. The positive correlation of cost with general service may represent a true association (high cost services are generally high quality services) or perceptions of better service provided when costs are higher. The positive correlation of cost with preference and choice are determined by their common association with general service. That is, higher cost is associated with higher levels of service and higher levels of service lead to higher preference and choice.

The model of consumer travel behavior described in Section 2 states that the impact of system characteristics on mode preference and choice is mediated by consumer perceptions of mode performance. Therefore, we expect system characteristics to be more highly correlated with perceptions of mode attributes than with preference or choice. The data correlation matrix, Table 5-1, indicates that this is the case. For example, travel time is more highly correlated (r = -.51) with consumers' perceptions of "general

Table 5-1

Correlation Matrix**

	System Characteristics				Perceptions			Feelings			Constraints	
	TT	BLOCK	SEAT	COST	GS	C/A	PC	BF	WF	CF	APD	P
Travel Time (TT)												
Blocks to Bus Stop	.05*											
Bus Seat Availability	-.09	.01*										
Cost	-.25	.04*	-.11									
General Service	-.51	-.07*	.22	.41								
Convenience/ Accessibility	-.07	-.19	.14	-.06	.04							
Psychological Comfort	-.01*	-.14	.28	-.30	.03*	.04*						
Pro-Bus Feelings	-.18	-.03*	.09	.13	.48	.32	.26	-				
Pro-Walk Feelings	-.41	-	-	-.24	.60	.26	.19	-	-			
Pro-Car Feelings	-.11	-	-	-.13	.32	.13	.25	-	-	-		
Autos per Driver (APD)	.05	-	-	.00*	-.01*	.26	.03*	-	-	+.09		
Preference	-.31	-.03*	-.02*	.30	.56	.31	-.05	.31	.48	.21	.20	
Choice	-.31	-.08	.06*	.32	.52	.31	-.09	.22	.40	.15	.30	.66

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*All correlations except those starred are significant at the .05 level.

**See text for a description of the computation of these correlations.

service" than it is with either preference (r = -.31) or choice (r = -.31). These correlation coefficients, and all other statistically significant ones (except those between cost and perceptions, preference, and choice discussed earlier), have the expected sign. Similar results are obtained for bus seat availability and blocks to bus stop. On the other hand, autos per licensed driver in the household (APD), which operates as a situational constraint, is more highly correlated with choice (r = .30) than with preference (r = .20). Furthermore, it is also significantly correlated with the perception of "convenience and accessibility" (r = .26), but has low correlations with the other variables.

The cognitive dimensions (perceptions) are viewed as independent determinants of preference and choice. Thus we expect these variables to be relatively independent of one another and to be highly correlated with preference and choice. The data are consistent with these expectations. Table 5-1 shows the intercorrelations between these variables to be very low, and generally insignificant. Furthermore, the correlations of general service and convenience/accessibility with preference and choice are positive and statistically significant.

The feelings variables measure perceptions and personal biases not captured by attribute ratings. Since these are alternative perceptual measures they should be correlated with the perception factor scores. Also if they are capturing personal and social beliefs they should be more highly correlated with the perception factor scores than with the system characteristics. Finally, we expect them to be correlated with preference and choice. Table 5-1 shows the perceptions and feelings to be highly intercorrelated. The mode-specific feelings also are highly correlated with preference and choice.

Finally, preference and situational constraints are viewed as the determinants of choice. Thus, choice should be highly correlated with these variables. Consistent with this expectation, choice is most highly correlated with preference (r = .66) and is highly correlated with auto availability (r = .30).

On the basis of the above analysis, we conclude that the data supports our conceptual model of consumer travel behavior (section 2), and we can therefore confidently estimate the relationships necessary to provide a sound predictive model based on the interrelated components shown in Figure 2-2.

6. PREFERENCES AMONG MODAL ALTERNATIVES

Model Structure

The conceptual model illustrated in Figure 2-2 describes the consumer response process in terms of (1) the formation of perceptions about and feelings towards modes, (2) preference formation based on perceptions and feelings, and (3) choice of mode based on preference and situational constraints. The correlation analysis of data on service attributes, perceptions, feelings, preference, and choice shows the data to be consistent with this behavioral structure.

Preference analysis is used to estimate the relative importance of the various perception and feelings measures in the formation of preference for the modal alternatives. The objective is to find a function which maps consumer perceptions and feelings to a preference rating index which ranks the alternatives consistently with respect to consumer preference (independent of availability and situational constraints). The relative importance weights are determined by estimating a linear compensatory model of the form:

$$PI_{im} = \sum_k w_k y_{imk} + \sum_m v_m F_{im} \delta_m \qquad (6\text{-}1)$$

where PI_{im} = the preference index of individual i for mode m,

y_{imk} = the factor score for individual i's perception of mode m along the k^{th} dimension,

F_{im} = individual i's feelings toward mode m,

w_k = the relative importance of the k^{th} perceptual dimension,

v_m = the relative importance of feelings towards mode m, and

δ_m = an indicator variable set equal to 1 for mode m and zero otherwise.

Preference logit models assume that the true preference for an alternative, PI^T_{im}, is composed of an observable part, PI_{im}, as in equation 6-1, plus a random error term, e_{im}, that is

$$PI^T_{im} = PI_{im} + e_{im} \qquad (6\text{-}2)$$

If the error terms for different individuals and modes are assumed to be independent and identically distributed (iid) Weibull random variables, the probability that individual i ranks alternative m as his/her first preference is given by McFadden [1973]:

$$p_{im} = \exp(\beta PI_{im}) \;/ \sum_{j=1}^{3} \exp(\beta PI_{ij}) \qquad (6\text{-}3)$$

The model given by equation (6-3) is a first preference logit model. The appeal of this model is that it explicitly accounts for stochastic behavior (Bass, 1974) and it does not make metric assumptions about preference rankings. Its drawbacks are that is uses only first preference information and it estimates average (i.e., across a group of individuals), rather than individual, importance weights.

Since respondents were asked to rank order their preferences for the various modes, we are able to overcome the former disadvantage by estimating a rank preference logit model. The rank preference logit model compares each pair of alternatives instead of comparing only the most preferred alternative to each other alternative. The rank preference logit model is expected to be similar to the first preference model in terms of the estimated importance weights, interpretability and prediction (Luce and Suppes, 1965).

Preliminary Model Investigations and Interpretation

Based on the criteria of percent variance explained and interpretability, the factor analysis of attribute ratings revealed that three, four and five dimensional solutions provided appropriate descriptions of consumer perceptions (section 3). The third criterion used for selecting the "best" factor solution is explanatory and predictive ability. Thus, initial models of mode preference were estimated and tested for preference recovery, employing a specification which included the factor scores for the cognitive dimensions identified by factor analysis in three, four, and five dimensions.* The three factor solution was selected because (1) it has almost

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*Variables representing cost and travel-time were tested but found to be inferior predictors of preference. These two variables together were able to explain approximately 15% of the uncertainty (information) compared to the 53% explained by the 3 perception factors.

identical explanatory power to the four and five factor solution, (2) the fourth and fifth factors were either not significant or only marginally significant, and (3) the three factor solution is simpler to interpret.

Estimated model parameters, standard errors of estimate, normalized importance weights, and goodness of fit statistics for preference logit models are reported in Table 6-1 (first preference models) and in Table 6-2 (rank preference models).*

When first preference alone is considered the fourth and fifth factors are always insignificant and extension of the three factor model to four or five dimensions adds little to the statistics for the overall model. When rank preference information is taken into account, the fourth factor (safety) is significant but the fifth factor (accessibility) is not. General service, convenience/ accessibility and psychological comfort are statistically significant in all models. Safety and accessibility (considered separately from convenience) are less important in explaining modal preference. The first preference and rank preference models are similar for each factor space. General service is consistently most important followed by convenience/accessibility and psychological comfort. However, the rank preference models place greater weight on general service than the first preference models.

The predictive ability of these models was investigated by examining the effectiveness of each model in predicting both first and rank preferences. The "preference recoveries" are compared to two different null models in Table 6-3. The market shares model predicts the probability that each

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*Appendix D provides a brief discussion of the information measure which is reported for all logit models in this report.

TABLE 6-1

FIRST PREFERENCE LOGIT MODELS

THREE, FOUR, AND FIVE FACTOR DIMENSIONS

3 DIMENSIONS			4 DIMENSIONS			5 DIMENSIONS		
	Model Parameter (t-statistic)	Normalized Importance Weight		Model Parameter (t-statistic)	Normalized Importance Weight		Model Parameter (t-statistic)	Normalized Importance Weight
General Service	1.79 (13.11)	.57	General Service	1.86 (12.65)	.56	General Service	1.78 (12.24)	.50
Convenience/ Accessibility	1.01 (8.83)	.32	Convenience/ Accessibility	0.97 (8.42)	.29	Convenience	1.09 (9.33)	.31
Psychological Comfort	0.34 (3.01	.11	Psychological Comfort	0.30 (2.85)	.10	Psychological Comfort	0.41 (3.75)	.12
			Safety	0.16 (1.25)	.05	Safety	0.12 (0.97)	.03
						Accessibility	0.14 (1.06)	.04
Likelihood ratio statistic (χ^2)		585.2			590.8			591.4
Information (Pseudo-R^2)		.533			.538			.539

TABLE 6-2

RANK PREFERENCE LOGIT MODELS

THREE, FOUR AND FIVE FACTOR DIMENSIONS

3 DIMENSIONS			4 DIMENSIONS			5 DIMENSIONS		
	Model Parameter (t-statistic)	Normalized Importance Weight		Model Parameter t-statistic)	Normalized Importance Weight		Model Parameter (t-statistic)	Normalized Importance Weight
General Service	1.70 (18.17)	.70	General Service	1.71 (17.79)	.65	General Service	1.65 (17.30)	.55
Convenience/ Accessibility	0.46 (7.69)	.19	Convenience/ Accessibility	0.45 (7.48)	.17	Convenience	0.64 (9.73)	.21
Psychological Comfort	.28 (3.45)	.11	Psychological Comfort	0.23 (3.05)	.09	Psychological Comfort	.37 (4.71)	.12
			Safety	0.24 (2.81)	.09	Safety	.18 (2.08)	.06
						Accessibility	-.16 (-1.79)	-.05
Likelihood ratio statistic (x^2)		747.4			754.3			759.5
Information (Pseudo R^2)		.417			.421			.424

TABLE 6-3

PREFERENCE RECOVERIES

GENERAL MODEL TYPE	VERSION	FIRST PREFERENCE RECOVERY	RANK PREFERENCE RECOVERY
FIRST PREFERENCE MODELS	3 FACTOR DIMENSIONS	78.1	67.9
	4 FACTOR DIMENSIONS	78.5	69.2
	5 FACTOR DIMENSIONS	77.9	68.7
RANK PREFERENCE MODELS	3 FACTOR DIMENSIONS	77.0	71.5
	4 FACTOR DIMENSIONS	78.1	71.4
	5 FACTOR DIMENSIONS	77.3	71.5
MARKET SHARES MODEL		54.7	48.4
EQUALLY LIKELY MODEL		33.3	33.3

individual i prefers alternative m to be the observed market share (in terms of mode preference) of mode m, while the equally likely (or random model) predicts this same probability to be 1/n, where n is the number of alternative modes. All of the models based on factor scores obtain similar preference recoveries which are substantially higher than either the market shares or equally likely models. The models based on three, four and five factors are indistinguishable with respect to preference recovery. As expected, first preference models are slightly better than rank preference models with respect to first preference recovery while rank preference models are slightly better than first preference models with respect to rank preference recovery.

Based on the similarity of the preference recoveries for models based on three, four and five factor dimensions, and the lack of statistical significance of the fourth and fifth dimensions, the three dimensional factor solution was selected to represent consumer perceptions of the three alternative modes. Since the first preference and rank preference models are generally similar, both in terms of explanatory and predictive ability, only first preference models are estimated in the additional analyses reported here.

Model Estimations and Interpretations

The preliminary models investigated above included only factor scores for cognitive dimensions. However, the conceptual model introduced in section 2 states that preference is a function of perceptions and the individual's disposition towards alternatives. Table 6-4 compares a first preference model based on cognitive dimensions and mode specific bias variables (model 1) with a model which includes variables representing mode dispositions as well (model 2). The mode disposition variables (for car, bus, and walk) are all significant and increase the information by

TABLE 6-4

FIRST PREFERENCE LOGIT MODELS

VARIABLE NAME	PARAMETER ESTIMATE (t-statistic) [NORMALIZED IMPORTANCE WEIGHT]*	
	MODEL 1	MODEL 2
General Service and Safety	2.06 (9.81) [.66]	1.70 (7.54) [.35]
Convenience & Accessibility	0.71 (4.54) [.23]	0.51 (3.15) [.11]
Psychological Comfort	0.34 (2.35) [.11]	0.17 (1.11) [.04]
Car Feelings**		0.36 (2.32) [.07]
Bus Feelings**		.93 (3.64) [.20]
Walk Feelings**		1.12 (3.72) [.23]
Bus Constant	-.33 (-1.27)	-1.03 (-3.07)
Walk Constant	.58 (2.04)	-.17 (-.47)
Likelihood Ratio Statistic (χ^2)	527.6	565.7
Information (%) (Pseudo-R^2)	54.2	58.1

*The normalized importance weights reported here exclude dummy variables even where the latter appear in the model.

**The mode feelings were treated as alternative specific variables, as they are defined differently for each mode.

3.9%. Their inclusion does not affect the relative importance among the mode performance variables. Thus, the model which includes mode dispositions is selected as the base preference model for further analyses. These results support the hypothesis that perceptual variables other than perceptions of mode performance influence preference.

From the managerial standpoint, the importance weights in model 2 indicate that the perceptions that most affect preference are "general service and safety" and "convenience and accessibility". Therefore, to have major impact on preference, strategies should be directed at these dimensions. Alternatively, since bus is perceived best, while car is perceived worst, on the psychological comfort dimension (see Figure 3-4), persuasion strategies might be directed at increasing the importance to consumers of this dimension. For example, this might entail stressing the importance of getting to one's destination without the hassles of driving, as in Greyhound's "leave the driving to us" approach.

The conceptual model of consumer travel behavior described in section 2 states that individual and situational differences affect the abstraction and aggregation processes, as well as the formation of choice. The abstraction process is not explicitly considered in this study, and is implicitly assumed to be the same for the whole sample, but the effect of individual and situational differences on preference and choice is discussed in section 8 of this report.

7. CHOICE OF TRAVEL MODE

Model Structure

The conceptual model states that due to situational and availability constraints a consumer does not always choose the transportation mode that he/she most prefers for a particular trip.* For this reason, we develop

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* Approximately 24% of the respondents chose other than their most preferred alternative for their most recent trip to downtown Evanston for non-work non-school purposes.

mode-choice models in addition to the preference models reported above. The choice model postulates that individuals associate a value U_{im} with each alternative and select that alternative which has the greatest value index. The individual value index, U_{im}, for alternative m is a linear combination of the preference index PI_{im}, and variables which reflect availability or situational constraints, S_{jim}, so that

$$U_{im} = \gamma PI_{im} + \sum_j \alpha_j S_{jim} \tag{7-1}$$

where U_{im} = a general value index of individual i for mode m,

PI_{im} = a preference index of individual i for mode m (see equation 6-1),

S_{jim} = the j^{th} situational constraint for individual i for mode m, and

γ, α_j = choice parameters.

The true value index (or "utility") is equal to the estimated index plus a random term which represents unobserved influences as well as specification errors. Under the same distributional assumption as for the logit preference models, we obtain the multinomial logit model (McFadden [1973]), which describes the probability of individual i choosing alternative m, L_{im}, by:

$$L_{im} = \exp(U_{im}) \;/\; \sum_j \exp(U_{ij}) \tag{7-2}$$

There is one major difference in the models reported here and multinomial logit models commonly used in the transportation literature. In the conventional choice models, the weights of all the parameters for variables influencing preference and choice are estimated simultaneously on the hypothesis that they are revealed by the choice decision. However, based on our conceptual model (Figure 2-2), the intermediate preference index PI_{im} is computed for each individual (i) and mode (m), and this index is used along with situational constraints in predicting choice.

The advantage of estimating importance weights by use of the conventional "revealed preference" (McFadden [1973]) choice model is that it does not rely on reported preference data but on reported choice behavior. Furthermore, when repeated choices are made, information on choice frequencies for the available alternatives can be incorporated. The drawback of the revealed preference approach is that the estimates of the importance weights may be biased if the non-preference choice elements are not carefully specified. This would occur if an omitted choice-related variable were correlated with an included variable. Also, the linked-model proposed here allows for improved managerial insight compared to the revealed preference model. Suppose, for example, that a given strategy substantially improves preference for bus but has little effect on the actual use of bus. Although both revealed preference and preference index choice models would reject such a strategy, the linked model would isolate the weakness in the strategy and help identify an improved strategy.

Model Estimation and Interpretation

The situational constraint used in this study is the number of autos per licensed driver in the household (APD). This variable is a measure of the availability of the auto mode. In this section we report the results of estimating mode choice models with and without inclusion of the auto availability index and we compare our hypothesized "preference index" choice model to the more conventional "revealed preference" choice model.

Preference index choice models with (model 3) and without (model 4) the automobile availability index are reported in Table 7-1. Inclusion of

TABLE 7-1

"PREFERENCE INDEX" CHOICE MODELS

	Model 3		Model 4	
	Parameter Estimate (t-statistic)	Normalized Importance Weight*	Parameter Estimate (t-statistic)	Normalized Importance Weight*
General Service and Safety	3.07 (10.61)	.35	3.67 (13.78)	.35
Convenience/ Accessibility		.11		.11
Psychological Comfort		.04		.04
Car Feelings		.07		.07
Bus Feelings		.20		.20
Walk Feelings		.23		.23
Autos per Driver (APD)	.90 (4.56)			
Likelihood Ratio Statistic (χ^2)	464.1		442.5	
Information (%) (Pseudo-R^2)	50.4		48.1	

*Weights as in model 2, Table 6-4.

the automobile availability index produces a significant improvement in the goodness of fit statistic used to evaluate multinomial logit models. This result supports our hypothesis on the influence of situational constraints on mode choice behavior.*

The preference index choice model (model 3) is compared against the revealed preference choice model (model 5) in Table 7-2. In the preference index choice model, the relative values of the parameters for mode perceptions and feelings are constrained to equal the importance weights obtained earlier (model 2, Table 6-4). Thus, the preference index model (model 4) has seven fewer degrees of freedom than the revealed preference model (model 6). We therefore expect that the revealed preference model will have higher, but not significantly higher, goodness of fit to the data.

The revealed preference model fits the data significantly better than the preference index model at the 2.5% level. However, the revealed preference model obtains non-significant parameters for three variables (psychological comfort, car feelings, and bus feelings) which theory suggests are important in the mode selection process.

Given these mixed results, we select the preference index model to describe the travel mode choice decision process. This model correctly predicts 80% of all trip choices and explains 52% of the information in the data set. This compares favorably to random or equally likely models (33% correctly predicted, 0% information) and the market shares model (50% correctly predicted, 29% information).

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*The automobile availability index is included as an additive value in the automobile utility (value index) function. Use of this index as a segmentation variable does not lead to a significant improvement in choice models. Thus, different values of APD appear to position travelers at different points on the same choice function rather than on different functions.

TABLE 7-2

"PREFERENCE INDEX" AND "REVEALED PREFERENCE" CHOICE MODELS

"Preference Index" Model (Model 3)			"Revealed Preference" Model (Model 5)		
	Parameter Estimate (t-statistic)	Normalized Importance Weight*		Parameter Estimate (t-statistic)	Normalized Importance Weights
General Service and Safety	3.07 (10.61)	.35	General Service and Safety	.98 (5.09)	.28
Convenience/ Accessibility		.11	Convenience/ Accessibility	.89 (5.23)	.26
Psychological Comfort		.04	Psychological Comfort	-.08 (-.52)	-.02
Car Feelings		.07	Car Feelings	.26 (1.68)	.07
Bus Feelings		.20	Bus Feelings	.31 (1.51)	.08
Walk Feelings		.23	Walk Feelings	1.00 (3.30)	.28
			Bus Constant	.24 (.71)	
			Walk Constant	-.56 (-1.25)	
Autos per Driver (APD)	.90 (4.56)		Autos per Driver (APD)	.95 (2.88)	
Likelihood ratio statistic (χ^2)	464.1			481.6	
Information (%) (Pseudo-R^2)	50.4			52.3	

*Weights as in model 2, Table 6-4.

8. MARKET SEGMENTATION

General Discussion

The preference and choice models reported earlier treat all respondents as a homogeneous group with respect to their preference and choice function. That is, each respondent is implicitly assumed to map his/her perceptions, feelings and situational constraints to preference and choice in the same manner. In practice, it may be that different groups of consumers are different in the manner in which they form preferences and choice. The behavioral model described earlier explicitly allows for this possibility. In this section, we examine a variety of market segments in an attempt to identify any differences which exist.

The usefulness of market segmentation is based on three distinct but interrelated propositions (Engel et al, [1972]):

- first, "consumers are different" and it is possible to identify differences in consumers with respect to some characteristics;
- second, "differences in consumers are related to differences in market demand" and it is useful to know how differences in characteristics are related to differences in behavior;
- third, "segments of consumers can be isolated within the overall market structure" and these segments can provide the basis for the design and/or marketing of selected transportation services.

The identification of differentiable market segments is important to the design and marketing of improved transportation because:

- it allows the operator to identify services which best meet the wants and needs of selected groups rather than some average service which may not be well suited to any market group, and
- it improves the understanding of the consumer response process and the mathematical representation of future travel behavior.

There are two primary approaches to market segmentation. The first is to identify segments of the population based on descriptive characteristics. This segmentation technique presumes that the identified segments are behaviorally similar and that there are differences between segments. That is, descriptive segmentation is used as a proxy for behavioral segmentation. The second approach is to analytically search for groups which are behaviorally homogeneous. In either case, it is appropriate to test the segments which have been identified to determine whether differences in behavior are significant among groups. Finally, it is useful to relate the identified segments to characteristics which enable the operator to target service improvements to behaviorally distinct groups. In this study, potential market segments are based on descriptive characteristics and tested for significance.

Identification of Potential Segments

Prior segments can be based on any descriptive variables. Those most commonly used are demographic (income, age, sex, auto ownership, etc.), experiential (length of residence, prior use of alternatives), and trip descriptive (length of trip, number of stops made, etc.). Table 8-1 lists the candidate variables considered for segmentation. These variables were subjectively chosen based on the literature and the experience of the research team.

The candidate variables were initially segmented at the most detailed level available in the original data. These candidate variables and different segmentations were initially tested for significant differences in mode preference rankings.* Table 8-2 shows the initial groups for each variable,

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*The test, based on comparison of the preference ranks assigned to each alternative by members of different groups, identifies significance of the original and modified groupings. The test is based on a modification of Friedman's T test (Friedman, [1937]) by Koppelman (1978). This test is described in Appendix G.

TABLE 8-1

CANDIDATE MARKET SEGMENTATION VARIABLES

AGE

EDUCATION

SEX

LENGTH OF RESIDENCE

OCCUPATION

INCOME

DRIVERS LICENSE

NUMBER OF CARS

BLOCKS TO NEAREST BUS STOP

OPINION ABOUT PUBLIC TRANSIT IN EVANSTON

OPINION ABOUT CONGESTION IN EVANSTON

ESTIMATED FREQUENCY OF BUS DURING RUSH HOUR

TRIP PURPOSE

STOPS ON TRIP TO DOWNTOWN EVANSTON

TABLE 8-2

CANDIDATE MARKET SEGMENTS AND RESULTS OF PREFERENCE RANK SCREENING TESTS

VARIABLE	ORIGINAL GROUPING	MODIFIED SEGMENTS	CHI-SQUARE TEST STATISTIC - (DEGREES OF FREEDOM)	LEVEL OF SIGNIFICANCE
AGE	0 - 19			
	20 - 29	≤ 29		
	30 - 39	30 - 59	63.09	
	40 - 49		(4)	
	50 - 59			$p<0.001$
	Over 60	Over 60		
EDUCATION	Elementary School			
	Some High School	Up to high school		
	High School Graduate		26.97	
	Some college/technical school	Some college/technichal school		$p<0.01$
	College/technical school graduate			
	Some graduate school	College graduate and up		
	Graduate degree(s)			
SEX	Male	No significant groups found		
	Female			
LENGTH OF RESIDENCE	Less than 1 year			
	1 - 3 years	Less than 3 years	41.78	
	4 - 6 years			
	7 - 10 years	More than 3 years	(2)	$p<0.001$
	More than 10 years			
OCCUPATION	Full Time Worker			
	Part Time Worker	Non-student	54.14	$p<0.001$
	Home Maker			
	Student	student	(2)	
INCOME	Less than \$10,000	Less than \$10,000		
	\$10,000 - 15,000			
	\$15,000 - 20,000		16.56	
	\$20,000 - 25,000	More than \$10,000	(2)	
	\$25,000 - 50,000			
	Over \$50,000			$p<.001$
DRIVERS LICENSE	Have license	Have license	16.68	$p<.001$
	No license	No license	(2)	

TABLE 8-2 (CONTINUED)

VARIABLE	ORIGINAL GROUPING	MODIFIED SEGMENTS	CHI-SQUARE TEST STATISTIC - (DEGREES OF FREEDOM)	LEVEL OF SIGNIFICANCE
NUMBER OF CARS	No car	no car		
	1 car 2 cars 3 or more cars	1 or more cars	33.80 (2)	p<0.001
BLOCKS TO NEAREST BUS STOP	1 block 1-2 blocks 2-4 blocks 4-8 blocks	No significant groups found		
OPINION ON PUBLIC TRANSIT IN EVANSTON	Very good Good Adequate Poor Very poor	No significant groups found		
OPINION ON CONGESTION IN EVANSTON	Very congested Congested in rush hr. Congested on certain days Occasionally congested Almost never congested	No significant groups found		
ESTIMATED FREQUENCY OF BUS DURING RUSH HOURS	5-10 minutes 10-20 minutes 20-40 minutes 40-60 minutes Over 60 minutes	No significant groups found		
TRIP PURPOSE	Shop	Shop		
	Doctor Eat Bank	Doctor, Eat, Bank	24.5	p<0.01
	Other Multiple	Other & Multiple	(4)	
STOPS ON TRIP TO DOWNTOWN EVANSTON	Yes No	No significant groups found		

modified segments based on similarities in preference ranking, and tests of significance of different preference ranking between the modified segments. Of the categories for which significant groups could be identified (see table 8-2); occupation, income, drivers license and number of cars were dropped because in each case one of the two groups had a very small percentage of the observations, thus precluding the estimation of preference and choice models. Thus, the classifications considered for preference and choice segmentation analysis are age, education, length of residence, and trip purpose.

Preference Segmentation Analysis

First preference logit models were estimated for each of the segments identified above. For each candidate variable, the models for the individual segments were compared to a model for the group as a whole.* Each candidate segmentation was tested to determine if it is significantly better than the grouped model in terms of goodness of fit measures.**

The results of this test for each potential segmentation strategy are summarized in Table 8-3 and reported in detail in Appendix F. None of the segmented models is significantly better than the corresponding group model at the .05 level. This suggests that consumers in the segments tested form their mode preferences similarly. This result is consistent with tests of socio-demographic preference segmentation in other service categories (Hauser and Urban [1977]).

More detailed study of the model parameters in the segments examined indicates that while there is no significant difference between the models in these segments, the significance and relative importance of the different

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* The sample used for estimating the "group model" is different for different segmentation variables due to missing data on some variables.

**A description of the test used is provided in Appendix E.

TABLE 8-3

SUMMARY OF PREFERENCE MODEL SEGMENTATION ANALYSIS

VARIABLE	CATEGORIES	CHI-SQUARE TEST STATISTIC*	DEGREES OF FREEDOM	LEVEL OF SIGNIFICANCE	DETAILS IN APPENDIX F TABLE
AGE	$\leq$ 29 30-59 over 60	23.4	16	-	F-1
EDUCATION	Up to high school Some college/ tech. school College grad. and up	22.1	16	-	F-2
TRIP PURPOSE	Shop Doctor, Eat, Bank Other & Multiple	16.4	16	-	F-3
LENGTH OF RESIDENCE	Less than 3 years More than 3 years	4.9	8	-	F-4

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*The chi-square statistic, for $\alpha = 0.05$, has the following values:

with 16 degrees of freedom, $\chi^2 = 26.3$

with 8 degrees of freedom, $\chi^2 = 15.51$

variables varies widely between the segments. For example, car feelings is important only to those between the ages of 30 and 59, well educated, who have lived in Evanston for more than three years.* Thus strategies aimed at influencing auto disposition may have an important impact on this group of people, but will likely have very little impact on other groups. At the same time, such strategies are likely to have more impact on trips for medical purposes, to eat out or go to the bank, than for other trips, including shopping. Therefore, while insignificant overall, the preference segmentation analysis leads to useful interpretations.

Choice Segmentation Analysis

Tests of choice segmentation are performed using the preference index computed in equation 6-1 and based on the common set of importance weights estimated for preference model 2 in Table 6-4. Results of this segmentation analysis are reported in Appendix H and summarized in Table 8-4. Significant segmentations by age and education level were obtained in this case. While the preference index is statistically significant in all the segments examined, the autos per driver variable is significant for the 30-59 age group and the college educated group, as well as in both length of residence categories. These age and education segments were previously identified as being more sensitive to car feelings in preference formation than other age and education groups.

Thus it appears useful to employ segmentation by either age or education in further analysis or prediction of mode choice behavior.

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*There is considerable overlap between these groups in the data examined.

TABLE 8-4

SUMMARY OF CHOICE MODEL SEGMENTATION ANALYSIS

VARIABLE	CATEGORIES	CHI-SQUARE TEST STATISTIC	DEGREES OF FREEDOM	LEVEL OF SIGNIFICANCE	DETAILS IN APPENDIX H TABLE
AGE	$\leq$ 29 30-59 over 60	23.3	4	$p<0.001$	H-1
EDUCATION	Up to high school Some college/ tech. school College grad. and up	18.0	4	$p<0.025$	H-2
TRIP PURPOSE	Shop Doctor, Eat, Bank Other & Multiple	2.1	4	-	H-3
LENGTH OF RESIDENCE	Less than 3 years More than 3 years	0.1	2	-	H-4

9. SUMMARY

This report describes in detail the application of a consumer oriented transportation service planning methodology to the development of travel mode choice models, in the context of nonwork/nonschool trips to downtown Evanston. In addition, details of the technical procedures employed are provided. The need for an improved understanding of consumer travel behavior is acknowledged by those concerned with the planning, provision and financing of transportation services. The approach described in the COTS reports provides important diagnostic information about travel behavior, thus assisting in the development of appropriate strategies, as discussed below.

Underlying the proposed methodology is a conceptual model of the interrelationships between system characteristics, perceptions, preference, constraints and choice (Figure 2-1). The structure of this model is confirmed through a detailed examination of the correlations among these variables (Section 5).

The conceptual model is operationalized in the form of component models of perceptions, feelings, preference and choice. These component models, and their interrelationships, are based on the proposed conceptual model (Figure 2-2). Both the perception and feelings measures are operationalized using factor analysis. Factor scores, determined from these analyses, are used in both preference and choice models. The results of such model-building efforts indicate that powerful mode preference and choice models can be estimated using these perceptual and feelings measures as explanatory variables. In particular, the research indicates that psychological measures of mode feelings as well as perceptions of mode performance are important in consumers' preferences for and, hence, choice of travel modes. This has important implications for strategy development.

Conventionally, individual mode choice models are of the "revealed preference" type. That is, observed (or reported) choice behavior is assumed to reveal the consumer's preferences. The conceptual model proposed here considers choice to be determined by preference and situational constraints, such as car availability. In other words, certain constraints are considered to mediate between preference and choice. (Approximately 24% of the sample did not choose their most preferred mode.) This concept is operationalized by using a "preference index" and a measure of car availability (autos per licensed driver) a "preference index" choice model. In the case of this data set, the revealed preference and preference index models yield similar results. The revealed preference model fits the data significantly better than the preference index model at the 2.5% level. However, the preference index model was selected as it provided results which are more easily interpreted and which are consistent with the theory.

The consumer oriented transportation service planning methodology provides important information about consumer travel behavior, allowing transportation poanners and managers to respond to consumers' needs and desires with respect to travel services. Report number 1 in this series presents a detailed description of the use of this approach for developing and evaluating various strategies.

Appendices

A - Common Factor Analysis

B - Factor Loadings for Mode Perceptions

C - Factor Loadings for Mode Feelings

D - Information Measure

E - Modified Friedman Test

F - First Preference Model Segmentation Analysis

G - Chi Square Test of Market Segments

H - Choice Model Segmentation Analysis

APPENDIX A

COMMON FACTOR ANALYSIS

Appendix A

Common Factor Analysis

This appendix provides a brief description of the common factor analysis model, as used in the COTSP research. It is not intended as a detailed discussion of the technique, for this the reader is referred to Rummel (1970).

The common factor analysis model assumes that consumer ratings of attributes include a common component which represents underlying dimensions, an attribute specific (or unique) component, and some measurement error. (see Figure A-1). Thus, the common factor analysis model is consistent with the theory that consumers perceive alternatives in terms of a small set of underlying dimensions (Bruner et al, 1956). Mathematically, the model is written as:

$$t_{im\ell} = \sum_k g_{\ell k} y_{imk} + s_\ell y^*_{i\ell} + e_{i\ell} \qquad (1)$$

where $t_{im\ell}$ = individual i's rating of mode m on attribute ℓ

$g_{\ell k}$ = loading of attribute ℓ on factor k

y_{imk} = factor score representing consumer i's perception of mode m along dimension k

s_ℓ = loading of the unique factor for attribute ℓ

$y^*_{i\ell}$ = factor score associated with the unique component of attribute ℓ, for individual i

$e_{i\ell}$ = error term associated with individual i and attribute ℓ

Both $g_{\ell k}$ and s_ℓ are assumed to be the same for all individuals in the sample, since they are estimated across individuals. Furthermore, we assume that they are the same for all modes (m) and we carry out the factor analysis across modes. While equation (1) above appears similar to a linear regression model, we note that neither the factor scores nor the factor loadings are known.

The factor loadings ($g_{\ell k}$) can be found by "factoring" the data correlation matrix with "communalities" replacing the unities on the diagonal of the correlation matrix (Rummel, 1970). However, these communalities are not known, only their upper and lower bounds (1 and squared multiple correlations, respectively) are known. Thus the solution procedure is an iterative one, beginning with squared multiple correlations on the diagonal of the correlation matrix. The factor loadings found in this way have the useful interpretation of being the correlation between the attribute and the factor, when the factors are orthogonal. That is, $g_{\ell k}$ is the correlation between attribute ℓ and factor k, while $g_{\ell k}^2$ represents the proportion of the variance in attribute ℓ accounted for by factor k. Thus, examination of a factor loadings matrix (for example, Table B-2) facilitates the interpretation of each underlying dimension (factor).

As a result of the common factor analysis solution process, an expression for the factor scores (y_{imk}) can be obtained by assuming the following linear regression model to hold:

$$y_{imk} = \sum_{\ell} \beta_{k\ell} \, t_{im\ell} + e_{ik} \tag{2}$$

where the β's are termed factor score coefficients. Solution of this equation* yields the factor scores which we employ as measures of perceptions and feelings in preference and choice models. The use of the factor scores in the preference and choice models enables each factor to represent the range of characteristics included in that factor. Further, these factor scores provide more reliable measures than would be obtained if the factor were replaced by a single representative variable.

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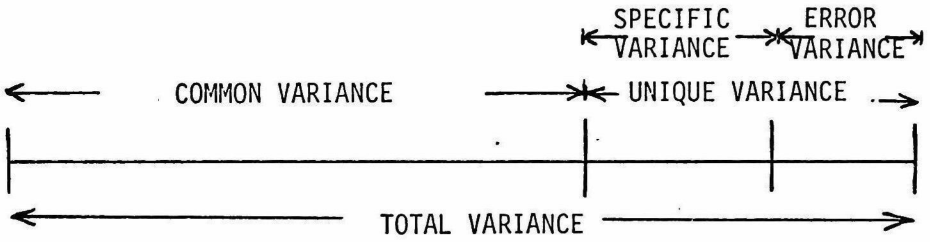
*Solution of equation (2) requires inversion of the data correlation matrix. If this matrix is nearly singular, unstable estimates of the factor scores will be obtained. As a result, one is sometimes forced to use the principal components factor model, where this problem does not exist.

Figure A-1

Components of Variance in the Common Factor Model



APPENDIX B

FACTOR LOADINGS FOR MODE PERCEPTIONS

TABLE B-3

FACTOR LOADINGS FOR 4 DIMENSIONAL FACTOR ANALYSIS OF 24 ATTRIBUTE RATINGS FOR BUS, WALK AND CAR

ATTRIBUTES RATED	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
ON TIME	.55	.41	-.09	.11
NO TRIP SCHEDULING NECESSARY	.25	.28	-.27	.00
RELAXING	.50	.12	.28	.04
CORRECT TEMPERATURE	.55	.02	.07	.19
NO WORRY OF ASSAULT	.34	.05	.17	.68
CAN COME AND GO AS I WISH	.24	.69	-.02	.02
ERRANDS TAKE LITTLE TIME	.68	.30	-.09	.11
NO WORRY ABOUT INJURY	.10	-.06	.39*	.40*
KNOW HOW TO GET AROUND	.09	.33	.20	.06
LITTLE EFFORT INVOLVED	.74	.06	.26	-.03
AVAILABLE WHEN NEEDED	.02	.67	.11	-.01
NOT MADE UNCOMFORTABLE BY OTHERS	.04	.21	.51	.17
NO PROBLEMS IN BAD WEATHER	.63	-.04	.14	.08
PLEASANT DRIVERS OR OTHER PERSONNEL	.09	.06	.36	-.03
GET TO DESTINATION QUICKLY	.79	.15	-.01	.03
PROTECTED FROM SMOKING	.09	.40	.02	.09
SAFE AT NIGHT	.52*	.05	-.03	.50*
NOT ANNOYED BY OTHERS	.04	.10	.51	.08
NO LONG WAITS	.17	.64	.01	-.05
EASILY CARRY PACKAGES	.65	.17	-.15	.27
EASY TO TRAVEL WITH SMALL CHILDREN	.57	.07	-.11	.15
NOT TIRING	.80	-.03	.21	.06
EASY GETTING IN AND OUT	-.14	.49	.32	-.04
EASY WALK ACCESS	-.10	.46	.32	-.06

Factor Interpretation:

Factor 1 - General Service
Factor 2 - Convenience and Accessibility
Factor 3 - Psychological Comfort
Factor 4 - Safety

*Attributes which load on more than one dimension

TABLE B-4

FACTOR LOADINGS FOR 5 DIMENSIONAL FACTOR ANALYSIS OF 24 ATTRIBUTE RATINGS FOR BUS, WALK AND CAR

ATTRIBUTES RATED	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
ON TIME	.49*	.50*	.00	.10	-.04
NO TRIP SCHEDULING NECESSARY	.21	.34	-.21	.01	-.04
RELAXING	.47	.18	.36	-.01	-.06
CORRECT TEMPERATURE	.56	.04	.06	.19	.03
NO WORRY OF ASSAULT	.33	.07	.23	.65	-.03
CAN COME AND GO AS I WISH	.18	.70	.04	.01	.14
ERRANDS TAKE LITTLE TIME	.63	.40	-.01	.10	-.07
NO WORRY ABOUT INJURY	.09	-.06	.45	.37	-.03
KNOW HOW TO GET AROUND	.09	.25	.18	.05	.24
LITTLE EFFORT INVOLVED	.74	.09	.26	-.05	.02
AVAILABLE WHEN NEEDED	-.01	.59	.12	-.00	.30
NOT MADE UNCOMFORTABLE BY OTHERS	.02	.16	.55	.14	.13
NO PROBLEMS IN BAD WEATHER	.64	-.02	.12	.07	.01
PLEASANT DRIVERS OR OTHER PERSONNEL	.10	-.01	.32	-.05	.16
GET TO DESTINATION QUICKLY	.76	.25	.03	.02	-.07
PROTECTED FROM SMOKING	.06	.40	.06	.08	.09
SAFE AT NIGHT	.52*	.09	.00	.51*	-.02
NOT ANNOYED BY OTHERS	.04	.05	.53	.04	.11
NO LONG WAITS	.11	.65	.07	-.06	.14
EASILY CARRY PACKAGES	.65	.22	-.14	.29	.01
EASY TO TRAVEL WITH SMALL CHILDREN	.58	.10	-.13	.17	.03
NOT TIRING	.80	.02	.22	.04	-.02
EASY GETTING IN AND OUT	-.11	.28	.19	-.02	.57
EASY WALK ACCESS	-.05	.23	.17	-.04	.65

Factor Interpretation:

- Factor 1 - General Service
- Factor 2 - Convenience
- Factor 3 - Psychological Comfort
- Factor 4 - Safety
- Factor 5 - Accessibility

*Attributes which load on more than one dimension.

APPENDIX C

FACTOR LOADINGS FOR MODE FEELINGS

TABLE B-1

FACTOR LOADINGS FOR 2 DIMENSIONAL FACTOR ANALYSIS OF 24 ATTRIBUTE RATINGS FOR BUS, WALK AND CAR

ATTRIBUTES RATED	FACTOR 1	FACTOR 2
ON TIME	.56	.35
NO TRIP SCHEDULING NECESSARY	.23	.17
RELAXING	.49	.20
CORRECT TEMPERATURE	.59	.04
NO WORRY OF ASSAULT	.49	.08
CAN COME AND GO AS I WISH	.24	.63
ERRANDS TAKE LITTLE TIME	.68	.25
NO WORRY ABOUT INJURY	.21	.06
KNOW HOW TO GET AROUND	.10	.38
LITTLE EFFORT INVOLVED	.70	.14
AVAILABLE WHEN NEEDED	.02	.67
NOT MADE UNCOMFORTABLE BY OTHERS	.10	.34
NO PROBLEMS IN BAD WEATHER	.63	.00
PLEASANT DRIVERS OR OTHER PERSONNEL	.08	.17
GET TO DESTINATION QUICKLY	.77	.14
PROTECTED FROM SMOKING	.12	.38
SAFE AT NIGHT	.63	.03
NOT ANNOYED BY OTHERS	.07	.24
NO LONG WAITS	.15	.60
EASILY CARRY PACKAGES	.70	.10
EASY TO TRAVEL WITH SMALL CHILDREN	.59	.03
NOT TIRING	.78	.04
EASY GETTING IN AND OUT	-.14	.57
EASY WALK ACCESS	-.10	.55

Factor Interpretation:

Factor 1 - General Service and Safety
Factor 2 - Convenience and Accessibility

TABLE B-2

FACTOR LOADINGS FOR 3 DIMENSIONAL FACTOR ANALYSIS OF 24 ATTRIBUTE RATINGS FOR BUS, WALK AND CAR

ATTRIBUTES RATED	FACTOR 1	FACTOR 2	FACTOR 3
ON TIME	.57	.40	-.08
NO TRIP SCHEDULING NECESSARY	.26	.27	-.27
RELAXING	.48	.14	.26
CORRECT TEMPERATURE	.58	.01	.11
NO WORRY OF ASSAULT	.48	.00	.30
CAN COME AND GO AS I WISH	.25	.68	-.04
ERRANDS TAKE LITTLE TIME	.69	.29	-.08
NO WORRY ABOUT INJURY	.18	-.07	.47
KNOW HOW TO GET AROUND	.09	.33	.20
LITTLE EFFORT INVOLVED	.69	.09	.21
AVAILABLE WHEN NEEDED	.02	.67	.09
NOT MADE UNCOMFORTABLE BY OTHERS	.06	.22	.54
NO PROBLEMS IN BAD WEATHER	.62	-.03	.14
PLEASANT DRIVERS OR OTHER PERSONNEL	.06	.09	.33
GET TO DESTINATION QUICKLY	.77	.16	-.03
PROTECTED FROM SMOKING	.12	.38	.04
SAFE AT NIGHT	.62	.00	.10
NOT ANNOYED BY OTHERS	.04	.12	.51
NO LONG WAITS	.16	.64	-.03
EASILY CARRY PACKAGES	.71	.13	-.08
EASY TO TRAVEL WITH SMALL CHILDREN	.59	.06	-.08
NOT TIRING	.77	.00	.19
EASY GETTING IN AND OUT	-.15	.51	.29
EASY WALK ACCESS	-.12	.48	.28

Factor Interpretation:

Factor 1 - General Service and Safety
Factor 2 - Convenience and Accessibility
Factor 3 - Psychological Comfort

TABLE C-1

FACTOR LOADINGS FOR 3 DIMENSIONAL FACTOR ANALYSIS OF 27 FEELING STATEMENT RATINGS

FEELING DESCRIPTION	FACTOR 1	FACTOR 2	FACTOR 3
DIFFERENT FROM BUS RIDERS	.00	-.31	-.03
ENJOY TRAVEL BY CAR	-.32	-.02	.61
ENJOY TRAVEL BY BUS	-.14	.62	.14
ENJOY TRAVEL BY FOOT	.73	.03	.12
DEPRESSING TO TRAVEL BY CAR	.13	-.15	-.72
DEPRESSING TO TRAVEL BY BUS	.00	-.61	-.30
DEPRESSING TO TRAVEL BY FOOT	-.64	-.15	-.31
PEERS SURPRISED IF RIDE BUS REGULARLY	-.11	-.58	.05
OUGHT TO TRAVEL BY CAR	-.51	-.21	.33
OUGHT TO TRAVEL BY BUS	.03	.48	-.06
OUGHT TO TRAVEL BY FOOT	.70	-.07	.01
PEERS SURPRISED IF DROVE CAR REGULARLY	.17	.15	-.23
IF WEATHER BAD, FEWER CAR TRIPS	-.08	.11	-.20
IF WEATHER BAD, FEWER BUS TRIPS	-.19	-.34	-.05
IF WEATHER BAD, FEWER WALK TRIPS	-.22	-.05	.03
IF GASOLINE PRICE DOUBLED, MORE CAR TRIPS	-.26	-.21	.11
IF GASOLINE PRICE DOUBLED, MORE WALK TRIPS	.69	-.03	.05
IF GASOLINE PRICE DOUBLED, MORE CAR POOL TRIPS	.14	.11	.27
IF GASOLINE PRICE DOUBLED, FEWER CAR ALONE TRIPS	.13	.21	.13
PEERS SURPRISED IF WALKED ALOT	-.66	-.16	.09
IF BUS FARES LOWER, MORE TRIPS BY BUS	.08	.55	-.27
IF BUS FARES LOWER, FEWER TRIPS BY CAR	.06	.53	-.27
IF BUS RAN MORE OFTEN, MORE BUS TRIPS	.20	.33	-.21
WOULD TRAVEL BY CAR REGARDLESS OF COST	-.41	-.42	.29
WOULD TRAVEL BY BUS EVEN IF LONG WALK	.11	.44	.03
IF PARKING COST DOUBLED WOULD WALK	.41	.04	-.02
WILLING TO CAR POOL SOME TRIPS	.05	-.01	.29

Factor Interpretation

Factor 1 - Walk Disposition
Factor 2 - Bus Disposition
Factor 3 - Car Disposition

TABLE C-2

FACTOR LOADINGS FOR 4 DIMENSIONAL FACTOR ANALYSIS OF 27 FEELING STATEMENT RATINGS

FEELING DESCRIPTION	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
DIFFERENT FROM BUS RIDERS	.05	-.25	.09	-.24
ENJOY TRAVEL BY CAR	-.19	.09	.64	.09
ENJOY TRAVEL BY BUS	-.06	.73	.12	-.15
ENJOY TRAVEL BY FOOT	.82	.08	.02	-.07
DEPRESSING TO TRAVEL BY CAR	.03	-.23	-.62	-.28
DEPRESSING TO TRAVEL BY BUS	-.08	-.69	-.26	-.08
DEPRESSING TO TRAVEL BY FOOT	-.69	-.18	-.14	-.14
PEERS SURPRISED IF RIDE BUS REGULARLY	-.06	-.52	.21	-.19
OUGHT TO TRAVEL BY CAR	-.41	-.12	.48	-.07
OUGHT TO TRAVEL BY BUS	.01	.46	-.15	.03
OUGHT TO TRAVEL BY FOOT	.69	-.08	-.12	.04
PEERS SURPRISED IF DROVE CAR REGULARLY	.16	.14	-.25	-.14
IF WEATHER BAD, FEWER CAR TRIPS	-.09	.10	-.16	-.13
IF WEATHER BAD, FEWER BUS TRIPS	-.21	-.34	.05	-.03
IF WEATHER BAD, FEWER WALK TRIPS	-.24	-.07	.05	.08
IF GASOLINE PRICE DOUBLED, MORE CAR TRIPS	-.15	-.09	.31	-.35
IF GASOLINE PRICE DOUBLED, MORE WALK TRIPS	.63	-.09	-.15	.25
IF GASOLINE PRICE DOUBLED, MORE CAR POOL TRIPS	.06	.04	.10	.58
IF GASOLINE PRICE DOUBLED, FEWER CAR ALONE TRIPS	.04	.12	-.06	.46
PEERS SURPRISED IF WALKED ALOT	-.62	-.11	.26	-.10
IF BUS FARES LOWER, MORE TRIPS BY BUS	-.02	.45	-.43	.12
IF BUS FARES LOWER, FEWER TRIPS BY CAR	-.03	.44	-.41	.10
IF BUS RAN MORE OFTEN, MORE BUS TRIPS	.14	.26	-.32	.04
WOULD TRAVEL BY CAR REGARDLESS OF COST	-.28	-.29	.51	-.23
WOULD TRAVEL BY BUS EVEN IF LONG WALK	.14	.46	-.05	-.04
IF PARKING COST DOUBLED WOULD WALK	.40	.04	-.10	.01
WILLING TO CAR POOL SOME TRIPS	-.01	-.10	.17	.59

Factor Interpretation

Factor 1 - Walk Disposition
Factor 2 - Bus Disposition
Factor 3 - Car Disposition
Factor 4 - Carpool Receptivity

TABLE C-3

FACTOR LOADINGS FOR 5 DIMENSIONAL FACTOR ANALYSIS OF 27 FEELING STATEMENT RATINGS

FEELING DESCRIPTION	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
DIFFERENT FROM BUS RIDERS	.05	-.23	.05	-.13	-.26
ENJOY TRAVEL BY CAR	-.18	.05	.72	-.12	-.01
ENJOY TRAVEL BY BUS	-.06	.76	.09	.09	-.11
ENJOY TRAVEL BY FOOT	.81	.08	.01	-.01	-.08
DEPRESSING TO TRAVEL BY CAR	.01	-.17	-.75	.03	-.18
DEPRESSING TO TRAVEL BY BUS	-.08	-.69	-.26	-.07	-.09
DEPRESSING TO TRAVEL BY FOOT	-.69	-.16	-.17	-.03	-.11
PEERS SURPRISED IF RIDE BUS REGULARLY	-.05	-.54	.20	-.18	-.27
OUGHT TO TRAVEL BY CAR	-.41	-.11	.46	-.18	-.14
OUGHT TO TRAVEL BY BUS	.01	.47	-.15	.14	.08
OUGHT TO TRAVEL BY FOOT	.69	-.06	-.14	-.02	.05
PEERS SURPRISED IF DROVE CAR REGULARLY	.14	.19	-.31	.03	-.07
IF WEATHER BAD, FEWER CAR TRIPS	-.09	.12	-.19	.05	-.10
IF WEATHER BAD, FEWER BUS TRIPS	-.22	-.27	-.06	-.22	.00
IF WEATHER BAD, FEWER WALK TRIPS	-.25	-.05	.02	-.07	.10
IF GASOLINE PRICE DOUBLED, MORE CAR TRIPS	-.16	.00	.16	-.28	-.33
IF GASOLINE PRICE DOUBLED, MORE WALK TRIPS	.65	-.16	-.04	.13	.21
IF GASOLINE PRICE DOUBLED, MORE CAR POOL TRIPS	.06	.06	.10	-.07	.62
IF GASOLINE PRICE DOUBLED, FEWER CAR ALONE TRIPS	.05	.07	.04	.13	.44
PEERS SURPRISED IF WALKED ALOT	-.62	-.08	.20	-.16	-.11
IF BUS FARES LOWER, MORE TRIPS BY BUS	.02	.16	-.02	.85	.00
IF BUS FARES LOWER, FEWER TRIPS BY CAR	.01	.17	-.04	.78	-.01
IF BUS RAN MORE OFTEN, MORE BUS TRIPS	.16	.15	-.16	.36	.01
WOULD TRAVEL BY CAR REGARDLESS OF COST	-.31	-.16	.30	-.45	-.22
WOULD TRAVEL BY BUS EVEN IF LONG WALK	.14	.50	-.09	.06	.01
IF PARKING COST DOUBLED WOULD WALK	.41	.05	-.11	.01	.02
WILLING TO CAR POOL SOME TRIPS	-.03	-.06	.15	-.13	.63

Factor Interpretation

Factor 1 - Walk Disposition
Factor 2 - Bus Disposition
Factor 3 - Car Disposition
Factor 4 - Fare Sensitivity
Factor 5 - Carpool Receptivity

APPENDIX D

INFORMATION MEASURE

Appendix D

Information Measure

A commonly used goodness-of-fit measure in the evaluation of individual choice models is the likelihood ratio index, as defined by McFadden, (1973). This measure is analogous to the R^2 commonly employed in linear regression, and is based on the value of the likelihood function:

$$\rho^2 = 1 - \frac{L_M(x)}{L_o} \qquad (1)$$

where $L_m(x)$ = log likelihood of the estimated model, M, with parameters, x,

L_o = log likelihood of the null (or base) model against which we wish to test model M

Note that $0 \leq \rho^2 \leq 1$, as long as the parameters of the null model are a subset of the parameters of model M. (Hence the commonly used "pseudo-R^2" term for ρ^2).

Hauser (1978) uses information theoretic concepts to provide an alternative interpretation structure for the likelihood ratio index. Let p_{ij}^o be the predicted probability that individual i chooses alternative j for the null model and let p_{ij}^M be this predicted probability for model M. Let $g_{ij} = 1$ if i selects j, and 0 otherwise. Then the information measure for the M^{th} model, $I_o(M)$, is given by:

$$I_o(M) = \frac{1}{I} \sum_i \sum_{j \varepsilon A_i} g_{ij} \log(p_{ij}^M / p_{ij}^o) \qquad (2)$$

where I = number of individuals in the sample

A_i = choice set for individual i

A suitable yardstick against which to measure this model is the information contained in a model that predicts each choice perfectly. Thus the maximum information is given by:

$$I_o(\max) = \frac{1}{I} \sum_i \sum_{j \varepsilon A_i} g_{ij} \log(g_{ij}/p^o_{ij}) \qquad (3)$$

The uncertainty explained by model M can thus be expressed by the proportion

$$U^2_M = I_o(M)/I_o(\max) \qquad (4)$$

Hauser (1978) has shown that as long as the null hypothesis against which we wish to test our model is independent of i, then U^2_M (equation (4)) is numerically equal to ρ^2 (equation (1)). Two commonly used null models, that are independent of i, are the equally likely model (equal probabilities of selection for all alternatives), and the market shares model (probabilities of selection given by market shares).

In the COTS research we refer to the information explained by a model, as opposed to the commonly used likelihood ratio index, although they are numerically the same in the case of the equally likely and market shares null models. This practice is adopted because of the intuitive interpretability of the information measure, as opposed to the likelihood ratio index.

Appendix E

Modified Friedman Test

Those variables considered as candidates for use in market segmentation were initially screened using a modification, due to Koppelman (1978), of Friedman's (1937) rank agreement test. This appendix provides a brief description of the approach and test statistics employed.

If a large number of individuals rank order a set of stimuli (e.g., modes) according to a common criterion (e.g., preference), then similarity of rank order between pairs (or within groups) of individuals suggests a similarity in the way those individuals apply that criterion. Let the rank assigned to the j^{th} stimulus by the b^{th} individual be R_{jb}. Let $\overline{R}_j$ be the average of the assigned ranks for the j^{th} stimulus provided by the B individuals selected from the population. Let the mean of $\overline{R}_j$ across the J stimuli be designated $\overline{R}$. The statistic:

$$T = \frac{12\ B}{(J+1)J} \sum_j (\overline{R}_j - \overline{R})^2 \qquad (1)$$

is asymptotically distributed as chi-square with (J-1) degrees of freedom, provided that B is sufficiently large.*

This distribution of T is based on the null hypothesis that there is no agreement in ranking among individuals in the population, i.e.,

$$H_o: \ \overline{R}_1 = \overline{R}_2 = \ldots . = \overline{R}_J \qquad (2)$$

When the null hypothesis is false the $\overline{R}_J$ will vary from the mean value, T will be large, and we will tend to reject the null hypothesis (2). Thus T provides a suitable test of common rank ordering patterns for an entire population.

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*Friedman (1937) shows that the distribution is almost exactly chi-square for values of B greater than 6.

Koppelman (1978) has extended this notion to test:

(i) common rank ordering within a number of population segments, and

(ii) different rank ordering between population segments.

The statistic for testing the null hypothesis of no agreement in rank structure within any of a number of groups is:

$$T' = \frac{12\ B}{J(J+1)} \sum_n B_n \sum_j (\overline{R}_{jn} - \overline{R})^2 \qquad (3)$$

where B_n is the number of individuals in the n^{th} population segment, and $\overline{R}_{jn}$ is the mean of $\overline{R}_j$ in the n^{th} segment.

T' is chi-square distributed with $N(J-1)$ degrees of freedom (Koppelman, 1978), where N is the number of segments analyzed. Large values of T' indicate a systematic ranking pattern within some or all of the selected subgroups.

However, T' as defined in (3) is determined solely by within segment rank agreement, and provides no information on the between segment agreement or disagreement. Koppelman (1978) shows this by decomposition of T' into 2 components. This decomposition reveals that:

$$\Delta T = T'-T = \frac{12}{J(J+1)} \sum_n B_n \sum_j (\overline{R}_{jn} - \overline{R}_j) \qquad (4)$$

provides a suitable test of the null hypothesis that there is no difference between groups, i.e.,

$$H_o\colon\ \overline{R}_{jn} = \overline{R}_j \quad \forall_j, n\ . \qquad (5)$$

Under a more restrictive null hypothesis, namely:

$$H_o\colon\ \overline{R}_{jn} = \overline{R}_j\ \underline{\text{and}}\ \overline{R}_j = \overline{R} \quad \forall_j, n \qquad (6)$$

ΔT is shown by Koppelman (1978) to be a chi-square random variable with $(N-1)(J-1)$ degrees of freedom. Koppelman also shows that the use of ΔT provides a conservative test of the null hypothesis we actually wish to test (5).

Thus the use of this test will result in the identification of market segments which are more highly differentiated than we might otherwise expect.

APPENDIX F

FIRST PREFERENCE MODEL SEGMENTATION ANALYSIS

TABLE F-1

FIRST PREFERENCE MODEL SEGMENTATION ANALYSIS

SEGMENTATION VARIABLE: AGE

Variable Name	Model Parameter (t-statistic) [Normalized Importance Weight]			
	SEGMENT			OVERALL
	≤ 29	30-59	≥ 60	
General Service and Safety	1.77 (4.03) [.31]	1.51 (4.48) [.32]	2.16 (3.43) [.30]	1.70 (7.54) [.35]
Convenience and Accessibility	.21 (.72) [.04]	.56 (2.16) [.12]	.68 (1.73) [.09]	.51 (3.15) [.11]
Psychological Comfort	.37 (1.39) [.06]	.13 (.54) [.03]	.02 (.04) [.00]	.17 (1.11) [.04]
Car Feelings	.18 (.63) [.03]	.62 (2.75) [.14]	-.32 (-.71) [-.04]	.36 (2.32) [.07]
Bus Feelings	2.44 (2.28) [.42]	.72 (2.28) [.15]	1.06 (1.76) [.15]	.93 (3.64) [.20]
Walk Feelings	.83 (1.57) [.14]	1.16 (2.34) [.25]	2.92 (2.25) [.41]	1.12 (3.72) [.23]
Bus Constant	-3.53 (-2.32)	-.88 (-1.81)	-.51 (-.81)	-1.03 (-3.07)
Walk Constant	.38 (.53)	-.91 (-1.52)	1.11 (1.30)	-.17 (-.47)
Number of Cases	132	231	80	443
Likelihood Ratio Statistic (χ^2)	164.2	314.7	110.2	565.7
Information (%) (Pseudo-R^2)	56.6	62.0	62.7	58.1

χ^2_{16} for segmentation = (164.2 + 314.7 + 110.2) - 565.7 = 23.4

Non-significant at the .05 level

TABLE F-2

FIRST PREFERENCE MODEL SEGMENTATION ANALYSIS

SEGMENTATION VARIABLE: EDUCATION

Variable Name	Model Parameter (t-statistic) [Normalized Importance Weight			
	SEGMENT			OVERALL
	High School	Some College	College Grad.	
General Service and Safety	1.10 (1.58) [.24]	1.71 (3.40) [.17]	2.10 (6.65) [.44]	1.68 (7.48) [.36]
Convenience and Accessibility	.74 (1.44) [.16]	.52 (1.49) [.05]	.51 (2.21) [.11]	.50 (3.10) [.11]
Psychological Comfort	.06 (.10) [.01]	.16 (.50) [.02]	.23 (1.18) [.05]	.17 (1.12) [.04]
Car Feelings	-.17 (-.31) [-.04]	.64 (1.63) [.07]	.41 (2.08) [.09]	.36 (2.33) [.08]
Bus Feelings	.61 (.95) [.13]	5.83 (2.83) [.59]	.49 (1.63) [.10]	.90 (3.55 [.19]
Walk Feelings	1.89 (1.59) [.41]	.94 (1.44) [.10]	1.00 (2.66) [.21]	1.12 (3.71) [.24]
Bus Constant	-1.10 (-1.45)	-5.20 (-2.50)	-.57 (-1.31)	-1.04 (-3.11)
Walk Constant	-1.18 (-.91)	.23 (.27)	.11 (.25)	-.18 (-.50)
Number of Cases	49	99	292	440
Likelihood Ratio Statistic (χ^2)	57.6	138.1	387.0	560.6
Information (%) (Pseudo-R^2)	53.5	63.5	60.3	58.0

χ^2_{16} for segmentation = (57.6 + 138.1 + 387.0) - 560.6 = 22.1

Non-significant at the .05 level

TABLE F-3

FIRST PREFERENCE MODEL SEGMENTATION ANALYSIS

SEGMENTATION VARIABLE: PURPOSE

Variable Name	Model Parameter (t-statistic) [Normalized Importance Weights]			
	SEGMENT			OVERALL
	Shop	Doctor, eat, bank	Other	
General Service and Safety	1.86 (5.06) [.37]	2.32 (4.63) [.44]	1.29 (2.94) [.25]	1.77 (7.65) [.37]
Convenience and Accessibility	.56 (2.36) [.11]	.55 (1.45) [.10]	.31 (.98) [.06]	.51 (3.12) [.11]
Psychological Comfort	.09 (.43) [.02]	.03 (.09) [.01]	.49 (1.58) [.10]	.15 (.96) [.03]
Car Feelings	.23 (.98) [.05]	.64 (1.96) [.12]	.47 (1.30) [.09]	.34 (2.17) [.07]
Bus Feelings	.54 (1.26) [.11]	1.27 (2.68) [.24]	1.32 (2.56) [.26]	.96 (3.73) [.20]
Walk Feelings	1.69 (3.14) [.34]	.43 (.83) [.08]	1.25 (1.81) [.24]	1.08 (3.57) [.22]
Bus Constant	-.93 (-1.85)	-.94 (-1.31)	-1.38 (-1.93)	-.97 (-2.89)
Walk Constant	-.62 (-1.04)	1.19 (1.73)	-.97 (-1.17)	-.09 (-.23)
Number of Cases	202	122	115	439
Likelihood Ratio Statistic (χ^2)	273.1	163.9	145.5	566.1
Information (%) (Pseudo-R^2)	61.5	61.1	57.6	58.7

χ^2_{16} for segmentation = (273.1 + 163.9 + 145.5) - 566.1 = 16.4

Non-significant at the .05 level

TABLE F-4

FIRST PREFERENCE MODEL SEGMENTATION ANALYSIS

SEGMENTATION VARIABLE: LENGTH OF RESIDENCE

Variable Name	Model Parameter (t-statistic) [Normalized Importance Weight]		
	SEGMENT		OVERALL
	< 3 years	> 3 years	
General Service and Safety	1.72 (3.96) [.37]	1.73 (6.43) [.35]	1.70 (7.54) [.35]
Convenience and Accessibility	.70 (2.32) [.15]	.42 (2.04) [.09]	.51 (3.15) [.11]
Psychological Comfort	.56 (1.82) [.12]	.02 (.11) [.00]	.17 (.11) [.04]
Car Feelings	.06 (.18) [.01]	.48 (2.57) [.10]	.36 (2.32) [.07]
Bus Feelings	.60 (1.31) [.13]	1.10 (3.53) [.22]	.93 (3.64) [.20]
Walk Feelings	.99 (1.68) [.21]	1.16 (3.10) [.24]	1.12 (3.72) [.23]
Bus Constant	-1.18 (-1.75)	-1.05 (2.62)	-1.03 (-3.07)
Walk Constant	-.49 (-.63)	-.05 (-.13)	-.17 (-.47)
Number of Cases	130	313	443
Likelihood Ratio Statistic (χ^2)	155.9	414.7	565.7
Information (%) (Pseudo-R^2)	54.6	60.3	58.1

χ^2_8 for segmentation = (155.9 + 414.7) - 565.7 = 4.9

Non-significant at the .05 level

APPENDIX G

CHI-SQUARE TEST OF MARKET SEGMENTS

Appendix G

Chi-Square Test of Market Segments

Let θ be a k element vector of parameters and let the null hypothesis imply that q elements of θ $(q<k)$ take certain values (i.e., q restrictions are imposed on the k parameters). Let L_R be the maximum of the likelihood function when the restrictions are imposed, and L_{UR} be the maximum value when the k parameters are unrestricted. Theil (1971) states that

$$-2 \ln \lambda \tag{1}$$

where $\lambda = L_R/L_{UR}$

is asymptotically distributed as χ^2 with q degrees of freedom.

Now, since $\lambda = L_R/L_{UR}$, (1) can be rewritten as

$$-2 \ln (L_R/L_{UR})$$

$$-2 \ln L_R + 2 \ln L_{UR} \tag{2}$$

Let L_o be the value of the likelihood for an "equally likely" model, i.e., a model with no parameters. Now (2) can be written as:

$$-2 \ln L_R + 2 \ln L_o + 2 \ln L_{UR} - 2 \ln L_o$$

$$= 2 \ln(L_o/L_R) - 2 \ln(L_o/L_{UR}) \tag{3}$$

but $-2[\ln(L_o/L_R)] = LRS_R$

and $-2[\ln(L_o/L_{UR})] = LRS_{UR}$

where LRS_R and LRS_{UR} are the likelihood ratio statistics for the restricted and unrestricted models, respectively.

Thus (3) can be rewritten as:

$$LRS_{UR} - LRS_{R} \tag{4}$$

Therefore one can test whether the imposition of the q restrictions is statistically significant or not, as long as LRS_{UR} and LRS_{R} are known.

To describe the application of this test in the context of testing for significant segmentation in preference or choice models, which have been estimated using the maximum likelihood technique, let us consider a variable for which we have identified g groups. Let the choice or preference model be specified in terms of k parameters. If we estimate the set of k parameters independently for each of the g groups, we would estimate a total of gk = K parameters. If we state our null hypothesis as: "the parameters are the same across the g groups", then we are in effect imposing (g-1)* restrictions on each parameter, or (g-1)k = q restrictions in all. Thus the restricted (or "group") model is obtained by imposing q=(g-1)k restrictions on the unrestricted model, and the difference in the likelihood ratio statistics between the unrestricted and restricted models is distributed as a chi-square variable with q degrees of freedom.

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*Although there are g groups, (g-1) <u>independent</u> restrictions will ensure that each parameter is constrained to be the same across the groups.

APPENDIX H

CHOICE MODEL SEGMENTATION ANALYSIS

TABLE H-1

CHOICE MODEL SEGMENTATION ANALYSIS

SEGMENTATION VARIABLE: AGE

Variable Name	Importance Weight (t-statistic)			
	SEGMENT			OVERALL
	≤ 29	30-59	≥ 60	
Preference Index	2.78 (6.39)	3.07 (6.48)	4.45 (4.55)	3.07 (10.61)
Autos per Driver	.17 (0.58)	1.92 (5.71)	-.01 (-.02)	0.90 (4.56)
Number of Cases	122	223	74	419
Likelihood Ratio Statistic (χ^2)	90.8	318.4	78.2	464.1
Information (%) (Pseudo-R^2)	33.9	65.0	48.1	50.4

χ_4^2 for segmentation = (90.8 + 318.4 + 78.2 - 464.1) = 23.3

Significant at $p < .001$ level

TABLE H-2

CHOICE MODEL SEGMENTATION ANALYSIS

SEGMENTATION VARIABLE: EDUCATION

Variable Name	Importance Weight (t-statistic)			
	SEGMENT			OVERALL
	High School	Some College	College Grad.	
Preference Index	3.59 (3.58)	3.31 (5.45)	2.78 (7.44)	2.87 (9.93)
Autos per Driver	-.67 (-1.00)	.18 (.39)	1.69 (6.07)	1.09 (5.09)
Number of Cases	44	93	279	416
Likelihood Ratio Statistic (χ^2)	35.7	95.6	352.0	465.3
Information (%) (Pseudo-R^2)	36.9	46.8	57.4	50.9

χ_4^2 for segmentation $= (35.7 + 95.6 + 352.0) - 465.3 = 18.0$

Significant at $p < .01$ level

TABLE H-3

CHOICE MODEL SEGMENTATION ANALYSIS

SEGMENTATION VARIABLE: PURPOSE

Variable Name	Importance Weight (t-statistic)			
	SEGMENT			OVERALL
	Shop	Doctor, Eat, Bank	Other	
Preference Index	3.54 (7.25)	2.63 (5.72)	2.97 (5.09)	3.11 (10.62)
Autos per Driver	.74 (2.31)	1.02 (3.13)	.82 (2.02)	.87 (4.41)
Number of Cases	188	117	110	415
Likelihood Ratio Statistic (χ^2)	218.2	117.4	127.3	460.8
Information (%) (Pseudo-R^2)	52.8	45.7	52.7	50.5

χ_4^2 for segmentation = (218.2 + 117.4 + 127.3) - 460.8 = 2.1

Not significant at p = .05 level

TABLE H-4

CHOICE MODEL SEGMENTATION ANALYSIS

SEGMENTATION VARIABLE: LENGTH OF RESIDENCE

Variable Name	Importance Weight (t-statistic)		
	SEGMENT		OVERALL
	< 3 years	> 3 years	
Preference Index	2.97 (5.75)	3.11 (8.90)	3.07 (10.61)
Autos per Driver	.82 (1.98)	.92 (4.07)	.90 (4.56)
Number of Cases	120	299	419
Likelihood Ratio Statistic (χ^2)	111.0	353.2	464.1
Information (%) (Pseudo-R^2)	42.1	53.8	50.4

χ^2_2 for segmentation = $(111.0 + 353.2) - 464.1 = 0.1$

Not significant at $p = .05$ level

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