TRANSPORTATION RESEARCH RECORD 649

Preferences, Perceptions, and Market Segments in Travel Behavior

TRANSPORTATION RESEARCH BOARD

COMMISSION ON SOCIOTECHNICAL SYSTEMS
NATIONAL RESEARCH COUNCIL

NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D.C. 1977

Transportation Research Record 649
Price $3.40
Edited for TRB by Francis R. Zwanzig

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Library of Congress Cataloging in Publication Data
National Research Council. Transportation Research Board.
Preferences, perceptions, and market segments in travel behavior.

(Transportation research record; 649)
1. Choice of transportation–Congresses. I. Title. II. Series.
TE7.H5 no. 649 [HE336.C5] 380.5'08s [380.5'2]
ISBN 0-309-02678-4 78-16514

Sponsorship of the Papers in This Transportation Research Record

Sponsorship is indicated by a footnote at the end of each report. The organizational units and officers and members are as of December 31, 1976.

Contents

Measurement of Psychological Factors and Their Role in Travel Behavior

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Psychological factors are conceptualized as intervening variables linking system and user characteristics to transportation judgments and decisions. The information-integration approach of experimental psychology was used to measure and assess psychological factors by using simple rating scales and algebraic models of individual decision processes. Two simulation experiments were conducted to illustrate this approach. In the first, perceived safety of highway driving was measured on a bipolar rating scale and shown to vary as a simple algebraic function of factors, such as driving speed, time of day, weather conditions, and number of hours of continued driving. Other judgments involving continued-driving time and reducing driving speed were obtained and shown to be highly related to safety ratings. This supports the idea that psychological factors such as safety can be measured objectively and used to understand and predict traveler behavior. In the second experiment, the desirability of forming car pools was assessed as a function of the number of riders in the pool, the sex of each rider, and the acquaintanceship of the rider and the respondent. The acceptability of a given potential rider was a multiplicative function of sex and acquaintanceship; sex played an important role when the rider was a nonacquaintance. The desirability of a given car pool was an average of the desirability of individual riders, so that a desirable rider would compensate for undesirable riders. The implication of such results to policy makers is discussed, but the need for expanded research is stressed.

As has been pointed out (5, 8, 9, 11, 12, 13, 15, 16, 18), there is need to study individual decision-making processes and the role of psychological factors in traveler behavior. Ultimately, it is the individual who must judge the convenience of mass transit, the desirability of car pooling, and the safety of highway driving. However, measuring qualitative factors, such as safety and convenience, has been a central problem in research on this. This paper will illustrate how such factors can be measured and related to traveler behavior.

ROLE OF PSYCHOLOGICAL FACTORS

Our conceptualization of the role of psychological factors is illustrated in Figure 1, which uses one of the studies discussed in this paper as an example. System, user, and environmental characteristics are considered as independent (or input) variables that can be manipulated or categorized in simulated (laboratory) studies. Judgments and decisions related to traveler behavior are dependent (or output) variables to be measured and recorded. (Predicting actual, rather than simulated, judgments and decisions is, of course, the ultimate goal.) Psychological factors are considered as intervening variables linking the system, user, and environmental characteristics to the observable behavior. Their ultimate usefulness will depend on the extent to which a small number of psychological factors can be used to explain and predict a wide variety of behaviors. Thus, it is important to investigate both sets of linkages illustrated in Figure 1: the links between the characteristics on the left and the perceived values of the psychological factors and those between the perceived psychological values and the behavior on the right.

Two experimental studies are described. One considers perceived safety and safety-related behavior in highway-driving situations and investigates the factors illustrated in Figure 1. The other considers the relative desirability of car pools of varying personal composition. These studies use the methodology of the information-integration approach of experimental psychology. This approach is first described; then the two experimental studies are described and discussed.

INFORMATION-INTEGRATION APPROACH

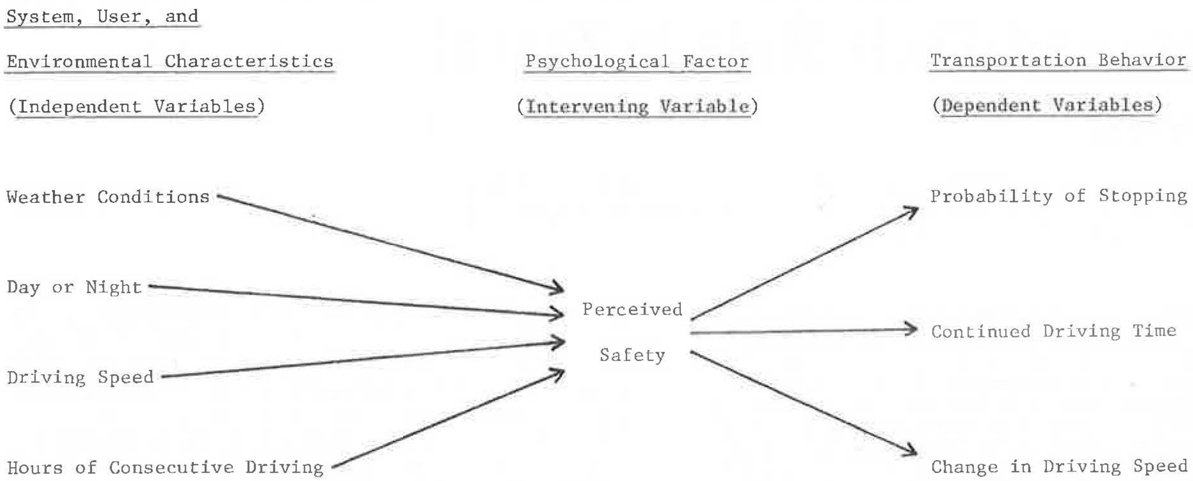
The primary goal of the information-integration approach is the analysis of how a variety of factors are combined or integrated to determine human judgments and decisions. The approach was developed by Anderson (2, 3) and has had a history of success in describing complex cognitive processes, including transportation modal choice (4, 11, 15, 16).

It is assumed that when a number of different factors have to be taken into account when making a judgment or decision, each piece of information can be characterized by two parameters: a scale value corresponding to the subjective evaluation of the information along the dimension of judgment [e.g., the perceived safety level of a highway driving speed of 88 km/h (65 mph)] and a weight representing the importance of the information for the judgment or decision to be made. The net effect of a given piece of information within a set of information is the product of its weight and scale value. The integrated judgment or decision is assumed to be represented by an algebraic function of the weights and scale values of the various pieces of information. For example, Levin has shown that the degree of preference for bus versus automobile can be described as a weighted average of time and cost factors (11).

Factorial experimental designs (complete or fractional) are typically used; each subject receives systematically programmed combinations of levels of stimulus factors and is asked to respond to each of the hypothetical situations thus formed. The responses are then analyzed to determine the relations between the informational variables and the subjective judgments or decisions. These relations are causal rather than circumstantial in the sense that they directly reflect the manipulation of factors in specified combinations, with extraneous factors controlled or balanced.

Goodness-of-fit tests are available through analysis of variance techniques to compare alternative models that describe the way in which the factors are integrated or combined (3). For example, lack of interaction between factors suggests an additive process of combining factors, and linear times linear interactions suggest a multiplicative relation between factors in which one factor acts as a modifier of the influence of other factors. Each of these processes will be seen in the experiments described below and should serve to illustrate the flexibility of the approach. Different models or parameters

Figure 1. Conceptualization of psychological factors as mediators of traveler behavior (safety example).



may apply to different homogeneous subgroups of decision makers. Levin has shown that automobile-biased and bus-biased individuals differ systematically in the weights they assign to varying levels of cost and time factors (11). In contrast, other modeling approaches that do not focus on individual decision-making processes make the a priori assumption that groups that are homogeneous with respect to socioeconomic characteristics will have similar decision-making processes.

Another feature of the information-integration approach that distinguishes it from other approaches is the use of simple rating scales to obtain numerical measures of subjective judgments. The recent technique in transportation research known as trade-off analysis has some of the features of the information-integration approach, but generates only rank-order data and transforms them to interval or ratio scales through conjoint measurement (6, 17). When someone ranks one particular set of mass transit characteristics higher than others, his or her absolute evaluation of that system may still be below his or her threshold for patronage. Furthermore, formal validity tests are generally lacking in such applications. In contrast, the data obtained in information-integration studies can offer information about the absolute as well as the relative rating of alternative systems, and the validity of the rating data is tested directly by the goodness-of-fit test of a given model. For example, an additive model will fit the data only if an additive rule describes the rating process, and the data form an interval scale.

Another distinctive feature of the information-integration approach is that known as functional measurement (2). Rather than rating factors in isolation, as is sometimes done in attitude assessment in transportation research (7), ratings of stimulus combinations are obtained to directly determine the trade-off between competing factors. The relative influence of each of several factors estimated in a multifactor information-integration task is the weight that is functional in the decision-making process. This takes into account the range of values of each factor, as well as the number of factors to be considered. In a similar manner, the psychophysical function relating subjective to actual values of each factor is also obtained directly from the multifactor judgments. This function is obtained empirically, rather than a priori by assuming linear functions, as is sometimes done.

The major features of the information-integration approach and their consequences for transportation research are summarized below.

Feature	Consequence
Experimental manipulation of stimulus factors	Causal relations between system characteristics and judgments or decisions
Simulated judgments and decisions	Predict effects of changes in system characteristics
Factorial designs	Goodness-of-fit tests for alternative integration models
Within-subject designs	Identification of homogeneous subgroups of decision makers
Simple rating scales	Absolute as well as relative measures of preference
Functional measurement of weights and scale values	Determination of relative importance of factors and determination of the relation between subjective and actual system values

EXPERIMENT 1: PERCEIVED SAFETY AND SAFETY-RELATED BEHAVIOR IN HIGHWAY DRIVING

This study uses the information-integration approach to examine the role of the psychological factor safety (more correctly, perceived safety) in highway driving. The independent variables shown on the left side of Figure 1 were manipulated factorially to form 48 unique combinations. In one experimental condition, each respondent was asked to rate how safe or unsafe he or she perceived each combination to be. This is our way of measuring safety, i.e., determining the relation between the manipulated factors and the safety ratings. In other experimental conditions, the respondents were asked how they might behave under situations described by the various combinations of factors. The relations between these behavior measures and the safety ratings tell us about the potential usefulness of the psychological factor safety as an explanatory mechanism for highway driving behavior.

Method

The respondents were told to consider that they were taking a vacation trip from Iowa City to San Francisco driving on I-80. They were presented a number of hypothetical situations of varying driving conditions. In all of the experimental conditions, each respondent received all combinations of the following factors describing the driving conditions: weather [clear skies, winds gusting to 56 km/h (35 mph), moderate to heavy rain, or no information about weather], automobile speed [80, 88, or 105 km/h (50, 55, or 65 mph)], time (daytime or after dark), and hours of continued driving

(3 or 8 h of previous driving). Each of the resulting combinations was described on a different page of a response booklet (the actual booklets expressed speeds in U.S. customary units only). In addition to the 48 combinations described above, each respondent received 12 practice and filler trials that included other stimulus levels, some of which were more extreme than those used in the main 4 × 3 × 2 × 2 experimental design (e.g., wind and rain).

The respondents were divided into three groups, each of which was required to respond differently to the information presented. All respondents were undergraduate students at the University of Iowa. The respondents in the safety-rating group (n = 17) were asked to rate each hypothetical situation by placing a mark somewhere along a 15-cm (6-in) line labeled very unsafe at the left end and very safe at the right end. The position of their mark indicated their safety rating for each situation. The responses were recorded to the nearest 0.5 cm (0.2 in), with 0 being the lowest level of safety and 15 being the highest level of safety.

The respondents in the continued-driving-time group (n = 20) were asked to indicate how much longer they would continue to drive under each of the given conditions.

The respondents in the changed-driving-behavior group (n = 22) were asked to indicate the following for each condition: (a) Would you alter your driving speed? (b) If your answer to the previous question is yes, in what way would your speed be altered—increased, decreased, or would you stop for the day? (c) If you would increase or decrease your speed, give the amount of change in miles per hour. All respondents in all groups worked through their response booklets at their own pace.

Results and Discussion

Safety Ratings

The mean responses for the safety-rating group are shown in Figure 2. The safety ratings were higher for 3-h consecutive driving than for 8; they were higher for day than for night, for clear weather than for wind and for wind than for rain; they were very nearly equal for clear weather and unknown weather, indicating a Pollyanna effect when weather conditions were not specified, and decreased as the speed increased. In the 4 × 3 × 2 × 2 analysis of variance, each of these factors represented a significant source of variance, with the following rank-ordering of importance (in terms of the proportion of the variance contributed by each factor): hours of continued driving, weather, time (day versus night), speed.

The near parallelism of the lines in each panel of Figure 2 suggests that the factors weather and speed are additive. The analysis of variance confirmed that these two factors did not interact. Furthermore, none of the factors weather, speed, and time interacted with each other, indicating that all of them combine additively in affecting safety ratings. However, the factor hours of continued driving tended to interact with the other factors; the hours times weather and hours times speed interactions were statistically significant, but the hours times time interaction did not reach statistical significance at the 0.05 level. All of these interactions with hours of continued driving were similar; the effects of weather, speed, and time were all less after 8-h continued driving than after 3. For example, it can be seen by comparing the left and right panels of Figure 2 that the lines for different weather conditions are closer together (i.e., represent smaller changes in safety ratings) at 8 h than at 3 h.

In other words, the factor hours of continued driving modified or multiplied the effects of the other factors, whereas the effects of the other factors were independent of each other. The pattern of results for safety ratings (R) can be described by a model of the following form:

$$R = H(W + S + T) \quad (1)$$

where H, W, S, and T represent subjective scale values for levels of hours of continued driving, weather, speed, and time respectively.

Continued-Driving Time

The mean responses for the continued-driving-time group are shown in Figure 3. The pattern of results is very similar to that of the safety-rating group (Figure 2). The relative importance of the four factors was about the same in each group. The main difference is

Figure 2. Mean safety ratings for each condition of experiment 1.

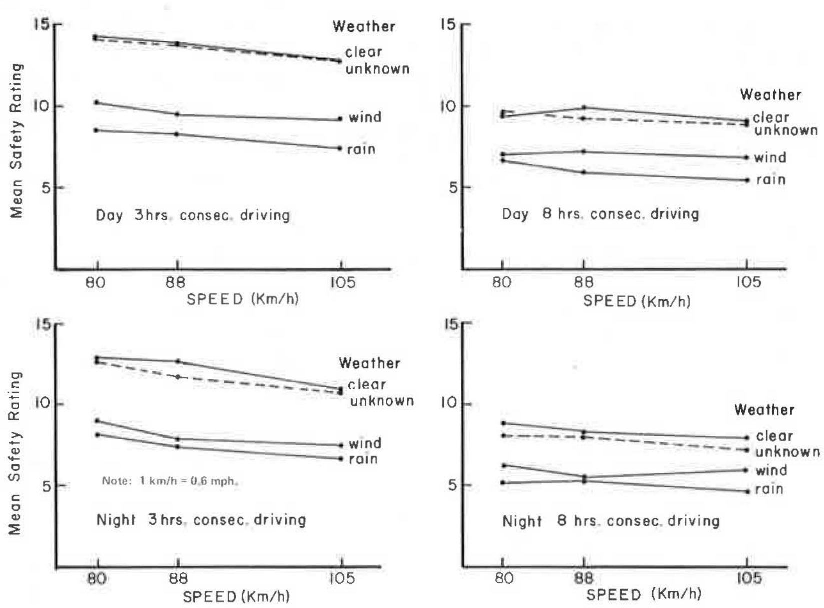
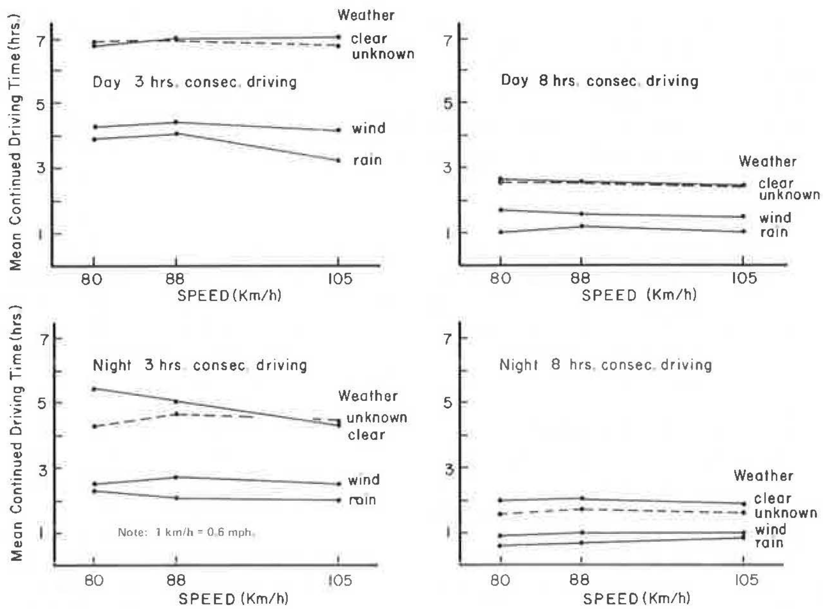


Figure 3. Mean continued-driving time for each condition of experiment 1.



that the effect of speed did not reach statistical significance in the analysis of continued-driving time.

The interaction effects were also similar in each group. Hours of continued driving interacted with weather and with time in the analysis of continued-driving time. As with the safety ratings, these interactions were due to smaller effects of weather and time after 8-h continued driving than after 3-h continued driving. With the exception of a small and nonsystematic interaction between weather and time, the other factors were additive.

A model of the same basic form would thus describe both the safety ratings and the estimates of continued-driving time. The correlation between the two measures is 0.94. Safety ratings are thus excellent predictors of how driving time will vary as a function of the factors manipulated in this experiment. Furthermore, the extremely high correlation with hours of continued driving time suggests that the safety ratings have interval scale properties.

Changes in Driving Behavior

The responses of the group who indicated changes in driving behavior were more complicated. The speed factor had a significant influence on the number of respondents who indicated that they would stop driving for the day. The greater the speed, the larger the number of respondents who indicated that they would stop. The mean change in speed for those respondents who did not indicate that they would stop was also affected by the designated driving speed. These effects can be interpreted as follows: Respondents adopt an optimal driving speed for each combination of weather, time, and hours of continued driving. For example, with clear weather, daytime, and 3-h continued-driving time, virtually all respondents indicated that they would continue driving, and the mean optimal driving speed was about 97 km/h (61 mph) [i.e., 9.5 km/h (6 mph) over the speed limit]. This means an upward adjustment for speeds of 80 and 88 km/h (50 and 55 mph) and a downward adjustment for speeds of 105 km/h (65 mph). Another example is rain, nighttime, and 8-h continued-driving time, where over half of the respondents indicated that they would stop, but the mean driving speed for those continuing was about 85 km/h (53 mph), which means an upward adjustment for a speed of 80 km/h (50 mph) and a downward adjustment for speeds of 88 and 105 km/h (55 and 65 mph).

Hours of continued driving had a smaller effect on mean speed change than on any other dependent measure; however, this factor had a large effect on the number of respondents who indicated that they would stop driving. Otherwise, the effects of the manipulated factors on mean speed changes were similar to those observed with the other dependent measures.

Taken together, the indicated changes in driving behavior suggest the effects of perceived safety plus another intervening factor that we might designate as desire to reach destination. As perceived safety decreases, respondents are more apt to indicate that they would stop; however, if they indicate continuing driving, it is apt to be at the same speed as before.

Summary of Results

The safety ratings varied systematically as a function of the manipulated factors, and the analysis of variance supported a simple model for describing how the factors combine. Establishing the integration rule relating the manipulated factors to the safety ratings is our way of measuring the psychological factor perceived safety.

Continued-driving time was shown to be related to the manipulated variables in much the same fashion as safety ratings. This establishes the link between perceived safety and other behavioral indicants and supports the conceptualization illustrated in Figure 1 that psychological factors can be used as intervening constructs to explain and predict traveler behavior.

The relation between safety ratings and changes in driving behavior was more complex, but perceived safety—in conjunction with another psychological factor—was a useful explanatory mechanism for the observed data.

EXPERIMENT 2: DESIRABILITY OF CAR POOLS OF VARYING PERSONAL COMPOSITION

This experiment used the information-integration approach to further study how psychological factors may influence traveler behavior by examining how the desirability of car pools varies as a function of personal—as opposed to the usual time, cost, and distance—factors. The factors include the sex of each rider and whether or not the rider is a prior acquaintance of the respondent.

Method

Nineteen female and 16 male undergraduate students at the University of Iowa participated in this experiment. They were instructed to assume that they lived 16 km (10 miles) from school in an area having many other students with whom car pools could be formed and were asked to rate the relative desirability of a series of hypothetical car pools varying in the number of riders, the sex of each rider, and whether each rider is an acquaintance or a student whom they do not know.

Each page of the response booklet contained a description of a different car pool. Below each description was a 15-cm (6-in) line labeled very undesirable at the left end and very desirable at the right end. The respondents were instructed to mark this line at a place that indicated their personal rating of the desirability of each hypothetical car pool. As in the first experiment, the responses were measured and recorded; 0 represented the low end of the scale and 15 represented the high end of the scale.

Car pools with one rider (in addition to the respondent) were described by the sex of the rider and whether or not the rider was an acquaintance of the respondent. There are thus four combinations with one rider: male acquaintance (MA), female acquaintance (FA), male nonacquaintance (MNA), and female nonacquaintance (FNA). Car pools with two and three riders were described by the sex of each rider and whether or not each rider was an acquaintance of the respondent. Ordinarily this would be represented by 16 combinations for two riders and 64 combinations for three riders. However, not all of these combinations are unique—e.g., if rider 1 is a male acquaintance and rider 2 is a female nonacquaintance, this is the same as if rider 1 is a female nonacquaintance and rider 2 is a male acquaintance. There are 10 unique combinations with two riders and 20 unique combinations with three riders. There are thus 34 different car-pool descriptions; each respondent received them in a different order of presentation. Six practice trials using some of the same descriptions used later were given at the beginning. The rating task was self-paced.

Results and Discussion

The results are summarized below.

Car-Pool Combination	Mean Desirability Rating: Male Respondent	Female Respondent
One rider		
MA	10.06	12.50
FA	10.47	12.32
MNA	7.00	3.29
FNA	9.50	6.53
Three riders		
3 Acquaintances	10.76	12.15
2 Acquaintances and 1 nonacquaintance	9.70	10.84
1 Acquaintance and 2 nonacquaintances	9.03	7.69
3 Nonacquaintances	8.16	3.49

The data for one rider show that both male and female respondents gave the lowest ratings to MNAs. For both sexes, car pools with a female rider were rated higher than those with a male rider, and car pools were rated higher when the rider was an acquaintance than when he or she was a nonacquaintance. Furthermore, the difference in ratings between female and male riders was much greater for nonacquaintances than for acquaintances. Statistically, this corresponds to an interaction between sex and acquaintance versus nonacquaintance. This interaction was statistically significant for female respondents and approached significance for male respondents. In simple terms, this relation means that if the rider is an acquaintance, the sex of the rider is of little consequence, but if the rider is not an acquaintance, males prefer a rider of the opposite sex and females prefer a rider of the same sex.

Although not shown above, the same general trends were seen for two riders and three riders. In each case, the lowest rating occurred when all riders were MNAs. These ratings for car pools with all MNAs become more extreme (i.e., lower) as the number of riders increases. This corresponds to the common set-size effect in information integration (1, 10), which is explained by assuming that information values are averaged with each other and with a neutral initial impression. However, when one rider was designated as an acquaintance, the ratings increased considerably, even if the other riders were MNAs. For example, female respondents gave a mean rating of 2.37 (which is very low on an absolute as well as a relative basis) for a car pool of three MNAs, but a mean rating of 7.95 (which is slightly above the neutral point on the desirability scale) for the combination of two MNAs and one MA. Even when a moderately negative-stimulus person (e.g., a FNA for female respondents) is combined with a MNA, the ratings are slightly higher than for all MNAs. This argues for a compensatory or averaging process in combining the desirability levels of different riders.

Several observations can be made about the data presented above. The first is that the ratings decrease as the relative number of acquaintances to nonacquaintances decreases. Another is that while male and female respondents show a similar pattern of rating responses, females give much lower ratings to car pools with all nonacquaintances.

Taken as a whole, the pattern of results for this experiment suggests a two-stage integration process in evaluating the desirability of a potential car pool. The characteristics of a given person (sex and whether or not the person is an acquaintance of the respondent) are combined multiplicatively to determine the desirability of that person as a potential car-pool rider, where the importance of sex depends on whether the person is an acquaintance or a nonacquaintance. The overall desirability of a given car pool is then the average of the desirability levels of the individual riders.

An integration model such as described above, when considered in light of the finding that male nonacquaintances are rated as undesirable car-pool riders, suggests the following policy for forming car pools of at least moderate desirability: Use a chaining approach in which rider 1 supplies the name of a rider 2, rider 2 supplies the name of a rider 3, and so on. In that way, every rider has at least one acquaintance to offset the undesirability of forming car pools with male nonacquaintances. The use of a continuous response scale enabled us to show that the overall desirability of a car pool may be slightly positive even when two out of three riders are seen as undesirable.

CONCLUSIONS

The experiments reported in this paper were designed to illustrate how the effect of psychological factors on traveler behavior could be studied by using the information-integration approach of experimental psychology. The first experiment showed that the psychological factor, safety, could be measured by asking subjects to rate the safety of a series of highway driving situations described by varying levels of weather, driving speed, time, and hours of continued driving. These ratings could be described by a relatively simple integration model. Continued-driving time was shown to follow an analogous model and was highly correlated to the safety measure, thus showing the linkage between the psychological factor and a relevant dependent measure of driving behavior. Another dependent measure showing intended changes in driving speed was also related to perceived safety. It would appear fruitful to continue the search for a relatively small number of psychological factors that underlie a variety of traveler behaviors. The present methods could be of value in such a search.

The second experiment studied interpersonal factors in car pooling that are of considerable interest and importance, but have largely been neglected because of their qualitative nature. The present methods led to an operationalization and quantification of the effects of these factors on the desirability of car pooling. An extension of these methods might show that interpersonal factors have similar effects on the desirability of other multiple-occupant transportation modes.

A number of features of the information-integration approach were illustrated in these studies; these are summarized below.

1. Experimental manipulation of factors in simulated judgmental tasks: We obtained judgments for situations that may not have actually occurred in a given respondent's history, but could conceivably be of future importance—for example, driving at night in the rain after 8 h of continued driving, and considering joining a car pool with one prior acquaintance and the others strangers.
2. Definition of additive and nonadditive processes: We determined that weather conditions, driving speed, and time of day all had independent (additive) effects on perceived safety, but in judging the desirability of a given car-pool rider, whether or not the person was a prior acquaintance modified the effect of the rider's sex. (Procedures such as additive conjoint measurement would have found difficulty in detecting such effects.)
3. Use of simple rating scales: We showed that subjective ratings of safety were highly related to hours of continued driving and thus that the rating scale has interval properties; a continuous measure of car-pool desirability allowed us to identify situations where changes produced shifts from the negative to the positive side of the neutral point.
4. Functional measurement: We developed a method for measuring the psychological factor, safety, and determined that the relative influence of factors was very nearly the same for continued driving time as for safety ratings; we developed a method for measuring the effects of interpersonal factors in car pooling. A recent extension of this study has shown that interpersonal factors had an effect comparable to the more traditional cost and time factors (15).

All of these findings were achieved at the cost of substituting simulated behavior for actual driving behavior or car-pooling decisions. We recognize the need to extend our studies to larger and more representative samples of real-world behavior. However, there is reason to be optimistic about the ability to generalize laboratory studies such as described here. For example, recent studies using the information-integration approach defined a behavioral measure of individual decision processes in modal choice that accurately predicted travel mode to work, especially when individual situational constraints were included in the prediction model (11, 15). The results of the present car-pooling study are consistent with field research findings concerning car-pooling behavior of various population segments in the Washington, D.C., metropolitan area (14). The present study showed that female respondents, in particular, assigned low desirability to nonacquaintances as potential riders. It was observed in the field research study that women in particular are resistant to telephoning a stranger to discuss a possible car pool. The present methods can extend the field results by developing a simple model that has direct policy implications (e.g., the chaining procedure described above). One way of testing the validity of this modeling approach would be to recalibrate the model with a specified target population, implement the policy strategy suggested by the model, and evaluate the effectiveness of the policy. This is the object of current work in our laboratory.

While extensions to real-world behavior are important to an integrated research program, laboratory studies such as those described in this paper can continue to be useful in opening the investigation of traveler behavior to include psychological factors and descriptions of individual decision-making processes that may underlie traveler behavior in a wide variety of real-world situations. The work reported here is part of a continuing series of studies applying the information-integration approach to problems in transportation research.

ACKNOWLEDGMENT

The research reported in this paper was supported by a grant from the National Science Foundation.

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

Comparative Analysis of Determinants of Modal Choices by Central Business District Workers

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The role of individuals' perceptions and preferences in traveler decision making is a growing and active area of theoretical and empirical research. This study was designed (a) to quantify the relation between perceived system attributes and modal choice, (b) to compare the magnitude of this relation to that of the alternative relations of sociodemographic and network time and cost data and modal choice, and (c) to determine whether the linkage between perceived system attributes and modal choice is dependent on the relations of sociodemographic and network data to modal choice. The sample was composed of Los Angeles central business district workers who live within approximately 3.2 km (2 miles) of a freeway that feeds radially downtown. Models were calibrated for three dependent-variable criteria; these were monthly differences in use for (a) automobile versus bus, (b) automobile versus car pool, and (c) bus versus car pool. The multiple coefficients of determination for modal choice as a function of perceived system attributes were statistically significant at the 0.001 level for all dependent-variable criteria. The coefficients ranged from 0.265 to 0.125, but the analogous coefficients for sociodemographic or planning data ranged from a low of 0.004 to a high of only 0.054. The effects of perceived system attributes on the dependent variables were not diminished by the other types of independent variables. Tests of significance for the individual components of combined models with these types of data showed the perceived-system-attribute data to be significant at beyond the 0.001 level in all cases. However, sociodemographic and network data appear to be influenced by the addition of perceived-system-attribute data to the degree of becoming nonsignificant in some cases. The overall conclusion is that perceived system attributes can be a statistically significant correlate of modal choice over and above any influence by network or sociodemographic variables or both.

The potential relevance of individuals' perceptions of and preferences for transportation modes and their service attributes to traveler decision making makes these topics active areas of theoretical and empirical research. Golob (1) and subsequently Golob and Dobson (2) have reviewed consumer-behavior models derived from market research and psychology and discussed their applicability to urban travel issues. An organizational structure has emerged from a conference on behavioral travel-demand that specifies the relation of perceived system attributes to traveler behavior (3). The perceptual models developed here are consistent with this organizational structure.

From an empirical perspective, the role of perceptions and preferences in traveler decision making is mixed. Hartgen (4) found that attitudes accounted for only 10 to 20 percent of the explained variation in traveler modal choices while situational variables, e.g., income and automobile ownership, accounted for 80 to 90 percent of the explained variance. A similar finding was reported by Dobson and Kehoe (5), who did not find a statistically significant correspondence between view of system attributes and actual modal choices, although they did find substantial correlations between perceptual measurements of transportation system attributes and anticipated satisfactions with innovative urban transportation modes. Thus, neither of these investigations offers strong support for perceptions or preferences as determinants of modal choice.

On the other hand, at least three other analyses support the concept that perceptions and preferences are determinants of modal choice. Dobson and Tischer (6) found 63 percent correct assignments to mode for a model based solely on perceived system attributes for which the chance probability of correct assignments was only 33 percent. Nicolaidis (7) reported higher correlations between comfort and modal choice than between either perceived time or cost differences and modal choice. Spear (8) found that the correlation ratio for a logit function fit was appreciably enhanced by the addition of a generalized convenience variable to a modal-choice model already specified in terms of perceived time and cost differences.

This study was designed to advance the level of understanding with respect to the potential relevance of individuals' perceptions and preferences to traveler decision making. Three questions are specifically addressed with respect to a sample of Los Angeles central business district (CBD) workers. These are as follows:

1. Is there a correspondence between perceived system attributes and modal choice?
2. What is the magnitude of the relationship between perceived system attributes and modal choice relative to those of network time and cost or of sociodemographic data and modal choice?
3. What is the nature of the interaction between perceived system attributes, network time and cost, and sociodemographic variables with respect to modal choice?

STUDY DESIGN

Sample

The sample was comprised of 889 individuals who work in the Los Angeles CBD and live within 3.2 km (2 miles) of a freeway that feeds radially to the CBD. It was selected from census tracts surrounding freeways and having a high incidence of downtown workers. The households were chosen from a telephone directory according to a random sampling procedure. However, only commuters who worked in the CBD were interviewed. If a household contained more than one CBD worker, the person taking the lesser used mode was interviewed.

Data Sets

The following types of data were collected from the home-interview survey: (a) frequency of modal use, (b) perceived system attributes, and (c) sociodemographic data regarding the individual and the household. An additional data set composed of network time, distance, and cost was derived at the aggregate level for the sample and is presented. These aggregate data were assigned to individual travelers depending on their origin and destination (O-D) zones.

Individuals were asked how frequently (per month) they used each of three modes—the single-occupant automobile, the bus, and the car pool—to travel to work. The frequency of use of each mode was subtracted from that of the other modes to obtain comparisons of modal use. These constructed variables—frequency of automobile use minus that of bus use, frequency of automobile use minus that of car-pool use, and frequency of bus use minus that of car-pool use—are used throughout the analysis as the dependent variables.

Beliefs about attributes of the three modes—the single-occupant automobile, the bus, and the car pool—were collected by using a semantic differential format in which each attribute was rated on a one to seven scale. The respondent was asked to describe the following 19 attributes for each of the modes.

1. Worry about being harmed by others versus do not worry about being harmed by others,
2. Easy to get where I am going after I leave the vehicle versus not easy to get where I am going after I leave the vehicle,
3. Is not crowded versus is crowded,
4. Usually do not have to wait a long time for vehicle versus usually have to wait a long time for vehicle,
5. Do not feel relaxed in this vehicle versus feel relaxed in this vehicle,
6. Am not exposed to weather versus am exposed to weather,
7. Can avoid waiting in lines in traffic versus cannot avoid waiting in lines in traffic,
8. Can come and go on my own schedule versus cannot come and go on my own schedule,
9. Very little extra time spent waiting for others or walking to or from vehicle versus much extra time spent waiting for others or walking to or from vehicle,
10. Would not cost much for parking versus would cost a lot for parking,
11. Comfortable versus not comfortable,
12. Not convenient versus convenient,
13. Not expensive versus expensive,
14. Not enough space for packages versus enough space for packages,
15. Easy to use versus not easy to use,
16. Cannot rely on it versus can rely on it,
17. Usually arrive at work on time versus usually do not arrive at work on time,
18. A slow way to travel during rush hour versus not a slow way to travel during rush hour, and
19. Can feel safe from vehicle accidents versus cannot feel safe from vehicle accidents.

(Hereafter, the terms belief and perceived system attributes will be used interchangeably.)

The following sociodemographic information was collected from each individual: marital status, number of people in the household, type of dwelling, income, age, race, sex, presence of children under 18, and number of automobiles in the household. Each of the variables was effect coded (9) and divided into category variables.

The automobile-network-time and distance data were derived from studies made available by the California Department of Transportation. The creation of the data was based on the following:

1. The 1967 Los Angeles Regional Transportation Study of the O-D in the five-county area,
2. A 1975 network update, and
3. Minimum time path assignments of the 1967 O-D patterns to the 1975 network.

The zones selected for analysis were those represented by one or more respondents. The automobile-network-time data were used to calculate an automobile impedance according to a formula that weighted out-of-vehicle time 2.5 times as heavily as in-vehicle time.

Automobile costs represent a combination of parking cost and a distance-based rate for gasoline, maintenance tires, and oil costs, as well as travel-related depreciation. Transit time data were developed in a fashion analogous to that for the automobile. Transit costs refer specifically to the bus fare.

Car-pool impedance was calculated by adjusting the automobile access time to account for the picking up of passengers, taking the line haul and egress to be the same as for the automobile. Car-pool cost was obtained by dividing automobile cost by mean car-pool occupancy.

Both the perceived system attributes and the sociodemographic data were subjected to data-reducing techniques that are described more fully below.

Hypothesis Testing of General Linear Forms

The primary focus of this paper is the analysis of the relative explanatory abilities of each of the data sets, separately and in conjunction with one another. By using a regression framework, it is possible to partition the regression sum of squares (R^2) into various components so that the effect of each independent variable (X_i) can be tested. One can thus obtain the independent explanatory power of a particular variable, or as in this case, set of variables, in terms of the percentage of variance accounted for in the dependent variable (Y) and its relative statistical significance (10, 11). The additional contribution of each independent variable in explaining the dependent variable can be determined by calculating R^2 with and without the particular variable.

This general analysis of the variance of the components requires three steps. First, a regression is performed for all independent variables, as in the following equation:

$$Y = a_0 + a_1 X_1 + a_2 X_2 \quad (1)$$

where a_0 is the intercept term and a_1 and a_2 are the slope coefficients. Then, a second regression is performed that omits the variable of interest, for example, X_2.

$$Y = b_0 + b_1 X_1 \quad (2)$$

where b_0 is the intercept term and b_1 is the slope coefficient. The R^2 of Equation 2 is then subtracted from the R^2 of Equation 1, leaving the amount of variance in Y that is explained by X_2, above and beyond that explained by X_1.

It is possible, however, that the explanatory variables are not completely independent from one another such that the effect of X_1 on the dependent variable depends on its combination with X_2. Significant interaction suggests that a given change in X_1 will produce different changes in Y for different values of X_2.

Testing for interaction follows the procedure described above. Two regression equations are necessary, but a new component—the interaction term—is added, as shown in Equation 3.

$$Y = c_0 + c_1 X_1 + c_2 X_2 + c_3 X_1 X_2 \quad (3)$$

where c_0 is the intercept term and c_1, c_2, and c_3 are the slope coefficients. The second regression omits the variable of interest, which in this case is the interaction term.

$$Y = d_0 + d_1 X_1 + d_2 X_2 \quad (4)$$

where d_0 is the intercept term and d_1 and d_2 are the slope coefficients. When the R^2 of Equation 4 is subtracted from the R^2 of Equation 3, the effect of the interaction between X_1 and X_2 is obtained.

The significance of each of the effects can be determined by using the following formula (9):

$$F = [(R^2_{y.12\ldots k_1} - R^2_{y.12\ldots k_2})/(k_1 - k_2)] \div [(1 - R^2_{y.12\ldots k_1})/(N - k_1 - 1)] \quad (5)$$

where

$R^2_{y.12\ldots k_1}$ = squared multiple correlation coefficient for the regression of Y on k_1 variables (the full model),

$R^2_{y.12\ldots k_2}$ = squared multiple correlation coefficient for the regression of Y on k_2 variables (the model with deleted terms),

k_1 = number of variables in the full model,

k_2 = number of variables in the model with deleted terms, and

N = sample size.

Regression analysis assumes a linear relation, but the functional form of the relation between planning data and modal choice has been most often specified in logit or probit form. One of the major problems of both logit and probit formulations, however, is the lack of standard measures for assessing the goodness of fit of the models or their statistical significance (12). There are no widely accepted statistics associated with the logit or probit forms available that allow a precise analysis of the effects of different data sets. Regression analysis and the related analysis of the variance of the components are the best such techniques, even though they require the assumption of linearity.

Because the concern of this analysis is not with model building, but rather with the comparison of independent effects of sets of explanatory variables, the form of the model is not central to the study design. Furthermore, it was assumed that any underrepresentation of the relation resulting from the imposition of the linear form would occur across data sets. And because the concern is with the comparability of data, the underrepresentation would not have any effect on the results.

These assumptions, however, were tested. The results of the linearity tests of the models and the analyses for bias showed only occasional deviations from linearity that were not biased.

RESULTS

This section of the paper describes the processing of the three types of data examined in the study and the model specifications of their relations to modal choices. The premodeling analysis included factor analysis and clustering of the sociodemographic data and factor analysis of the perceived-system-attribute data. The model specification activities involved calibrations of regression models, tests of hypotheses based on a general procedure for analysis of the variance of the components, and tests for data nonlinearity and bias in the model estimates.

Premodeling Analysis of Perceived System Attributes

For each transportation mode—single-occupant automobile, bus, and car pool—19 belief ratings were obtained. To reduce the number of variables quantifying the perceived system attributes and to take advantage of natural correlations among the variables, a principal-component factor analysis with a varimax rotation was computed for the beliefs about each mode. The factor scores were then estimated for the calibration of modal-choice models that include the perceived system attributes. These premodeling computations were implemented through use of the Statistical Package for the Social Sciences computer program (13).

Table 1 gives the labels and definitions of the factors that are based on the perceived-system-attribute structure with respect to single-occupant automobiles, buses, and car pools. The criterion for the selection of the factors to be retained for analysis was a principal-component eigenvalue greater than 1. The rotated factor-loading matrices were examined for an obvious gap between high and low factor loadings. The boundary criterion was set at 44 and gave readily interpretable dimensions. Attributes with factor loadings at or above the lower bound were used to define a factor.

Table 1 shows that the factor structures for the different modes are relatively similar. For example, all modes have factors that include traffic wait, cost, comfort, and convenience. Although the definitions of the factors differ slightly across modes, there is a general pattern. Furthermore, the number of factors is relatively constant across modes. There are five factors each for the bus and single-occupant-automobile modes, and there are four factors for the car-pool mode.

Table 1. Factor definitions of beliefs about modes.

Mode	Factor Label	Belief Variable	Factor Loading
Single-occupant automobile	F_1 (comfort and convenience)	Comfort	0.70
		Convenience	0.68
		Ease of use	0.63
		Arrive on time	0.59
		Ease to destination	0.56
		Relaxing	0.53
		Flexible schedule	0.54
	F_2 (cost)	Cost	0.76
		Parking cost	0.72
	F_3 (safety)	Vehicular safety	0.54
		Personal safety	0.74
	F_4 (traffic wait)	Travel time	0.75
		Waiting time in traffic	0.69
	F_5 (extra time, crowding, and weather)	Crowding	0.73
		Waiting for vehicle	0.74
		Weather	0.59
		Extra time	0.60
Bus	F_1 (comfort)	Comfort	0.71
		Space for packages	0.65
		Crowding	0.50
		Relaxing	0.66
	F_2 (convenience)	Convenience	0.74
		Ease of use	0.80
		Reliability	0.60
		Arrive on time	0.71
		Ease to destination	0.64
		Wait for vehicle	0.61
	F_3 (cost and safety)	Cost	0.45
		Vehicular safety	0.59
		Personal safety	0.51
		Parking cost	0.66
	F_4 (traffic wait)	Travel time	0.78
		Waiting in traffic	0.55
	F_5 (extra time and weather)	Weather	0.73
		Flexible schedule	0.54
		Extra time	0.52
Car pool	F_1 (comfort)	Comfort	0.56
		Space for packages	0.53
		Reliability	0.56
		Vehicular safety	0.46
		Personal safety	0.53
		Relaxing	0.66
	F_2 (convenience)	Convenience	0.48
		Ease of use	0.56
		Arrive on time	0.53
		Ease to destination	0.62
		Crowding	0.61
		Waiting time	0.75
		Weather	0.50
		Extra time	0.57
	F_3 (cost)	Cost	0.73
		Parking cost	0.74
	F_4 (traffic wait and flexible schedule)	Travel time	0.47
		Waiting in traffic	0.81
		Flexible schedule	0.45

Premodeling Analysis of Sociodemographic Data

The category-coded sociodemographic data were analyzed by a principal-component factor analysis with a varimax rotation. The common-factor criterion used for the perceived-system-attribute data suggested a six-factor solution. However, after a review of solutions with three through six factors, a four-factor solution was selected on grounds of interpretability. The sets of high factor loadings used to define factors were chosen on the same basis as those used for the perceived-system-attribute data. The factor scores were then computed and clustered to find homogenous travel markets via an average linkage clustering algorithm by using the Biomedical Computer Program P2M (14). Blashfield (15) notes that this clustering approach has been shown to be effective in at least four empirical studies of alternative clustering methods.

The cluster analysis resulted in a total of 11 groups that formed at an amalgamation distance of 1.644 or less. Further amalgamations of these 11 groups produced increases in the amalgamation distance that were substantially and consistently larger than the earlier increases. Five of the groups have cluster sizes of at least 71 workers, but the remaining 6 groups have cluster sizes of 30 or fewer. Therefore, the centroids of the sociodemographic-factor-score space for the 5 largest groups were used as the nuclei of a 5-group solution by assigning respondents from the other 6 groups to their nearest neighbor in the 5-group solution. With one exception, no large centroid coordinate was modified by more than 5 percent. Even for the exception, the new centroid coordinate did not result in a different interpretation of characteristics of the respondents. This centroid position, cluster three on the first factor score, changed from 0.83 to 0.61.

Table 2 summarizes the results of the cluster analysis for the five-group solution after the addition of the six smaller groups. Assigning all of the sample to the five clusters changes the bases for the interpretation of only one cluster solution. The first factor of cluster three was decreased significantly and altered the interpretation of that segment. The large factor-score centroid coordinates are used as indicators of the descriptive characteristics of a group.

Table 2 shows that the groups occupy disparate positions in the factor-score space. Cluster four is characterized by three-or-more-person households that reside

Table 2. Summary of sociodemographic cluster analysis.

			Sociodemographic-Factor-Score Centroids			
Cluster	Sample Size	Descriptive Characteristics	Household Size and Type of Residence	Income	Age	Automobile Ownership
1	125	Households having three or more automobiles	-0.40	-0.16	-0.17	-2.25[a]
2	108	Households having income >$30 000	-0.50	-2.01[a]	-0.37	0.52
3	138	Households having one or more workers that are at least 55 years old	0.61	0.27	-1.79[a]	0.43
4	254	Households having three or more persons, including a child under 18 years old, residing in a single-family house	-1.06[a]	0.44	0.24	0.47
5	264	Households having one or two persons residing in an apartment or households having one or more workers that are less than 55 years old	0.92	0.34	0.63	0.18

[a] Used as indicators of the descriptive characteristics of a group.

Table 3. Multiple coefficients of determination of models calibrated with a single type of data.

Type of Data	Frequency of Use					
	Automobile - Bus		Automobile - Car Pool		Bus - Car Pool	
	Coefficient	p	Coefficient	p	Coefficient	p
NT (time and cost)	0.033	<0.001	0.004	>0.10	0.016	0.001 to 0.01
SD (sociodemographic)	0.054	<0.001	0.030	<0.001	0.012	0.01 to 0.05
B (modal beliefs)	0.265	<0.001	0.124	<0.001	0.178	<0.001

Table 4. Multiple coefficients of determination of models calibrated with two or three types of data.

Types of Data	Frequency of Use					
	Automobile - Bus		Automobile - Car Pool		Bus - Car Pool	
	Coefficient	p	Coefficient	p	Coefficient	p
NT + SD	0.077	<0.001	0.032	<0.001	0.027	<0.001
NT + B	0.269	<0.001	0.126	<0.001	0.181	<0.001
SD + B	0.279	<0.001	0.140	<0.001	0.181	<0.001
NT + SD + B	0.282	<0.001	0.142	<0.001	0.184	<0.001

Table 5. Multiple coefficients of determination of models calibrated with two or three types of data and interaction terms.

Types of Data	Frequency of Use		
	Automobile - Bus	Automobile - Car Pool	Bus - Car Pool
NT + SD + (NT * SD)	0.094	0.033	0.042
NT + B + (NT * B)	0.274	0.127	0.189
SD + B + (SD * B)	0.284	0.150	0.196
NT + SD + B + (SD * B)	0.288	0.153	0.200
NT + SD + B + (NT * SD)	0.293	0.143	0.194
NT + SD + B + (NT * B)	0.286	0.143	0.192
NT + SD + B + (SD * B) + (NT * SD)	0.299	0.154	0.209
NT + SD + B + (SD * B) + (NT * B)	0.293	0.154	0.208
NT + SD + B + (NT * SD) + (NT * B)	0.296	0.143	0.201
NT + SD + B + (SD * B) + (NT * SD) + (NT * B)	0.303	0.154	0.216
NT + SD + B + (SD * B) + (NT * SD) + (NT * B) + (NT * SD * B)	0.332	0.166	0.249

Note: All multiple coefficients of determination are statistically significant beyond the 0.001 level.

in single-family homes, and cluster five is characterized by one and two-person households that live in apartments. Clusters three and five differ in that cluster three represents households with at least one worker who is at least 55 years old, but cluster five represents households with a worker who is less than 55 years of age. Clusters one and two are relatively extreme groups that are characterized by households with three or more automobiles or an income of at least $30 000 respectively.

A similar clustering attempt was made for the perceived-system-attribute data, but initial efforts did not result in interesting cluster patterns.

Model-Specification Statistics

The three different dependent-variable criteria were (a) the frequency of automobile use minus that of bus use, (b) the frequency of automobile use minus that of car-pool use, and (c) the frequency of bus use minus that of car-pool use. Time and cost data were treated as the difference between the modes for these variables. The five sociodemographic clusters given in Table 2 were effect coded. These were four categories of sociodemographic variables. These variables were coded with values of 1, 0, and -1 depending on the cluster to which a respondent was assigned. These same sociodemographic-category variables were used for all three dependent-variable criteria.

To prevent the development of models with an excessive number of terms, only the scores for two perceived-system-attribute factors were used for each mode. These were F1 and F2 for the bus mode, F1 and F2 for the car-pool mode, and F1 and F5 for the single-occupant-automobile mode. These factors were chosen for inclusion because they accounted for the largest percentage of variance in the common-factor solution for beliefs about each mode. Only those factor scores that pertained to the dependent variable were included in a model. Therefore, the perceived-system-attribute terms for an automobile-minus-bus model consisted of the F1 and F5 scores for the automobile and the F1 and F2 scores for the bus.

Models Calibrated With a Single Type of Data

Table 3 gives the multiple coefficients of determination and the associated statistical significance levels for models calibrated with a single type of data for each of the three dependent-variable criteria. The results for models calibrated exclusively with beliefs about modes have consistently and substantially larger multiple coefficients of determination than do the results for models calibrated with time and cost and sociodemographic data. The multiple coefficient of determination for the perceived system attributes is statistically significant beyond the 0.001 level for all three dependent-variable criteria. Furthermore, the signs of the regression coefficients in the belief models are always in the correct direction. For example, in the automobile-minus-car-pool model, car-pool factors F1 and F2 have negative signs, but single-occupant-automobile factors F1 and F5 have positive signs. This shows that the higher use of the single-occupant automobile relative to that of the car pool is associated with a more positive perception of driving alone than of riding or driving in an automobile with others.

When models calibrated with time and cost data are compared with models calibrated with sociodemographic data, it appears that sociodemographic data are marginally more highly correlated with modal use. The multiple coefficients of determination for the sociodemographic data are always statistically significant by at least the 0.05 level. The time and cost data are not statistically significant for the automobile-minus-car-pool model, because the automobile and car-pool impedances are the same except for a constant added for the picking up of passengers. However, the signs of the regression coefficients for the time and cost data were not always correct. For example, in the automobile-minus-bus model, the cost term had a statistically significant positive sign. (Automobile cost is composed of several elements, some of which the individual may not consider to be work-trip related. It is possible that the individual considers only the daily out-of-pocket costs, such as parking fees, when evaluating the use of the automobile for the work trip. In any case, several attempts made to lower the objective measure of automobile cost had the effect of changing the sign or making the cost-coefficient statistically insignificant. However, the multiple coefficient of determination for the planning data remained unchanged.) The signs of the regression coefficients for the sociodemographic data do not appear to be counter intuitive.

Models Based on Two or Three Types of Data With No Interaction Terms

Table 4 gives the multiple coefficients of determination and the associated statistical significance levels for models based on two or three types of data with no explicit interaction terms. The four specific sets of types of data that are considered include two-way models of network time and cost, sociodemographic, and belief data and a three-way model that includes all three types of data.

A number of important details can be observed in Table 4. All the models are statistically significant beyond the 0.001 level. This result implies that any two-way or three-way model in the table can reliably estimate a trend of modal use with respect to its independent-variable set. However, the models based solely on time, cost, and sociodemographic data have multiple coefficients of determination that are approximately three to six times smaller than those of the models based on beliefs and either network time and cost or sociodemographic data. Therefore, perceived system attributes again show a strong correspondence with modal choice. Finally, the three-way model represents only a very minor improvement in the percentage of variance accounted for in the dependent variable in comparison to either of the two-way models that include beliefs.

Models Based on Two or Three Types of Data With Interaction Terms

Table 5 gives the multiple coefficients of determination for models calibrated with two or three types of data that have explicit terms for interaction among the data types. These interaction terms are formed by the product of the corresponding single type-of-data terms. There are a total of 11 models with explicit interaction terms. Those models that systemically incorporate two-way interactions before the final inclusion of a three-way interaction set of terms were designed to facilitate hypothesis testing based on analysis of the variance of the components as discussed by Appelbaum and Cramer (16), Cohen (17), Dobson (18), Kerlinger and Pedhazur (9), and Overall and Klett (11).

There is only one model described in Table 5 that does not include any belief data. This model, which is given in the first row, has multiple coefficients of determination that are substantially lower than those of the models that are based partly on belief data. This relation highlights the potency of belief data in accounting for the variation of modal use. In general, the addition of more or higher level interaction terms increases the percentage of variation accounted for by a model. For example, the last model described, which includes all possible two-way interaction terms and the set of three-way interaction terms, has larger multiple coefficients of determination than any other across the three dependent-variable criteria. Interaction terms enhance the size of the multiple coefficient of determination, but they vastly complicate the models. A model specified by NT + SD has 6 terms plus a constant, but one specified by NT + SD + (NT * SD) has 14 terms plus a constant, and the last model in Table 5 contains 75 terms, including the constant!

Hypothesis Testing Based on a General Procedure for Analysis of the Variance of the Components

While the summary statistics given in Tables 3, 4, and 5 are informative, they do not show the relative statistical significance of the different types of data. The general procedure for the analysis variance of the components described in the discussion of Equations 1 through 5 permits testing for the relative statistical significance of alternative classes of data based on their multiple coefficients of determination.

The procedure for assessing the statistical significance of the interaction terms proceeded in a hierarchical fashion. R^2 [NT + SD + B + (SD * B) + (NT * SD) + (NT * B) + (NT * SD * B)] was compared with R^2 [NT + SD + B + (SD * B) + (NT * SD) + (NT * B)]. The three-way interaction set of terms (NT * SD * B) was not found to be statistically significant. The statistical significance of the two-way interaction denoted by (NT * SD) was tested through the comparison of R^2 [NT + SD + B + (SD * B) + (NT * B) + (NT * SD)] with R^2 [NT + SD + B + (SD * B) + (NT * B)]. It was not statistically significant and neither were any of the other two-way sets of interaction terms. These findings of nonsignificance were invariant across the dependent-variable criteria. As a consequence of the lack of statistical significance for the interaction terms, the statistical significance of NT, SD, and B was tested through the set of models without interaction terms that are summarized in Tables 3 and 4.

Table 6. Tests of significance for network, sociodemographic, and belief data.

	Frequency of Use								
	Automobile - Bus			Automobile - Car Pool			Bus - Car Pool		
Type of Data	Significance	Variables Held Constant	Model	Significance	Variables Held Constant	Model	Significance	Variables Held Constant	Model
B	$p < 0.001$	NT	B + NT	$p < 0.001$	NT	B + NT	$p < 0.001$	NT	B + NT
	$p < 0.001$	SD	B + SD	$p < 0.001$	SD	B + SD	$p < 0.001$	SD	B + SD
	$p < 0.001$	NT + SD	B + NT + SD	$p < 0.001$	NT + SD	B + NT + SD	$p < 0.001$	NT + SD	B + NT + SD
SD	$p < 0.001$	NT	SD + NT	$p < 0.001$	NT	SD + NT	$p < 0.05$	NT	SD + NT
	$p < 0.01$	B	SD + B	$p < 0.01$	B	SD + B	NS	B	SD + B
	$p < 0.001$	NT + B	SD + NT + B	$p < 0.01$	NT + B	SD + NT + B	NS	NT + B	SD + NT + B
NT	$p < 0.001$	SD	NT + SD	NS	SD	NT + SD	$p < 0.01$	SD	NT + SD
	NS	B	NT + B	NS	B	NT + B	NS	B	NT + B
	NS	SD + B	NT + SD + B	NS	SD + B	NT + SD + B	NS	SD + B	NT + SD + B

Table 6 summarizes the results for the tests of significance for the network, sociodemographic and belief data sets when one or both of the other types of data are held constant. The belief data are shown to be uniformly statistically significant at beyond the 0.001 level, no matter which combination of variables they are compared to or what dependent variable is being considered. This is the only type of variable to demonstrate such a strong and unequivocal relation with modal use.

The sociodemographic data demonstrate a consistently strong relation to modal use beyond the 0.01 level of significance across the automobile-minus-bus use and automobile-minus-car-pool-use dependent-variable criteria. However, it is nonsignificant for two of three tests with respect to the bus-minus-car-pool-use dependent-variable criterion. The network data show the weakest pattern of relation to modal use, being nonsignificant in seven of nine tests.

SUMMARY AND CONCLUSIONS

The principal goals of this paper were (a) to establish whether there is a relation between perceived system attributes and modal choice, (b) to compare the magnitude of any linkage between perceived system attributes and modal choice with those of the linkages between sociodemographic and network data and modal choice, and (c) to establish the degree to which a linkage between perceived system attributes and modal choice is dependent on the linkages of sociodemographic and network data to modal choice. It was clearly shown that perceived system attributes or beliefs about modes are strongly associated with modal choices. Furthermore, the correlation between beliefs and modal choice is substantially larger than the correlations between either sociodemographic or network data and modal choice. Finally, the linkage between perceived system attributes and modal choice cannot be accounted for by relations of sociodemographic or network data or both and modal choice.

There is unquestionably a strong association between perceived system attributes and modal choice. The multiple coefficients of determination for modal choice as a function of beliefs about modes ranged from 0.265 to 0.124, and these coefficients were always statistically significant beyond the 0.001 level. The relation between perceived system attributes and modal choice is not influenced by either sociodemographic or network data. Two-way and three-way interaction terms were found not to be statistically significant, and the statistical significance of the perceived-system-attribute terms is not diminished beyond the 0.001 level when they are combined with sociodemographic or network data in two-way and three-way models. Network data do not independently contribute to the estimation of modal choice when combined with belief data. In other words, belief variables account for variance in modal choice above and beyond time and cost data, but the reverse is not true. The sociodemographic data overlap somewhat less with the belief data, but there is still a tendency for diminution of the sociodemographic effect when it is combined with the belief set.

The models and hypothesis-testing features of the empirical analyses reported here are based on the assumption of linear relations between modal choice and various sets of predictor variables. For the majority of linearity tests that were computed (but are not reported here), the nonlinearity assumption can be rejected. However, a pattern of significant nonlinear deviations emerges for the automobiles versus bus comparisons. Even these significant deviations, nevertheless, do not result in substantial differences between R^2 and eta square, a nonlinear analog to R^2. Therefore, the nonlinear characteristics were not substantively important for the data sets studied here.

The sample used in this research—CBD workers—is potentially atypical and sets a basis for restricting the generality of conclusions. The modal split is 56.2 percent single-occupant automobile, 25 percent bus, and 18.8 percent car pool. The CBD restriction introduces an enhanced level of availability of non-single-occupant-automobile modes with respect to a more random areawide sample. Therefore, beliefs that favor buses or car pools can be more easily translated into actual modal use patterns. For corridor planning analyses and planning studies of short-term low-cost improvements, this situation may be more general than is commonly believed.

No single model is recommended by the research reported here. If the effect of travel time and cost needs to be measured, it is generally possible to calibrate statistically significant models. Models based on network data combined with sociodemographic data were always found to be statistically significant. However, the sign for the travel-cost variable was incorrect. The addition of belief data to a model with network or sociodemographic data or both substantially increases the percentage of variance accounted for relative to that of the old model. While curvilinear models, such as those based on a logit formulation, are preferable on logical grounds for modal-choice analysis, a generalized curvilinear model was only slightly superior to linear representations on empirical, statistical grounds.

The results reported here are apparently at variance with those previously found by Hartgen (4) and Dobson and Kehoe (5), neither of whom found a strong linkage between perceived system attributes and modal choices. However, there are substantial differences between this study design and theirs. Among the most important is that the earlier analyses used data from an areawide random survey while this study design is restricted to CBD workers, for whom it is appreciably easier, relative to areawide workers, to translate favorable beliefs about buses and car pools into actual modal choices.

On the other hand, these results support and extend the findings of Dobson and Tischer (6), Nicolaidis (7), and Spear (8), whose studies found attitudes to be significantly correlated with modal choices. Spear restricted his sample to CBD workers who were not automobile or transit captives. Nicolaidis conducted his study in a college town. Dobson and Tischer used a sample that was closely related to the one studied here. The earlier Dobson and Tischer study is extended by the consideration of more than just belief data to permit the evaluation of perceived system attributes with respect to other possible causal factors for modal choice.

ACKNOWLEDGMENTS

The California Department of Transportation (Caltrans) and the Southern California Rapid Transit District (SCRTD) kindly provided the data that permitted the calibration of models with network time and cost information for single-occupant automobiles and buses. Norman P. Roy of Caltrans and Patrick Conway of SCRTD were particularly helpful in making information available. The advice of David S. Gendell, Thomas A. Hillegass, and Samuel L. Zimmerman, all of the U.S. Department of Transportation (U.S. DOT), was of assistance in the development of the network coding standards and the treatment of the network data for incorporation in modal-choice models. The respondent data were collected through a contract with a market research firm. Finally, William E. McGarvey and Mark T. Stahr, both of U.S. DOT, are gratefully acknowledged for assistance in the running of computer programs and the preliminary analysis of results. We accept full responsibility for the accuracy of the findings and the conclusions derived from the findings.

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

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Development of Market Segments of Destination Choice

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This paper discusses the development of individual-choice models of the destination choice of nongrocery shopping locations. Two key features of the approach are the use of perceptual data for characterizing alternative destinations and an attempt to segment the population before the model building on the basis of homogeneity of perceptions of destinations. Data were obtained about the perceptions of shoppers of several shopping locations and on their preferences for various attributes of the shopping locations. The attributes were selected as those that make up the image of a shopping location independent of the transportation system. Several techniques are discussed for segmenting the population by perception, all of which are based on analysis of the psychological distance between shopping locations. Given the special properties of psychological distances, two forms of analysis were undertaken. First, correlations were computed for the set of interpoint distances for each socioeconomic group identified in the data. High correlations indicate similarity of perceptual space, while low correlations indicate lack of similarity. Second, the group interpoint distances were used as inputs to an individual scaling process that attempts to fit the perceptions into a common perceptual space by stretching or compressing the axes of the space by obtaining weights on each axis for each observation. In this case, market segmentation was sought through a hierarchic, fusion clustering process on the axis weights for each socioeconomic group. The results of these analyses converge well. Length of residence and age were found to be important segmentation variables. Sex and income were not found to be very powerful segmentation variables, but occupation may be worth study as a basis for segmentation.

In the last decade, there have been numerous developments in the formulation, refinement, and operation of travel-demand models at the level of the individual trip maker (1), by using behavioral constructs from psychology and microeconomics. For various reasons, most of this work has taken place in the subchoice of travel mode, primarily that for the work trip. From time to time, extensions of the behavioral approach beyond the modal-choice process have been proposed, but little progress had been made in such extensions until recently.

A major problem in achieving such extensions is the characterization of the elements of utility of other subchoices. In modal-choice models, utility was characterized initially in terms of the physical attributes of alternative modes of travel, such as travel times and costs and frequency. Although these physical attributes provide only an incomplete specification of alternative travel modes, they have proved sufficient to allow much progress in the development of modal-choice models. Even here, however, recent research (2, 3, 4, 5) has used psychometric techniques to add nonphysical measures to the modal-utility specification. The use of simple physical measures, such as those in modal choice, has not generally appeared to be appropriate for extensions to other travel choices. Standard transportation planning procedures have characterized the attractiveness of destinations (aggregated into geographic zones) by the number of trips they attract or by variables such as floor area and employment, i.e., size measures only. Similarly, the decision to make a trip has been modeled as an aggregate phenomenon based on a very restricted set of variables, such as automobile ownership or population (6). Other pertinent choices, such as time of day and frequency, have not been a part of the traditional transportation planning process. Attempts to develop realistic models of these choices have been hampered by a lack of variables suitable for the characterization of the determinants of these choices (7) and have largely had to await some alternative method of investigation and the measurement of pertinent variables.

The use, in the early 1970s, of psychometric techniques to aid in the further development of modal-choice models (2, 3, 4, 5) suggested a way in which other modeling areas could also be developed. Specifically, this paper reports a preparatory step toward the development of destination-choice models that are based on individual and group perceptions of alternative destinations (8, 9). The major concern here is the idea of segmenting the population before building the model, to improve the accuracy and responsiveness of the model and to increase our understanding of the choice process. The principles of market segmentation have been expounded and used extensively in marketing studies (10), but only recently has the potential of the technique been recognized in connection with travel-demand estimation (11).

The subject here is the choice of destination for nongrocery shopping trips. A choice-based survey described elsewhere (12) was carried out at several shopping locations in the north and northwest suburbs of Chicago. There were several important reasons for using a choice-based sample. The most important was the necessity that a recent nongrocery shopping trip be in the respondent's mind when responding to the survey. Given the relative infrequency of such trips, it would be necessary to approach a very large number of households to achieve a sufficient sample. Second, the available budget made interview surveys inappropriate, while a mail-out-mail-back survey seemed unlikely to bring a high enough response rate. Finally, the objects of the research did not require a generalizable model at this stage, which removed the necessity to control the biases in the choice-based procedure selected. The survey obtained data about a recent shopping trip of each respondent, the preferences of the respondent for a number of different shopping locations and for attributes of shopping locations, the perceptions of the respondents of the attributes of a number of shopping locations, and some socioeconomic details of the respondent. The analysis was conducted on approximately 7000 responses. Some slight variations in sample size occurred due to varying nonresponse rates among the different socioeconomic variables.

METHODS FOR IDENTIFYING MARKET SEGMENTS

The principal hypothesis used in this research is that socioeconomic characteristics are a reasonable basis for grouping the population according to common perceptual spaces of attractiveness of shopping locations. In other words, it is assumed (a) that persons within a given socioeconomic group are more likely to have a homogeneous perception of such an attractiveness space than are those in diverse groups and (b) that segmentation based on cognition will be useful in travel-demand research. Socioeconomic characteristics were used because of their availability from such sources as censuses, which would increase considerably the usefulness of segmentation based on them. Segmentation was based on cognition rather than on behavior for several reasons. First, behavior segmentation requires time-series data from which dynamic behavior can be mapped or, alternatively, data determined before and after a major change in a shopping opportunity, and both are extremely expensive and difficult to obtain and beyond the scope of this project. Second, segmentation based on cognition is useful and relevant if behavior is also shown to be a function of cognition. (Another phase of this project is seeking such relationships, in which cognitive segmentation can provide incremental improvements in model structure.)

The hypotheses embedded in the use of the socioeconomic variables as market segmenters are as follows:

1. Length of residence acts as a proxy variable for learning about shopping opportunities and may indicate different levels of knowledge.
2. Income may be expected to determine sensitivity to price-related variables. Low-income persons may react more strongly to price variables than do higher income persons.
3. Age may be a partial proxy for the types of products sought when shopping and also for comparative sensitivity to service variables and variety measures.
4. Sex may be a segmenter variable on the experience sought in shopping and on comparative sensitivity to most of the range of attributes except price.
5. Occupation would be expected principally to discriminate behavior and cognition between those who are employed and those who are not (including students, the retired, and housewives). Beyond this, it may be a proxy for various life-style variables.

Given these basic assumptions, the research is aimed at determining whether the finest level of groupings obtained in the survey is necessary to characterize homogeneity. The procedure adopted was, therefore, a hierarchical combination of the smallest groupings into larger groupings that yet represent homogeneity in perception. Socioeconomic variables are not the only basis for market segmentation, personality variables may be more appropriate, although less useful to the practicing transportation planner.

The appropriate subgroupings of the population are shown in Table 1. The basis of the grouping process is to obtain a perceptual space for each subgroup and then determine the similarity of the spaces among groups. The initial analysis was carried out on the basis of one socioeconomic variable at a time, without examination of two or three-way classifications of the population. These are a part of another analysis that is not yet completed, but proving extremely expensive.

The segmentation technique is based on the use of aggregate measures for each socioeconomic group. The

Table 1. Socioeconomic groups for first-cut analysis.

Characteristic	Subgroup	Dimensionality
Sex	Female	3
	Male	4, 3
Age, years	≤16	4, 3
	16 to 21	4, 3
	22 to 29	4
	30 to 39	3
	40 to 49	3
	50 to 59	4, 3
	≥59	4, 3
Income, $	≤10 000	3
	10 001 to 15 000	2, 3
	15 001 to 20 000	3
	20 001 to 25 000	4
	25 001 to 50 000	4
	≥50 000	3, 2
Occupation	Military	—[a]
	Salesperson	4
	Teacher	3
	Professional person	4, 3
	Craftsperson	3
	Clerical worker	3, 2
	Student	4
	Housewife	4, 3, 2
	Government worker	4, 3
	Retired person	4, 3
	Other	3
Length of residence, years	≤4	4, 3
	4 to 6	4, 3
	7 to 10	4, 3
	≥10	4, 3

[a]Too few responses in this category to develop multidimensional solution information.

ideal procedure would be to obtain individual perceptual spaces and group the sample on the basis of similarity of these spaces. However, individual spaces can be determined only by the Individual Differences in Orientation Scaling (IDIOSCAL) program (14), which has an upper limit of 25 individuals. Individual weights for a common space can be determined for a maximum of 100 individuals through the Individual Scaling (INDSCAL) program (15). Clearly, with 30 initial subgroups, the IDIOSCAL program would be quite infeasible, and the use of the INDSCAL program would require repeated solutions using several unrelated random samples of 100 individuals to ensure removal of small-sample biases and idiosyncracies. Convergence of solutions also could not be ensured among the separate samples. The alternative used here was the multidimensional scaling (MDSCAL) procedure, which generates average interpoint distances in the most efficient space possible (the procedure for this is described below). These average distances were then input into the INDSCAL program to provide one of the grouping procedures examined. Thus, MDSCAL is not being used as a scaling procedure, but rather as a mechanism to determine a set of interval-scaled average interpoint distances. On this basis, the scales that are represented by the axes of the solution space become irrelevant. Also, because the usual input data to the INDSCAL program are interval data, differences among the scales are irrelevant.

To understand the problems of seeking homogeneity of perceptual spaces, some understanding is necessary of the MDSCAL procedures and the results generated by these procedures. The perceptual spaces are, in this case, to be generated as aggregate spaces for a preselected group or subgroup of the population; i.e., for each socioeconomic group identified in Table 1, one aggregate perceptual space is to be developed. The aggregate, i.e., MDSCAL, procedure involves the selection of a dimensionality that is most efficient for representing the aggregate information obtained on perceived distances between the set of stimuli (shopping centers in this case). These distances can be obtained by direct questions that request information directly about the similarity that persons perceive between alternative shopping centers vis-à-vis some prespecified metric or quality. For example, in this study, the respondents were asked to rate all possible combinations of seven regional shopping centers (Woodfield, Chicago Loop, Edens Plaza, Plaza del Lago, Golf Mill, Old Orchard, and Korvette City) on a scale of one equals completely similar to seven equals completely different in response to the question, "If all the shopping centers were equally easy to get to, how similar do you think they are to each other?" Alternatively, these distances can be derived by asking the respondents to rate each of a set of shopping centers on a number of different attributes that are postulated as making up the quality or metric to be used for judging similarity. Thus, in this study, the respondents were asked to rate the seven shopping centers on a scale of good to poor for a series of attributes such as eating facilities, layout of store, prestige of store, quality of merchandise, reasonable price, ease of returning or servicing merchandise, variety or range of merchandise, availability of credit, and availability of sale items. If a set of n stimuli are used in either of these two types of questions, then the distances between the stimuli may be represented uniquely in (n - 1)-dimensional space. For example, the survey used seven shopping-center locations for the two types of questions. Thus, the interpoint distances can be represented uniquely in six-dimensional space. Significant reduction of multidimensional spaces can be achieved only for n/3 dimensions or fewer; i.e., reductions to $[(n/3) + 1]$ dimensions can always be achieved with satisfactory results even from random data on interpoint distances. However, it is extremely difficult to find a sufficiently large number of persons with a common set of shopping centers (in the sense of all being known about) having as many as seven locations. Extensions to larger numbers of shopping locations appear infeasible.

In the method used, average distances were computed for each of the identified subgroups in the population. These distances are distances between each of the seven shopping centers in the perceived space of attractiveness to shop. The first task of the analysis is to find the most efficient dimensionality in which to express the perceptual space for the attractiveness concept without distorting the perceived distances between the shopping centers. This is the procedure that the MDSCAL program performs. In collapsing the dimensionality of the space, the procedure requires that a monotonic relation be preserved between the original interpoint distances and those in each successive reduced-dimensionality space. The requirement of monotonicity is placed on the procedure, rather than a requirement of strict linearity, because the data from which the information is derived is ordinal in nature. Thus, it would not be appropriate or correct to invest ratio properties in the base data, nor to require preservation of the sizes of the intervals between stimulus points in the space in the collapsing process. In the process of developing a perceptual space through the MDSCAL program, the orthogonal axes describing the space are located arbitrarily. Thus, there is no ready mechanism for comparing the final resulting multidimensional spaces from different socioeconomic subgroups of the population with each other, since no two spaces are necessarily located in any common way. Both rotation and translation of the axes are possible from one space to another. Figures 1, 2, and 3 show three solutions from the MDSCAL process for different subgroups of the population. It is clear from these that conclusions about homogeneity or heterogeneity of subgroups cannot be drawn, given that the axes can be rotated or translated at will from one group to the next.

To be able to segment the sample, it is necessary to find a means by which alternative spaces can be compared. Two processes appeared possible from the multidimensional-scaling work. First, the multidimensional scaling results in the production of a new set of interpoint distances for the most efficient space determined. These interpoint distances, which represent average distances for members of each subgroup in the most efficient dimensionality space, can be considered as a set of candidate values that describe each subgroup in terms of the perceptual space. Thus, one may compute either a rank or a metric correlation between the sets of distances of one group and another. Since there are seven stimuli in the space, there are 21 interpoint distances that are necessary to describe each multidimensional solution, which may be used to compute either a rank (Spearman) correlation or a linear (Pearson) correlation between them. Such a measure is computed irrespective of the rotation and translation of the representation of the multidimensional space. All that one is looking for here is a correlation of the distances between each pair of points. Because the original data from which the spaces were derived is ordinal, rather than cardinal, and the procedure for developing the multidimensional space requires only the preservation of the ordinal information, it may be more appropriate to consider a rank correlation, rather than a linear correlation. However, both types of correlations were run for these data, and comparisons were made between the results obtained. In general, rank correlations might be expected to be somewhat higher than linear correlations, and this proved to be the case. One may conclude that the Spearman correlations are generally a less sensitive test of interrelation. Indeed, the results of the parallel tests were that whenever the Pearson correlations were significant, the Spearman correlations were also significant. However, there were several cases in which the Spearman correlations were significant, but the Pearson correlations were not. On the basis of the greater sensitivity of the Pearson correlations, these are the ones used below.

The second procedure for determining the comparisons between alternative attractiveness spaces involved the use of the average interpoint distances for each subgroup as an input to the INDSCAL method of analysis. The INDSCAL model is a method for developing perceptual spaces on an individual-by-individual basis. The procedure requires, however, that all individuals be fitted to a space that has common dimensionality. Thus, for example, a target space can be preselected and a determination made of how each individual can be fitted into that space by differential scaling of the relevant axes. Alternatively, the method can be used to generate its own target space as being that one that can be most readily fitted to the entire set of observations used as input. When used on individual data, the interpoint dis-

Figure 1. Two-dimensional space for clerical workers.

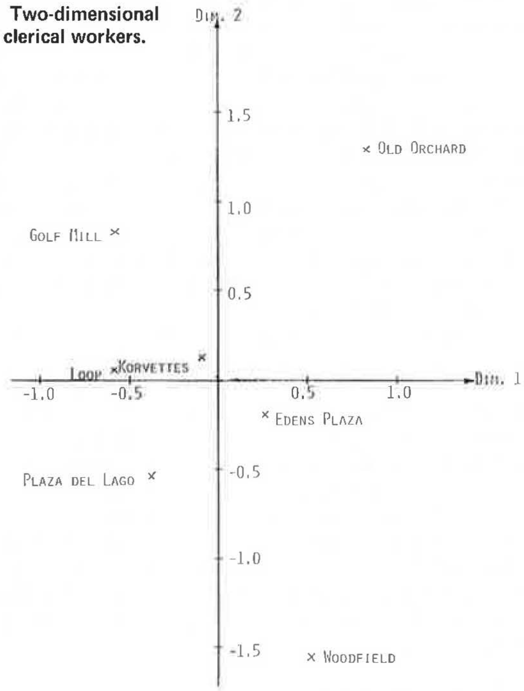


Figure 2. Two-dimensional space for incomes greater than $50 000.

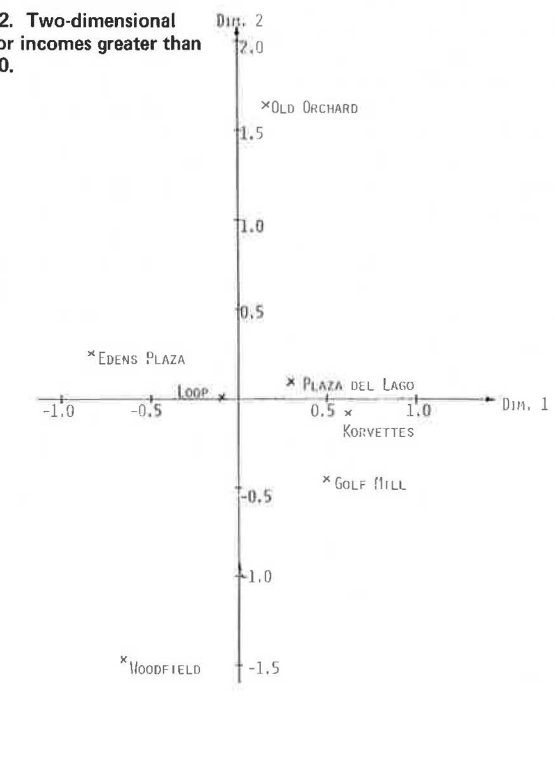
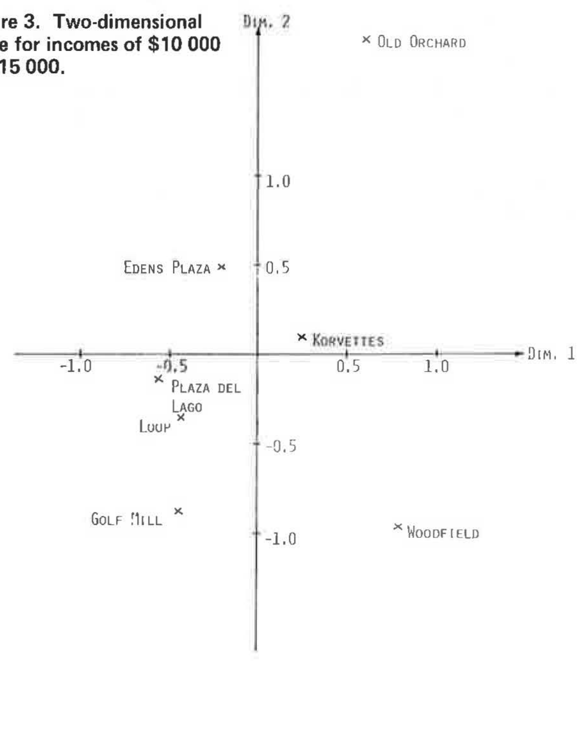


Figure 3. Two-dimensional space for incomes of $10 000 to $15 000.



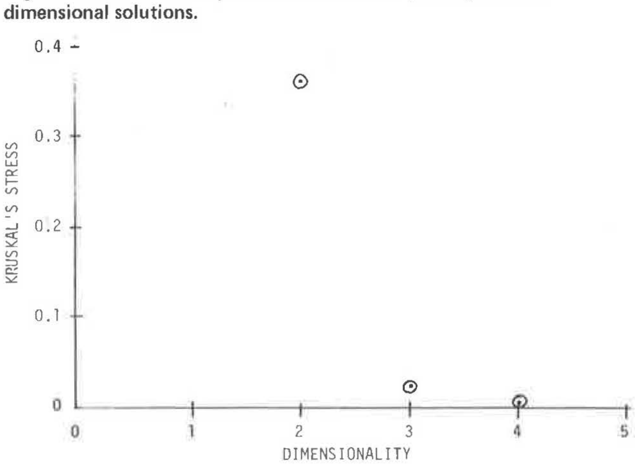
tances are computed from the original responses to the questions on either direct or derived similarities, as for MDSCAL, and a space is determined in the lowest dimensionality possible for representing all individuals. The INDSCAL procedure generates a set of weights for each individual, where these weights represent the necessary scaling of the axes for the lowest dimensionality space used, that permit each individual to be fitted into a common space with the least possible distortion of his or her own interpoint distances. The INDSCAL procedure is carried out in a metric process in which the actual distances are preserved. This description of the INDSCAL procedure is one that is relevant for its conventional use.

As outlined above, it was hypothesized that average interpoint distances derived from the MDSCAL procedure might be substituted for the individual data that would normally be the input to the INDSCAL procedure. In this manner, each of the multidimensional spaces found for the socioeconomic subgroups could be fitted to a common space, and the output weights on the various dimensions of the common space would provide a metric that could be used in some type of correlation or cluster analysis. Naturally, such a process loses the information of variance within each group, but it is not clear how serious such a loss would be here. However, there is no way in which the information can be incorporated in the process.

After each of the socioeconomic subgroups has been fitted into a common space and the weights for each of the axes of that common space have been obtained, a cluster analysis can be performed on the weights from which a hierarchy of groupings of the original subgroups can be determined. It is important, however, that neither of the methods proposed here have associated with them any statistical measures of goodness of fit.

The selection of a parsimonious space has been discussed above, but there has been no discussion of the question of how parsimony and efficiency are determined. As an aid to such selection, a statistic (stress) has been developed by Kruskal (13) that measures the degree of distortion introduced by each solution produced. Thus, as the dimensionality is reduced from the original configuration of, for example, six dimensions, a value of stress can be computed that can then be used to determine whether or not the lower dimensionality solution is acceptable. A set of empirical values has been determined for stress, in terms of specifying the degree of goodness of fit to the original data. These values are provided with descriptions in the following form: perfect fit, excellent fit, good fit, fair fit, or poor fit. Ideally, a plot of the value of stress versus dimensionality will show a characteristic elbow (Figure 4). Conceptually, this figure indicates that initially reduction in dimensionality causes no distortion in the interpoint distances, but that a point is reached at which a further reduction of one dimension causes significant distortion. It may therefore be assumed that the dimensionality immediately preceding the substantial increase in stress indicates the most efficient and parsimonious MDSCAL solution. Lower dimensionalities clearly introduce serious distortions into the data, while higher dimensionalities are not necessary, since no distortion occurs when they are reduced. The stress will not always behave in this precise fashion. It will, however, either remain approximately constant, exhibit a well-defined elbow, or have a generally upward-sloping curve as the dimensionality is reduced. In general, no other forms are possible.

Figure 4. Dimensionality versus stress for two, three, and four-dimensional solutions.



In this study, all the socioeconomic groups were run for four, three, and two-dimensional solutions. In each case, a plot was obtained of the stress versus the dimensionality, and this was used to select the appropriate dimensionality for that particular socioeconomic group. In most cases, the change of stress with dimensionality followed the ideal plot shown in Figure 4, and, the selection of the most efficient dimensionality was obvious. In some cases, however, the stress followed a more-or-less straight line that increased with decreasing dimensionality. In these cases, a solution was chosen that was based on the interpretations of fit developed by Kruskal. Where possible, the lowest dimensionality was chosen that was consistent with the empirical range for good to excellent fit. In some cases, the change in stress was such that two or more dimensionality solutions fell within the same region of fit, and in these cases, more than one dimensionality was selected as a solution. The solutions selected are shown in Table 1.

The interpoint distances from the selected multidimensional representations were then used as inputs to an INDSCAL procedure from which weights were determined for each of the subgroups. These weights were subjected to cluster analysis.

CORRELATION ANALYSIS

The first form of analysis used was the determination of the Pearson and Spearman correlations among the interpoint distances from the MDSCAL solutions. One set of correlations was determined for four-dimensional solutions, a second set for three-dimensional solutions, and a third set for two-dimensional solutions. It was not felt to be valid to compute correlations between groups whose representations were in different dimensionalities. The distinction between the two types of correlations is that the Spearman correlations are correlations only on the rank ordering of the interpoint distances, while the Pearson correlations are of a linear-regression type that are determined by assuming the distances to be metric distances. The only correlations of interest are those within a particular socioeconomic group. These are shown in Figures 5, 6, and 7. (Only the Pearson correlations are shown, because these were consistently lower than the Spearman correlations.)

In these figures, an empirical rule that may be used is that correlations below 0.5 indicate relatively little association between the variables and correlations above 0.5 indicate a fairly substantial degree of association. Thus, one may conclude that there are relatively high correlations between the sexes for the three-dimensional solutions. On the basis of the four-dimensional solutions, one could potentially place the under 16-year-old group with the 16 to 21-year-old-group, and the 16 to 21-year-old group with the 22 to 29-year-old group.

Figure 5. Pearson correlations: four-dimensional solutions.

Occupation	Sales	Prof.	Stud.	Housewife	Gov't	Ret'd
Salesman		.627	.431	.394	.308	.572
Professional			.155	.457	.143	.619
Student				.325	.432	.218
Housewife					.538	.860
Government						.288
Retired						

Income	$20-25,000	$25-50,000
$20-25,000		.643
$26-50,000		

Length of Residence	<4 yrs.	4-6 yrs.	7-10 yrs.	over 10 yrs.
<4 yrs.		.870	.566	.532
4-6 yrs.			.449	.383
7-10 yrs.				.876
over 10 yrs.				

Age Group	<16	16-21	22-29	50-59	60 and over
<16		.679	.500	.528	.574
16-21			.555	.312	.451
22-29				.546	.671
50-59					.726
60 and over					

Figure 6. Pearson correlations: three-dimensional solutions.

Sex	Male	Female
Male		.632
Female		

Occupation	Teach	Prof.	Crafts	Cler/Sec	Hswfe	Govt.	Ret'd	Other
Teacher		.522	.608	.870	.852	.409	.755	.465
Professional			.310	.422	.499	.122	.578	.433
Crafts.				.636	.537	.318	.670	.483
Cler./Sec.					.922	.496	.799	.577
Housewife						.559	.816	.390
Government							.358	.174
Retired								.487
Other								

Income	<$10K	10-15K	15-20K	>50K
<$10K		.637	.901	.598
10-15K			.586	.794
15-20K				.599
>50K				

Age	<16	16-21	30-39	40-49	50-59	60+
<16		.234	.209	.187	.306	.149
16-21			.455	.368	.422	.613
30-39				.443	.342	.644
40-49					.577	.684
50-59						.793
60+						

Length of Residence	<4 yrs.	4-6	7-10	Over 10
<4 yrs.		.723	.490	.490
4-6 yrs.			.447	.445
7-10 yrs.				1.00
Over 10 yrs.				

Figure 7. Pearson correlations: two-dimensional solutions.

Subgroup	Cler.	Hswfe	$10-15K	>$50K
Cler.		.835		
Hswfe				
$10-15K				.784
>$50K				

However, the correlation between the under 16-year-old group and the 22 to 29-year-old group is relatively low, and an optimal combination would be under 22, rather than breaking at 16. A high degree of correlation is shown between the 50 to 59-year-old group and the over 60-year-old group. Relatively high correlations seem to be demonstrated between the over 60-year-old group and all of the other age groups except the 16 to 21-year-old group. It is not completely clear why this might be so, but may indicate that this particular age category is not a useful one for discriminating perceptions of shopping opportunities. In contrast, there is a very low correlation between the under 16-year-old group and the 16 to 21-year-old group in a three-dimensional solution, and the only high correlations are those between the 40 to 49, 50 to 59, and over 60-year-old groups. In fact, the conclusion from this figure would probably be that one age group of over 40 would be sufficient to describe age groups with respect to perception of shopping-center destinations.

It does not appear to be very meaningful to consider major combinations of occupational categories. There are some quite strong correlations between certain occupational categories and very weak ones among others. For example, there are high correlations between clerical workers and teachers, between housewives and clerical workers, and between housewives and retired persons, but the conclusions that can be drawn from this are not clear. Nevertheless, the correlations are reported for completeness. The correlations based on income indicate that income is not a good discriminator of perceptions of shopping-center destinations. Indeed there are no correlations in any of these figures below 0.5, and some of the highest correlations are found in these tables. There is a very clear polarization on length of residence with a high correlation between those persons who have lived in the area less than 4 years and those who have lived in the area 4 to 6 years and a similarly high correlation between those who have lived in the area 7 to 10 years and those who have lived there more than 10 years. Both figures, which are for different dimensionalities, exhibit the same pattern. Correlations between the other pairs of groups are substantially lower, all less than 0.5. One can conclude from this that a grouping of length of residence with a break point at 6 years would appear to be appropriate. This is by far the strongest result obtained in this analysis.

Table 2. Clustering of four-dimensional solutions within socioeconomic variables.

Original Characteristic	Cluster
Length of residence, years	
≥10	≥6
7 to 10	≥6
4 to 6	≤6
≤4	≤6
Occupation	
Salesperson	Salespersons
Professional person	Professional persons
Student	Students
Housewife	Housewives and retired persons
Retired person	Housewives and retired persons
Government worker	Government workers
Age, years	
≤16	≤22
16 to 21	≤22
22 to 29	22 to 29
50 to 59	50 to 59
≥59	≥59
Income, $	
20 001 to 25 000	20 001 to 25 000
25 001 to 50 000	25 001 to 50 000

Table 3. Clustering of three-dimensional solutions within socioeconomic variables.

Original Characteristic	Cluster
Sex	
Female	Combine sexes
Male	Combine sexes
Age, years	
≤16	≤22 and ≥59
16 to 21	≤22 and ≥59
30 to 39	30 to 39
40 to 49	40 to 49
50 to 59	50 to 59
≥59	≤22 and ≥59
Occupation	
Teacher	Teachers
Professional person	Professional persons, craftspersons, and government workers
Craftsperson	Professional persons, craftspersons, and government workers
Clerical worker	Clerical workers, housewives, and retired persons
Housewife	Clerical workers, housewives, and retired persons
Government worker	Professional persons, craftspersons, and government workers
Retired person	Clerical workers, housewives, and retired persons
Other	Other
Income, $	
≤10 000	≤10 000
10 001 to 15 000	10 001 to 15 000
15 001 to 20 000	15 001 to 20 000
≥50 000	≥50 000
Length of residence, years	
≤4	≤6
4 to 6	≤6
7 to 10	≥6
≥10	≥6

CLUSTER ANALYSIS

A cluster analysis was performed on the weights for each subgroup obtained from the INDSCAL procedure by using the hierarchic fusion process (16). This analysis provided various hierarchical levels of clustering of the subgroups. Generally, only the lowest level of clustering was considered worth examining. The results of the clustering of four-dimensional solutions are shown in Table 2, and those of the three-dimensional solutions are shown in Table 3. The two-dimensional solutions were not subjected to a separate cluster analysis. On the basis of these two tables, it is again evident that length of residence may be divided at 6 to 7 years, based on the original categorization in the questionnaire. This result occurs for both the three and the four-dimensional solutions and is consistent with the results of the correlation analysis. Again, some groupings of occupations appear within the two tables, and these are generally similar to those found in the correlation analysis. For example, the correlation analysis found a high correlation between housewives and retired persons for the four-dimensional solutions, and this appears again in Table 2. Similarly, one could group clerical workers with housewives and retired persons, and the same grouping appears in Table 3. However, there is one inconsistency in the occupational groupings, in that the cluster analysis groups professional persons, craftspersons, and government workers, but these groups have very low correlations with one another.

Both the correlation analysis and the cluster analysis on INDSCAL weights showed a possible grouping, at four dimensions, of the under 16 and the 16 to 21-year-old groups. The cluster analysis did not show a grouping of those in the 50 to 59 and over 59-year-old groups. The results of the three-dimensional solutions remain consistent in grouping the under 16 and the 16 to 21-year-old groups, but this was not found so in the correlation analysis. The cluster analysis also grouped the over 59-year-old groups with the same group, a correlation that was not shown in the correlation analyses. Again, in the separate analyses, the cluster analysis shows no clustering of income groups, while the conclusion drawn from a correlation analysis was that income was a very weak determinant of perceptual differences within the population. Finally, both the correlation analysis and the cluster analysis indicate that sex is a poor discriminator of perceptual differences.

In the correlation analysis, it was not appropriate to run correlations across different dimensionality solutions. As a result, the correlation analysis has a number of gaps, where solutions are not always obtained in the same dimensionality for all subgroups. In contrast, it was reasonable to attempt a cluster analysis of the INDSCAL results combined across all dimensionalities. To do this, the INDSCAL program was run in a four-dimensional and in a three-dimensional mode, and all the MDSCAL results were input. Because the MDSCAL results used for the INDSCAL program comprise only the interpoint distances, the dimensionality of the solution does not affect the number of interpoint distances that are determined in any space. The results of the combined runs are shown in Table 4. In general, there are many consistencies across the three-dimensional and four-dimensional solutions for the combined re-

Table 4. Clustering of all solutions in three and four dimensions.

Original Characteristic	Dimensionality	Three-Dimensional Cluster	Four-Dimensional Cluster
Sex			
Female	3	Combine sexes	Combine sexes
Male	3	Combine sexes	Combine sexes
	4	Male	Male
Age, years			
≤16	3	≤16	≤16
	4	≤22	≤22
16 to 21	3	16 to 21	16 to 21
	4	≤22	16 to 21
22 to 29	4	22 to 29	22 to 29
30 to 39	3	30 to 39	30 to 39
40 to 49	3	40 to 49	40 to 49
50 to 59	3, 4	50 to 59	50 to 59
≥59	3, 4	≥59	≥59
Income, $			
≤10 000	3	≤10 000	≤10 000
10 001 to 15 000	2, 3	10 001 to 15 000	10 001 to 15 000
15 001 to 20 000	3	15 001 to 20 000	15 001 to 20 000
20 001 to 25 000	4	20 001 to 50 000	20 001 to 50 000
25 001 to 50 000	4	20 001 to 50 000	20 001 to 50 000
≥50 001	2, 3	≥50 001	≥50 001
Occupation			
Salesperson	4	Salespersons	Salespersons and professional persons
Teacher	3	Teachers, housewives, clerical workers, and retired persons	Teachers, housewives, clerical workers, and retired persons
Professional person	3, 4	Professional persons, craftspersons, and government workers	Salespersons and professional persons
Craftsperson	3	Professional persons, craftspersons, and government workers	Craftspersons and professional persons
Clerical workers	2, 3	Teachers, housewives, clerical workers, and retired persons	Teachers, housewives, clerical workers, and retired persons
Student	4	Student	Student
Housewife	2, 3, 4	Teachers, housewives, clerical workers, and retired persons	Teachers, housewives, clerical workers, and retired persons
Government worker	3, 4	Professional persons, craftspersons, and government workers	Craftspersons and government workers
Retired person	3, 4	Teachers, housewives, clerical workers, and retired persons	Teachers, housewives, clerical workers, and retired persons
Other	3	Other	Other
Length of residence, years			
≤4	3, 4	≤6	≤6
4 to 6	3, 4	≤6	≤6
7 to 10	3	≥6	≥6
	4	≥6	7 to 10
≥10	3, 4	≥6	≥10

sults, and similarly, consistency between these results and those for the separate dimensionality solutions in Tables 2 and 3. The differences between Table 4 and the results given in Tables 2 and 3 are more consistent with the results of the correlation analysis. This may be because the level of clustering is set arbitrarily in each instance, and the level at which clusters are formed and reported in Table 4 may be a higher one than that at which they are formed and reported in Tables 2 and 3. Unfortunately, there are no statistical measures that can be used to define or assess levels of clustering. One of the notable results is the clustering of incomes from $20 000 to $50 000 that is more consistent with the results of the correlation analysis. Similarly, the occupational grouping of teachers, housewives, clerical and secretarial workers, and the retired is also consistent with the results of the correlation analysis. The identification of student and other occupational categories as having no strong grouping with any other group is also borne out in both Table 4 and the earlier results of the correlation analysis. The groupings of sex, ages, and length of residence are fairly consistent between Table 4 and Tables 2 and 3 and again with the correlation analysis.

A further point of interest in Table 4 concerns the groupings of the solutions for different dimensionalities of the same attribute. In general, when the two-dimensionality solutions for the same subgroup are clustered, the selection of the lower dimensionality solution would not introduce any biases into the process; i.e., in these cases, the lower dimensionality can be considered as appropriate. This would be the case, for example, for the age groups of under 16 and 16 to 21, 50 to 59, and over 59 years. Similarly, it would be appropriate for the income group of $10 000 to $15 000 and for the occupational groups of teacher, professional person, clerical worker, housewife, government worker, and retired person. Likewise, it would be appropriate for the length-of-residence variable to be considered only at a three-dimensional solution, rather than at a four. There does not appear to be a close similarity between the three-dimensional and four-dimensional solutions for males. This suggests that a significant bias is introduced by dropping from four dimensions to three dimensions and may therefore require further analysis of whether or not sex is a good discriminating variable of perception.

CONCLUSIONS

The results of this analysis of market segmentation lead to a number of conclusions. First, both the correlation analysis and the cluster analysis of the INDSCAL weights appear to have generated convergent validities of the primary findings for grouping or not grouping among the socioeconomic characteristics. Thus, it may be concluded that the length of residence in the area and age are reasonably powerful market-segmentation variables. By and large, few new groupings of age were determined from the analysis, the only significant one being the grouping of the two lowest age groups into the single one of those individuals under 22 years old. It is possible that some of the higher age groups might potentially benefit from combination, but the two sets of analyses are not consistent on this point. It can also be concluded that sex and income do not exhibit great potential as bases for market segmentation of preferences for shopping destinations. Finally, it can be concluded that occupation may be a potential variable of segmentation, but the precise logic of its effect in defining market segments is not clear from this analysis. Subsequent work has suggested that occupation may be acting as a surrogate for other variables, such as a combined level of education and income variable, and possibly as a proxy for a stage-in-the-family-life-cycle variable, where dealing with housewives and the retired. It is also possible that some of the correlations and clustering found in the occupation variable may be spurious, due to high correlations with underlying structural variables. Thus, the original hypotheses on the socioeconomic variables have only been partially validated by this research.

Beyond this, it is clearly necessary to subject these conclusions to more stringent tests designed to determine whether or not the subgroups themselves are appropriate for market segmentation. This analysis has not addressed the question of whether these subgroups are themselves appropriate for segmenting the market, since no investigation has been undertaken of the comparative within and between-group variances, and it is not apparent how the approaches described here could be extended to covering this point.

It is also evident that testing must be undertaken on more than one-way clustering of the population. Thus, it would be appropriate to examine the possibility that two or more socioeconomic variables are needed simultaneously to define market segments in the population.

Finally, it is possible that perceptions of the attractiveness of a destination may vary with the type of goods being purchased and with an individual's knowledge of the shopping centers. Neither of these two variables were entered into the market-segmentation process reported here. It would appear appropriate to include such variables in subsequent analyses, to determine whether such variations might exist.

ACKNOWLEDGMENTS

The work reported in this paper was conducted under a contract from the Program for University Research, Office of the Secretary, U.S. Department of Transportation. The paper represents my position and not necessarily that of the U.S. Department of Transportation. The work was accomplished with much help from the research team of the project, particularly Jean M. Blin, Peter L. Watson, James Clark, and Yosy Prashker.

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

Evaluation of Alternative Market Segmentations for Transportation Planning

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In transportation planning, market segmentation is the division of a total population of travelers into groups (segments) that are relatively homogeneous with respect to certain personal characteristics (the segmentation base). It is desirable that the segments be distinct in terms of travel behavior and their reactions to changes in the travel environment, such as the introduction of new transportation services. This paper describes a comparison of market segmentation using six different bases—two based on demographic variables, two on travel choice constraints, and two on attitudinal variables. The six segmentations were compared with respect to five criteria judged to be important considerations in transportation planning: measurability (data availability), statistical robustness, substantiality (size and importance of the resulting segments), relation to travel behavior, and relation to planning of service options. The comparisons showed that no single segmentation base was superior, according to all criteria, but that the segmentation based on multivariate choice constraints satisfied more of the criteria than did the other segmentations. Segmentations of the traveling population based on attitudes were found to have certain specific uses, but to be inferior to choice-constraints segmentation for most planning purposes.

In an effort to better match transit service to the wide range of needs and expectations that may exist in a given community, planners have recently been giving increased attention to the concept of market segmentation. Market segmentation is a procedure for dividing the (travel) market into homogeneous subsets of customers (segments), where any subset may be selected as a target market for a distinct combination of service characteristics, price levels, or promotional strategies. The primary object of market segmentation is to increase consumer appeal by meeting consumer desires (4). Thus far, it has been applied to only a limited extent in the public sector, where the objectives of such agencies as transit operators are not as clearly defined as are those of private firms (11, 13).

One of the critical aspects of segmentation is the selection of an appropriate base. Although the application of market segmentation of public transit is still a new concept, a number of alternative approaches to segmentation that propose or advocate different segmentation bases have already been suggested. Lovelock (11) discusses the relative merits of a number of such bases.

This study compares the results of several segmentations of the same set of travelers using alternative segmentation bases. The bases are compared with respect to five criteria. The first three criteria have been discussed in the marketing literature (4, 10); the other two are relevant to issues of transportation planning.

1. Measurability: The information gained from a segmentation should be cost-effective in terms of the time and money required to collect and process the necessary data.
2. Statistical robustness: The segments should be significantly different from one another in a statistical sense. The between-segment variations should be relatively larger than the within-segment variations. This helps to ensure that the segments are not the result of random variations in the data and improves the assignment of new travelers to the segments.
3. Substantiality: The segments should be large enough to account for a significant proportion of the population under study or should be sufficiently important with respect to planning policy to merit the time and cost of separate attention.
4. Relation to travel behavior: A segmentation that accounts for a large proportion of the variance in manifest travel patterns would be more useful than one that does not. Segments that differ in terms of modal choice, route choice, or trip timing and frequency are similarly desirable.
5. Relation to planning of service options: If particular transportation service packages serve consumers having very different social or economic characteristics, a segmentation base that defines consumer groups compatible with service options would be more useful than a base that does not. Similarly, if promotional activities are best targeted to consumers having certain preferences, perceptions, and desires, a segmentation procedure that identifies those groups would be more useful than one that does not.

By using data from the Ottawa-Hull metropolitan area in Ontario and Quebec, six alternative bases for market segmentation were chosen. Some of the bases divided the population of work-trip commuters into groups based on demographic or socioeconomic characteristics, some on the basis of such travel constraints as automobile ownership and bus availability, and some on the basis of their stated attitudes. Segmentations using each of these types of variables have been advocated in the transportation planning literature and are related to approaches proposed in the marketing literature (4, 6, 11). For example, Nicolaidis and Dobson (12) segmented travelers on the basis of perceived importance of attributes of transportation modes, and Nicolaidis and Sheth (13) did so on the basis of attitudes toward general environmental conditions. Recker and Golob (15) grouped individuals on the basis of what they termed choice constraints of transportation alternatives, and Costantino and others (2) used demographic and socioeconomic measures.

SEGMENTATION BASES

The six segmentation bases compared in this study were developed from data collected in two home-interview surveys administered in the Ottawa-Hull metropolitan area by the Ottawa-Carleton Regional Municipality. The first survey was a conventional home-interview, household trip-inventory survey. The characteristics of all trips made during a 24-h period and the detailed socioeconomic and demographic characteristics of the respondents were recorded. The second survey covered attitudes toward alternative modes of transportation and toward transportation-related issues in general. This attitudinal survey was administered as a home interview to a subsample of the respondents who had completed the trip-inventory survey. In each of the segmentations, only those respondents who indicated that they made a regularly scheduled work trip were segmented. Thus, the analyses reported in this paper are relevant mainly to travel in the Ottawa metropolitan area for work-trip purposes.

The first two segmentations divided the population into groups that are homogeneous with respect to demographic characteristics. The underlying assumption is that travel demands and consumer responses to marketing are strongly associated with socioeconomic status or cultural variables. The first demographics segmentation was based on a multidimensional matrix of the following descriptors: language (English versus French), number of vehicles in the household, length of time lived at the current residence, number of residents in the household, type of residence (single family versus attached versus apartment), sex, age, education, possession of driver's license, employment (homemaker and student versus working), occupation (managerial and professional versus clerical and sales versus service and craftsperson), and income. The second demographics segmentation used only a single variable: Language was chosen because the residents of the study area were clearly distinguishable into those of English-speaking and those of French-speaking cultures.

This comparison of single versus multidimensional demographics segmentations was intended to determine whether the increased complexity of the multidimensional approach adds any significant value above that of a more simplistic measure. Also, because many cities include unique cultural or ethnic groups, the inclusion of a single cultural variable was intended to test the effectiveness of such a simple categorization as a market-segmentation base.

The second pair of segmentations dealt with travel-choice constraints. Many authors (8, 15) believe that such variables as automobile ownership and the availability of bus service influence travel behavior and responses to marketing more significantly than do demographics differences. The choice-constraints segmentations were intended to test such hypotheses. The multidimensional choice-constraints segmentation includes data—bus access time (waiting plus walking times), bus transfers needed, and automobile availability—related to automobile availability, accessibility to bus service, and the appropriateness of the routing of buses that were available to the respondents. Because these data are sometimes unavailable and because of the general goal of determining whether simple measures are as effective as complex ones, a segmentation based solely on automobile ownership was also included.

The last two segmentations were based on the respondents' answers to the attitudinal questions included in the Ottawa survey. Attitudes have been proposed as useful bases for market segmentation by a number of authors (12, 13). Two types of attitudinal data were examined. For the first, the segmentations were performed on the basis of general attitudes toward transportation. Six-point Likert scales were used to measure the degree to which the survey respondents agreed with each of the following 16 statements concerning general transportation-related conditions:

1. Traffic congestion in this city is a major problem that must be solved.
2. It is necessary to reduce the use of automobiles in the city by supplying an effective network of rapid public transit.
3. By and large, automobiles have outlived their usefulness except for trips between cities or into the country.
4. Driving in the city is frustrating and can cause anxiety and tension.
5. Riding in public transportation makes people feel awkward or lonely or just part of a crowd.
6. I could feel embarassed taking someone to a social function by public transit.
7. Drastic action must be taken to improve the public transit service in this city.
8. An automobile is more than just transportation; having a nice automobile to drive is appealing in itself.
9. Although automobiles are sometimes necessary, they are also a nuisance. I would just as soon do without one if other transportation met my needs.
10. I enjoy (would enjoy) driving an automobile.
11. Not having an automobile available is like being trapped.
12. The lack of adequate transportation facilities for all leads to family squabbles.
13. The government should actively discourage people from using automobiles in busy sections of the city by making it more difficult to drive and park there.
14. Children need good public transportation or they make too many demands on their parents to drive them around.
15. Your social life definitely suffers if there is no automobile available.
16. To be honest, there is no public transportation system I can picture that would make me give up using my automobile in the city.

Specific attitudes toward transportation alternatives were the final segmentation base. Six-point semantic differential scales (very important to not important) were used to measure the importances travelers placed on the following 25 attributes characterizing bus and automobile modes when making modal choices:

1. Comfortable seating,
2. Dependability of on-time arrival,
3. Availability more or less when you want it,
4. Attractiveness of vehicle,
5. Low noise level in vehicle,
6. Vehicle safety,
7. Smoothness of ride,
8. Privacy from other people,
9. Avoiding exposure to traffic congestion,
10. Minimum exposure to bodily crowding,
11. Low out-of-pocket cost,
12. Low riding time,
13. Low walking time,
14. Low waiting time,
15. Opportunity to meet and talk with other people,
16. Opportunity to relax,
17. Opportunity to read,
18. Continuous ride with few stops,
19. Protection from weather on entire trip,
20. Flexible destination, can go anywhere,
21. Not having to change vehicles,
22. Year-round temperature comfort in vehicle,
23. Assurance of having a seat,
24. Security from undesirable acts of others, and
25. Low level of pollution.

SEGMENTATION PROCEDURE

The six segmentations were performed by using similar procedures with slight variations among the situations where the segmentation base had only one variable, a few variables, or a large number of variables containing possible multicolinearities. For the two unidimensional segmentation bases, language and automobile ownership, the segments were formed by the natural categorization of respondents according to their values of the variables. The version of the procedure applied to the only base having a few variables—multidimensional choice constraints—involved standardizing the base variables to zero mean and unit standard deviation to eliminate scale biases and then clustering the individuals in the space of the standardized variables. The last version of the procedure was applied to the multidimensional demographics, general attitudes, and attribute-importance bases, which all had a larger number of variables containing possible intercorrelations. This procedure involved factor analyzing the variables and then clustering the individuals in the space of the resulting latent factors.

The specific factor-analysis technique used was principal-components analysis applied to the variable correlation matrix, followed by varimax rotation to facilitate factor interpretation (7). An iterative technique described by Recker and Golob (16) was used to determine, and consequently eliminate from factoring, those few variables that might have contained primarily noise and would not add any information to the factor results. The selection of the latent factors that best expressed the variable interrelations was made on the bases of criteria also described by Recker and Golob.

The specific cluster-analysis technique used in both of the latter two versions of the procedure involved a customized algorithm closely related to the ISODATA algorithm and to the class of cluster-analysis techniques referred to as K-means clustering (1). For a given number of segments, the algorithm assigned each respondent to the segment with the property that the distance between that respondent and the centroid of the segment was smaller than the distance between the respondent and the centroid of any other segment; new centroids were then computed and the process repeated. A procedure was used for determining the final number of segments from successive analyses with different numbers of segments based on matrices of generalized distances between segments in the factor spaces (5) and on the summary compactness indexes for each clustering [Λ-statistic due to Wilks (18)].

SEGMENTATION RESULTS

Factor analysis of the 12 demographic and socioeconomic variables in this segmentation base gave four latent factors. These factors accounted for approximately 62 percent of the variance in the original variables and were labeled as social rank, life cycle, occupation, and household size through interpretation of the correlations among the factors and the original variables. Cluster analysis of the 324 survey respondents for which full data were available gave three segments. These three segments were given subjective labels based on interpretation of the positions of their centroids in the space of the four factors. This information and the proportions of the samples that were assigned to each segment are given in Table 1, which also includes the results of the other five segmentations. The sample sizes (Ns) of the segments are given below.

Base	Segment	N
Multidimensional demographics	French speaking	107
	Younger and more renters	96
	Older and more males	121
Language	English speaking	180
	French speaking	98
Multidimensional choice constraints	Mobile	211
	Inappropriate bus routing	99
	Poor bus accessibility	94
	Automobileless	91
	Busless	48
Automobile ownership	None	17
	One	191
	Two or more	86
General attitudes	Not automobile dependent	124
	Driving conditions acceptable	143
	Public transit acceptable	151
	Transportation improvements needed	121
Attribute importances	Ambivalent	82
	Service versus personal environment	186
	Total environment versus travel convenience	122
	Travel convenience versus service	114

The work-trip travelers surveyed in the Ottawa metropolitan area were divided into English-speaking and French-speaking segments. There was complete data on these variables for 278 survey respondents.

Cluster analyses of the 543 respondents for whom perceived constraints on choice of mode were available gave five segments. Interpretations of the positions of the segments in the three-dimensional choice-constraint space gave the segment labels shown in Table 1. Segments four and five were labeled automobileless and busless respectively to reflect that the majority of respondents did not own an automobile or did not have bus service available to them.

The 294 survey respondents for whom complete data on automobile ownership were available were divided into no-automobile, one-automobile, and two-or-more-automobiles segments.

Factor analysis of the levels of agreement with the 16 statements measuring general attitudes gave four factors that accounted for 63 percent of the variance in the factored variables. These factors were subjectively labeled as anticongestion, automobile dependence, new intraurban transport is needed, and public transit is depersonalizing.

Cluster analysis of the 539 respondents for whom full data on the base variables were available gave four segments.

Factor analysis of the importance ratings of the 25 modal attributes gave five factors that accounted for 56 percent of the variance in the factored variables. These factors were labeled as service, vehicle comfort, system environment, travel convenience, and personal environment. Cluster analysis of the 505 respondents for whom full information was available gave four segments.

TESTS OF SEGMENTATION REDUNDANCIES

The question arises as to whether or not the six segmentations merely represent six ways of dividing the total population into the same basic groups. This question can be rephrased in a statistical sense for each pairwise comparison of segmentations: If it is known into which segment a particular respondent is classified in one segmentation, can it be predicted with significantly better than random probability into which segment this same respondent will be classified in another segmentation? It can be expected that the two segmentations using demographic bases (the multidimensional demographics and language segmentations) will be highly related, that the two choice-constraint segmentations (the multidimensional choice-constraints and automobile-ownership segmentations) will be related, and that possibly the two attitudinal segmentations will be re-

Table 1. Segmentation results.

Type of Variables	Segmentation Base	Segment	Percentage of Segmentation Total
Demographic	Multidimensional	French speaking	33
		Younger and more renters	30
		Older and more males	37
		Total	100
	Language	English speaking	65
		French speaking	35
		Total	100
Choice constraint	Multidimensional	Mobile	39
		Inappropriate bus routing	18
		Poor bus accessibility	17
		Automobileless	17
		Busless	9
		Total	100
	Automobile ownership	None	6
		One	65
		Two or more	29
		Total	100
Attitudinal	General attitudes	Not automobile dependent	23
		Driving conditions acceptable	27
		Public transit acceptable	28
		Transportation improvements needed	22
		Total	100
	Attribute importances	Ambivalent	16
		Service versus personal environment	37
		Total environment versus travel convenience	24
		Travel convenience versus service	23
		Total	100

lated. However, if there are strong relations among segmentations using different types of bases, these relations must be considered when interpreting the results of the comparative analyses given in this paper.

The Pearson χ^2 test of association through contingency tables of segment membership (9) was used to identify possible redundancy in the segmentations. As expected, the two demographics and the two-choice constraints segmentations are associated at the 95 percent confidence level, but the two attitudinal segmentations are not significantly associated (even allowing much lower confidence bounds on acceptance of random occurrences). Of the 12 comparisons of pairs of segmentations from different types of segmentation bases, only the multidimensional demographics versus automobile-ownership pair was found to be significantly associated. This result is consistent with the models calibrated in many transportation planning studies to distribute and forecast automobile ownership (3).

Thus, the conclusion of the redundancy test is that comparisons among segmentations using different types of bases need be qualified only when the demographics versus automobile-ownership pair of segmentation is involved. Furthermore, comparisons between the two attitudinal segmentations are valid also without qualification.

EVALUATION OF SEGMENTATIONS

The results of the evaluations of the six segmentation bases on the five criteria are summarized in Table 2.

Measurability

The three types of segmentation bases are clearly distinguishable with respect to measurability. The demographic data are the most readily available; these data are collected in almost every origin-destination home-interview survey, on-board transit-user survey, or other traveler survey designed to gather information about individual respondents and their households. Consequently, if an acceptable sample of such survey responses is available for the population to be segmented, demographics segmentation bases are cheapest in terms of the time and cost of data collection and processing.

Choice-constraints data are of the type needed for estimating disaggregate travel-demand models. It can thus be expected that these data will be collected in future origin-destination surveys. However, at present, data on travelers' perceptions of constraints on choices of modes, routes, and trip times are limited. On the other hand, collection of choice-constraint data requires that only a few questions be asked of respondents. [For the specific data used in the analyses reported here, these questions have been given by Recker and Golob (16).] This relative simplicity makes possible the use of cost-effective data-collection techniques such as telephone surveys.

Attitudinal data usually require a separate survey. Moreover, because of the complexity of the explanations of the questions and the monitoring of responses, these surveys usually must be administered as home interviews. Their higher data-collection costs can be offset by the use of the data obtained in providing nonsegmentation planning information, but discussion of such uses is beyond the scope of this paper. Thus, in the present evaluation, the two attitudinal segmentations share a common burden of costs that must be offset by gains in planning information over and above the level of information provided by the competing demographics and choice-constraints segmentations.

Statistical Robustness

Two tests of the degree to which the different segmentations succeeded in identifying distinct structure in the segmentation-base data were conducted for those four segmentations that involved multiple base variables (i.e., the multivariate segmentations). The first test focused on an overall statistic measuring the effectiveness of a cluster analysis in determining segments that

Table 2. Evaluation results.

Type of Variables	Segmentation	Evaluation Criterion: Measurability	Statistical Robustness	Substantiality	Relation to Travel Behavior	Relation to Planning of Service Options
Demographic	Multidimensional	+	+	0	0	0
	Language	+	–	0	0	-
Choice constraint	Multidimensional	0	+	0	+	0
	Automobile ownership	+	–	0	+	0
Attitudinal	General attitudes	-	-	0	-	+
	Attribute importances	-	-	0	-	+

Note: + indicates that a segmentation was judged to be significantly superior on a criterion; 0 indicates that a segmentation was judged to be neither superior nor inferior on a criterion; - indicates that a segmentation was judged to be significantly inferior on a criterion.

are both compact and significantly different from one another. For reasons discussed by Friedman and Rubin (6), the overall test statistic chosen was the Wilks Λ-criterion. This statistic, which is invariant under linear changes of scales on which variables are measured, is defined as the ratio of the determinant of the pooled within-segment variance (a measure of the compactness of the clusters) to the determinant of the between-segment variance (a measure of the dispersion of cluster centroids in the variable space). By using a variance-ratio transformation proposed by Rao (13), the possibility that the clusters could occur in randomly structured data was evaluated for each of the segmentations.

For each of the four multivariate segmentations, the hypothesis that a segmentation structure was due to random variation in the data was rejected at a very high confidence level. Thus, no one segmentation performed better than the others, and the segmentations were judged to be indistinguishable in terms of the Wilks Λ-criterion.

The second test of statistical robustness involved how successfully the observations could be assigned to their correct segments. Such assignments are commonly done by using linear functions of the base variables determined through multigroup discriminant analysis (17). These functions were calculated for each of the multivariate segmentations, and the discriminant classifications for each of the travelers in the original sample were compared with their cluster-analysis segment assignments. The percentage of correct classifications for each group in each segmentation and for each segmentation are shown in Table 3.

The four multivariate segmentations are distinguishable in terms of their percentages of correct discriminant classifications. The multidimensional choice-constraints and multidimensional demographics segmentations showed the most successful classifications. Moreover, with the sole exception of the relatively small busless segment in the choice-constraints segmentation, the individual segments in these two segmentations were uniformly high in correct classifications. Such balanced classification success is deemed to be desirable in the absence of independent information about the differential planning importances of various segments. The general-attitudes segmentation showed a modest classification performance that was balanced among its four segments. Finally, the attribute-importances segmentation showed the poorest classification performance, both in terms of overall success and of balance among the four segments.

Substantiality

Market segmentation can contribute to the efficiency of planning and marketing when the segments are substantial in size and when the distribution of segment sizes contains few extremes. For example, a segmentation that included more than 90 percent of the travelers in one cluster and only 1 or 2 percent of the travelers in another would be difficult to use in the planning or marketing of services. The distribution of cluster sizes cannot be considered in the abstract, however, but must also be analyzed in terms of the significance of particular segments to transportation programs. Thus, if the current policy emphasizes transit planning for the elderly, it might be useful to isolate the elderly in a segmentation procedure even though they might constitute a very small proportion of the total pool of travelers.

Table 1 showed the proportions of the samples that were assigned to each cluster in each of the six segmentations. The multidimensional demographics and general-attitudes segmentations divided the sample into segments of approximately equal size and containing few extremes. However, both of these segmentations gave rise to segments that could not be identified with transportation policy questions. All of the other segmentations gave rise to cluster-size distributions that were quite acceptable. The smallest proportion assigned to any segment was the 9 percent of the travelers who were assigned to the busless segment in the multidimensional choice-constraints segmentation. The busless, however, constitute a group of high salience with respect to current transportation planning policy and, in a segmentation that gave rise to five clusters, this proportion seems quite acceptable. On balance, then, the segmentations are relatively indistinguishable with respect to the substantiality criterion.

Relation to Travel Behavior

One of the important criteria by which the usefulness of a market-segmentation base can be judged is the extent to which the resultant segments are distinguishable in terms of travel behavior. If the clusters of travelers resulting from a segmentation have significantly different travel demands and trip patterns, this segmentation is more useful for planning and marketing than one that gives clusters that are undifferentiated in terms of travel. Three steps were involved in comparing the six segmentation bases with respect to this criterion. First, the segmentation bases were compared to determine which of them resulted in segments having different frequencies of modal choice for the journey to work. Second, the groups in each segmentation were compared to determine whether they differed in terms of such trip characteristics as trip length, access and egress times, number of transfers and other reported work-trip characteristics. Finally, a multidimensional logit model of modal choice was applied to each segment in each segmentation to determine whether certain ones resulted in better goodness of fit of the demand model. The independent variables in these choice models consisted of the satisfaction ratings of the survey respondents on attributes of automobile and bus.

The data used to determine differences in terms of the frequency of modal choice were the reported frequencies with which respondents traveled to work as automobile drivers, automobile passengers, or bus passengers during the 4-week period preceding the survey day. Multiple-group discriminant analysis was used, and discriminant functions were determined for each of the six segmentation bases by using the three modal-choice frequencies as independent variables. If no statistically significant discriminant function could be found for a particular segmentation, it was concluded that the segmentation did not distinguish on the basis of modal-choice frequencies. If a satisfactory discriminant function could be computed, it was concluded that those independent variables that had significant coefficients (using an F-test and a 0.99 significance level) varied significantly among the segments produced by that base. Table 4 shows the results of these discriminant analyses. For each segmentation, mean modal-frequency values are shown only for those cases in which the means are significantly different from one another.

No significant discriminant function could be found for either the general-attitudes or the attribute-importances segmentations. Thus, it was concluded that these attitudinal segmentations have little statistical association with modal-choice frequencies. On the other hand, the segmentation based on multidimensional choice constraints resulted in segments having significantly different frequencies with which the work trip was made as an automobile driver and as a bus passenger. Segmentation on the basis of automobile ownership, rather than the more complex choice-constraints base, also produced segments that differed significantly with respect to two of the three modal-choice frequencies. Segmentations based on demographics and on the single dimension of language produced clusters that differed from each other in terms of only one modal-choice variable—the frequency of bus use. In summary, then, the segmentations based on choice constraints best described travelers' modal-choice frequencies, while the segmentations based on attitudes were the poorest discriminators of modal choice.

The analysis to determine which of the segmentations produced groups that differed in terms of trip characteristics was based on eight reported, or perceived, trip characteristics. By following a procedure similar to that used in the analysis of modal-choice frequencies, discriminant functions were estimated by using as independent variables any of the eight trip characteristics that could explain the various segmentations in a statistically significant manner.

Table 5 shows the results of these discriminant analyses. Once again, it was not possible to construct a statistically significant discriminant function for segmentation based on general attitudes or attribute importances. Similarly, the multidimensional choice-constraints segmentation gave a discriminant function that included three of the eight variables. The choice-constraints segmen-

Table 3. Results of segmentation discriminant analyses.

Type of Variables	Segmentation	Percentage of Overall Correct Classification	Segment	Percentage of Correct Classification
Demographic	Multidimensional	95	French speaking	95
			Younger and more renters	95
			Older and more males	96
	Language	—	—	—
Choice constraint	Multidimensional	98	Mobile	99
			Inappropriate bus routing	98
			Poor bus accessibility	100
			Automobileless	100
			Busless	85
	Automobile ownership	—	—	—
Attitudinal	General attitudes	87	Not automobile dependent	87
			Driving conditions acceptable	84
			Public transit acceptable	87
			Transportation improvements needed	89
	Attribute importances	77	Ambivalent	65
			Service versus personal environment	81
			Total environment versus travel convenience	72
			Travel convenience versus service	85

Table 4. Results of discriminant analyses based on modal-choice frequencies.

Type of Variables	Segmentation Base	Segment	Mean No. of Work Trips Made During Last 4 Weeks: Automobile Driver	Automobile Passenger	Bus User
Demographic	Multidimensional	French speaking	NS	NS	1.9
		Younger and more renters	NS	NS	6.9
		Older and more males	NS	NS	5.7
	Language	English speaking	NS	NS	6.0
		French speaking	NS	NS	2.3
Choice constraint	Multidimensional	Mobile	13.3	NS	4.8
		Inappropriate bus routing	16.4	NS	3.3
		Poor bus accessibility	15.0	NS	2.1
		Automobileless	0.5	NS	12.9
		Busless	17.5	NS	0.0
	Automobile ownership	None	NS	5.1	13.1
		One	NS	3.3	4.7
		Two or more	NS	2.6	3.1
Attitudinal	General attitudes	All	NS	NS	NS
	Attribute importances	All	NS	NS	NS

Table 5. Results of discriminant analyses based on work-trip characteristics.

Type of Variables	Segmentation: Base	Segmentation: Segment	Trip Characteristics: Trip Time by Mode Actually Used (min)	Trip Time by Bus (min)	Access Time to Bus, Walking (min)	Egress Time for Mode Actually Used (min)	Egress Time for Bus (min)	Number of Transfers, Bus	Type of Bus Service Available[a]	Avg Wait for Bus (min)
Demographic	Multidimensional	French speaking	31.3	NS	2.1	NS	NS	NS	NS	NS
		Younger and more renters	24.8	NS	3.0	NS	NS	NS	NS	NS
		Older and more males	24.4	NS	2.7	NS	NS	NS	NS	NS
	Language	English speaking	24.6	40.6	NS	NS	NS	NS	2.0	NS
		French speaking	31.0	49.0	NS	NS	NS	NS	1.8	NS
Choice constraint	Multidimensional	Mobile	NS	22.0	1.7	NS	NS	NS	NS	2.4
		Inappropriate bus routing	NS	64.3	4.5	NS	NS	NS	NS	7.8
		Poor bus accessibility	NS	47.8	6.4	NS	NS	NS	NS	10.9
		Automobileless	NS	44.5	4.3	NS	NS	NS	NS	5.9
		Busless	NS	90.4	6.2	NS	NS	NS	NS	12.3
	Automobile ownership	None	NS	NS	NS	NS	NS	0.4	NS	NS
		One	NS	NS	NS	NS	NS	0.3	NS	NS
		Two or more	NS	NS	NS	NS	NS	0.7	NS	NS
Attitudinal	General attitudes	All	NS	NS	NS	NS	NS	NS	NS	NS
	Attribute importances	All	NS	NS	NS	NS	NS	NS	NS	NS

[a] Types of bus service were coded as follows: 1 = no bus available, 2 = local bus service, 3 = express bus service only, 4 = local and express bus service available. The scale was assumed to be interval in this analysis.

tation gave clusters that had significantly different values of bus trip time, varying from a mean of 22 min for the mobile cluster to 90 min for the busless cluster. Access time varied significantly among the groups produced by the choice-constraints segmentation, from 1.7 min among the mobile segment to 6.4 min among the segment having poor bus access. Average waiting times for buses also varied significantly among the choice-constraints clusters, from only 2.4 min for the mobile cluster to 12.3 min for the busless. Also, the simplified choice-constraints segmentation, based solely on automobile ownership, distinguished travelers more poorly than did the multidimensional choice-constraints segmentation, since only the number of transfers entered the discriminant function for the automobile-ownership classification. The segmentation based on language distinguished among clusters on the basis of three of the eight trip characteristics, while that based on multidimensional choice-constraints discriminated on the basis of only two of the eight variables. Overall, the segmentations based on attitudinal variables distinguished as poorly among trip characteristics as they did among modal-choice frequencies. The segmentations based on multidimensional choice constraints and on language were the most effective at discriminating on the basis of trip characteristics.

The final test of association between the various segmentation bases and travel behavior involved the fitting of a separate travel-demand model for each segment produced in each segmentation. If models applied to segments drawn from one base yield goodness-of-fit measures that are consistently superior to those produced by a different segmentation, the first segmentation base is deemed superior to the second for purposes of demand modeling.

The methodology underlying the estimation of modal-choice models for each of the segments in the four segmentations has been described in detail by Recker and Golob (16). Briefly, it involved factor analyzing the attribute-satisfaction ratings for the two alternative modes to remove multicolinearity and calibrating a probabilistic choice model using attributes representing the latent perception factors as explanatory variables. The choice model used was the logit model with maximum likelihood estimation of parameters, and the dependent variable was the respondent's modal choice on the survey day. Only those explanatory variables were used in the final estimation that had coefficients significantly different from zero at the 95 percent confidence level.

Table 6 lists two goodness-of-fit indexes for the choice models. The first—pseudo R^2—is analogous to the coefficient of determination in linear models and is expressed as the ratio of explained log likelihood to total log likelihood. Unfortunately, this measure has no known distributional properties and can be shown to have a maximum value significantly less than 1.0. The second is calculated from posterior probability estimates. The primary disadvantage of this statistic is that cases in which only slight errors in probability are made (e.g., 51 percent posterior probability in favor of choosing the mode not actually chosen) are treated the same as cases in which gross errors are made.

There is little differentiation among the results for the six segmentations. The overall weighted averages of the indexes for the multidimensional choice-constraint segmentation were slightly higher than the others, but the difference was not sufficient to permit conclusions to be drawn. Moreover, the results for the choice-constraints segmentation were mediated by the fact that the sample size for one segment was insufficient to permit estimation of the choice model, and another segment exhibited very poor results.

Fourteen of the 19 segments for which choice models were estimated exhibited goodness-of-fit indexes that were substantially better than the indexes of the aggregate model. Thus, choice-model descriptive power can be increased through the use of segmentation, although there is little evidence to favor the use of one segmentation basis over the others for modeling travel choices.

Considering the three measures of the association between segmentation bases and travel behavior that were used here, it must be concluded that the choice-constraints segmentation is superior to the others in distinguishing travel behavior. However, the differences among the segmentations are not always large, and the objectives of a particular segmentation study might justify the use of other segmentation bases. The attitudinal bases are clearly the weakest for distinguishing travelers on the basis of travel behavior.

Relation to Planning of Service Options

Demand models were estimated for each segment produced by all six segmentation bases. These models were evaluated to assess their potential contribution to

Table 6. Results of goodness of fit of choice model.

Type of Variables	Segmentation Base	Segment	Goodness of Fit of Choice Model: Pseudo R^2	Goodness of Fit of Choice Model: Percentage of Correct Classification
Demographic	Multidimensional	French speaking	0.61	92
		Younger and more renters	0.30	79
		Older and more males	0.34	77
	Language	English speaking	0.35	75
		French speaking	0.55	91
Choice constraint	Multidimensional	Mobile	0.47	83
		Inappropriate bus routing	0.66	91
		Poor bus accessibility	0.74	94
		Automobileless	0.29	80
		Busless	—	—
	Automobile ownership	None	—	—
		One	0.39	81
		Two or more	0.60	89
Attitudinal	General attitudes	Not automobile dependent	0.19	77
		Driving conditions acceptable	0.48	83
		Public transit acceptable	0.52	85
		Transportation improvements needed	0.50	86
	Attribute importances	Ambivalent	0.35	81
		Service versus personal environment	0.37	78
		Total environment versus travel convenience	0.49	84
		Travel convenience versus service	0.44	83

the design and evaluation of transportation plans. On the basis of arguments advanced by Recker and Golob (16), it was assumed that modal-choice models using satisfaction ratings on automobile and bus attributes were appropriate demand models to use. Because a system attribute, such as bus waiting time, would be affected by the implementation of plans that change headways on bus routes, it is desirable that satisfactions with bus waiting time be a significant explanator of modal choice for some of the segments used in the study. It is, in other words, desirable that the segmentations used in a particular planning study divide the total population such that some of the groups are sensitive to changes in key attributes. If market segmentation is to be effective, it is desirable that models estimated on segments of the population be more sensitive to service variables than are models estimated on the total population.

This comparison is dependent on the particular planning study under consideration. Three types of planning studies were chosen: those involving primarily changes in bus service characteristics, those involving changes in automobile costs and traffic congestion, and those involving primarily changes in bus comfort and amenity factors.

An attribute describing the bus or automobile mode was judged to be a significant explanator of modal choices for a particular segment if statistical tests showed a significant coefficient for that attribute in a modal-choice model. These tests were performed by using the attitudinal choice models described above; the dependent variable in the model estimated for each segment was the binary modal-choice variable, and the potential independent variables were the satisfaction ratings of the attributes of the bus and the automobile. The attributes are the same 25 for which the importance ratings were obtained. Care was taken not to allow independent-variable multicolinearity to affect the tests of significance.

For planning studies involving bus service characteristics, the segmentations were indistinguishable. An example is the planning of new bus routes for areas not being served. Four attributes of travel included in the attitudinal survey of workers in Ottawa were proposed as attributes that could conceivably be affected directly by such plans: bus availability, bus walking time, bus waiting time, and number of bus transfers. The segmentations were indistinguishable with respect to differential sensitivities to these four attributes.

For planning studies involving automobile costs and traffic congestion, the two demographics segmentations were deficient. The multidimensional choice-constraints segmentation and the two attitudinal segmentations produced groups that were homogeneous with respect to their differential sensitivities to the three proposed direct-effect attributes.

Finally, for planning studies involving bus comfort and amenity factors, the multidimensional demographics and general attitudes segmentations were the most appropriate. The evaluation of the possible introduction of a new transit vehicle, such as one based on new standards for bus design issued by the U. S. Department of Transportation, is an example of such a study. The results indicate that the multidimensional demographics and general attitudes segmentations are the most appropriate for use in such a study.

CONCLUSIONS

The evaluation results are summarized in Table 2. Different segmentation bases will be useful for different purposes; the findings of this study do not recommend a single segmentation base as superior. Most of the criteria that were used in this study failed to differentiate among the four nonattitudinal segmentations (i.e., multidimensional demographics, language, multidimensional choice constraints, and automobile ownership).

The choice-constraints segmentations performed as well as or better than all others on most criteria. Having clear advantages in measurability and statistical robustness over the attitudinal segmentations, the choice-constraints segmentations displayed the strongest and most easily interpreted associations with travel behavior. These results argue for the use of these segmentation bases in many planning programs.

Segmentations based on attitudinal variables performed poorly when compared with segmentations based on choice-constraints variables on several criteria. The availability of attitudinal data is usually lower because cost of its collection is higher. However, attitudinal segmentations did perform more satisfactorily than the other bases in assessing demand sensitivity to potential comfort or amenities improvements in transit service (e.g., bus shelters or bus interiors). It may well be that attitudinal segmentations are useful primarily for certain sophisticated marketing purposes, including product design refinements and the development of promotional strategies.

The demographics segmentations gave results that were somewhere between the choice-constraints and the attitudinal segmentations with respect to most criteria. The demographics segmentations gave rise to satisfactory, although not outstanding, associations with potential service improvements. The major advantage of the demographics segmentations is, of course, a high level of measurability. One surprising result was that demand models calibrated for the demographics segmentations were not found to be sensitive to changes in automobile-travel costs or traffic congestion; demand models estimated for the demographics segments could not be used to estimate responses to possible changes in such automobile-travel attributes.

DIRECTIONS FOR FUTURE RESEARCH

First, the data set used in this study was limited to work trips, and a broadening of the analysis to trips for other purposes would be extremely useful. Second, this was a case study in one metropolitan area, and the extent to which the unique characteristics of the Ottawa area may have influenced the findings is unknown. Further study using data from other cities would be desirable. Finally, the criteria that were used in the evaluation of the segmentation bases are still considered preliminary. It was difficult to formulate operational measures to match each criterion, and the list of criteria may be too short. The criteria generally emphasized relations between segmentations and travel-behavior variables or demand modeling. Modal choice, however, was the primary measure of traveler behavior used, and other measures including automobile ownership and household-location decisions might also be included. The list of criteria used could also be strengthened by including additional measures tailored more precisely to the evaluation of segmentations in terms of their contributions to promotional efforts in transit marketing.

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

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Perceptual Maps of Destination Characteristics Based on Similarities Data

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Individual travel-choice behavior may be characterized by individual perceptions of travel alternatives, individual preferences for the attributes of these alternatives, and the availability of these alternatives. The research reported in this paper was part of a general study of how individuals choose locations for nongrocery shopping trips. It identifies a perceptual space that represents the way individuals perceive shopping locations and evaluates the stability of generality of the perceptual representation across independent samples. The perceptual space developed consists of three dimensions that represent (a) size and variety, (b) price and quality, and (c) environment and parking and is similar for two independent samples of individuals. These results characterize the underlying aspects that individuals use to summarize their perceptions of shopping locations, demonstrate the feasibility of developing perceptual spaces for destination choices, and support the use of perceptual spaces developed for small samples as representative of the population from which they are drawn. The results of the cumulative research of which this is a part indicate that it is feasible to develop choice models based on perceived, rather than on engineering, characterizations of transportation alternatives. Relating travel choices to perceptions provides the ability to evaluate the importance of attributes that are not measurable by direct (engineering) methods.

The primary object of a research project at the Transportation Center of Northwestern University is the development of improved models of travel-destination choice behavior, particularly with respect to selection of shopping locations. The improvements proposed are based on an analysis of the processes by which individuals perceive, evaluate, and choose among the alternatives that are available to them. Extensive development of travel models based on the analysis of individual choice behavior has been made in recent years. These models predict expected individual choice probabilities for a set of alternatives on the bases of the characteristics or attributes of the available alternatives and the characteristics of the individual making the choice. The attributes of alternatives are normally measured or evaluated by objective or engineering means.

Confining the modeling process to objective performance measures only excludes consideration of characteristics for which there are no objective measures. Thus, attributes such as comfort, privacy, and security are excluded from the characterization of alternatives despite recent findings that it is appropriate to include them on behavioral grounds (3, 6, 8). The exclusion of these variables may lead to misspecification of the choice models being developed. Furthermore, this exclusion makes it impossible for planners to evaluate the potential impacts of strategies designed to change the excluded characteristics of transportation alternatives.

The present approach represents measurable characteristics at values determined by direct or engineering means. This fails to account for individual variations in perceptions that may have important effects on choice behavior and prevents policy makers from evaluating strategies designed to modify individual perceptions of travel alternatives.

The research of which this paper is a part is designed to correct these limitations by developing methods that describe individual perceptions of shopping locations and using these perceptions as input to a choice function. This paper describes that portion of the research designed to develop and characterize individual perceptions of shopping locations by using multidimensional scaling techniques. The results of research in the development of perception-based choice models and comparisons of alternative methods for the analysis of individual perceptions will be reported in other papers.

The approach taken here is to develop and describe a common perceptual space for groups of individuals and to locate shopping locations in this perceptual space. The perceptual space represents the underlying characteristics that individuals use in differentiating alternative shopping locations. The development and identification of the perceptual spaces for independent samples parallels methods described previously for the identification of aspects of comfort of transportation modes (6).

The primary object of this study is the identification of the perceptual space that describes the way individuals perceive shopping-location alternatives. This identification includes the number of dimensions necessary to represent individual perceptions of shopping locations and the underlying characteristics of each of these dimensions. The identification of the perception space is based on individual reported similarities between pairs of shopping centers.

The second object of this study is the determination of whether the perceptual space developed for a random sample of individuals is representative of the perceptual space for the population from which they are drawn. The method of analysis used is limited to the development of a perceptual space based on data collected for 100 individuals. It is hypothesized that this space is representative of the perceptual space for the entire group of individuals. This hypothesis is tested by comparison of the perceptual space developed for two randomly selected samples of individuals.

METHODOLOGY

The methodology used in developing and comparing the perceptual maps of shopping-center attractiveness had four phases. The first phase was the construction of measures of similarity between pairs of shopping centers for each member of a representative set of individuals. These similarity measures were used in the second phase to develop a multidimensional perceptual space. The third phase was the identification of the dimensions of the perceptual space. The fourth phase compared the perceptual spaces developed for two different samples of individuals. The analysis was based on individual data related to perception preference and use of the seven shopping locations described below.

Shopping Location	Description
Chicago Loop	Downtown Chicago central shopping district
Edens Plaza	Moderate-sized shopping center on major highways
Golf Mill	Moderate-sized shopping center on major highways
Korvette City	Small discount shopping area
Old Orchard	Relatively large suburban shopping center
Plaza del Lago	Exclusive shopping center characterized by Spanish architecture and specialty shops
Woodfield	One of largest shopping centers in Midwest

Phase One: Constructing the Similarities Measures

The measure of similarity between two stimuli can be considered to be the perceived psychological proximity between the stimuli. Thus, the lower the rating of similarity, the closer two stimuli should appear on a perceptual map. When n stimuli exist, there are $n(n - 1)/2$ distinct pairs for which similarity measures can be computed. There are several techniques for obtaining data on direct-pair comparison similarities (4). The method used in this study required individuals to rate the similarity between pairs of shopping locations on a scale of one to seven as described by Stopher in a paper in this Record. These ratings were transformed to a scale that ranked the dissimilarity between pairs of shopping locations (tied dissimilarities received the average rank of all tied pairs). The result of this transformation was the normalization of the similarity ratings across individuals so that each individual's transformed ratings sum to the same number $(1 + 2 + \ldots + 21 = 231)$.

Phase Two: Generating the Perceptual Configurations of Shopping Locations in Multidimensional Space

Multidimensional scaling methods were used to define the number of dimensions needed to represent the individual's perception space and place the shopping center locations in the perception space. The multidimensional scaling program used in this study, INDSCAL (1), identifies a common perception space for a group of individuals. Differences in perceptions among individuals are represented by the relative influence of each spatial dimension in the individual's overall determination of dissimilarities between pairs of stimuli. There are two basic assumptions in the INDSCAL program. First, all individuals are assumed to perceive the shopping locations in terms of the same underlying dimensions. This assumption is necessary for the development of a common perceptual space. Second, the similarity judgments of each individual are assumed to be related to the group similarity space by differential weighting of the underlying dimensions. In this manner, individual similarity measures for pairs of stimuli, shopping locations, are given by

$$d^i_{jk} = \left[\sum_{t=1}^{r} w_{it}(x_{jt} - x_{kt})^2\right]^{1/2} \quad (1)$$

where

d^i_{jk} = estimated similarity distance between stimuli j, k for individual i;
r = number of dimensions in the perception space;
w_{it} = weight that individual i places on dimension t, and
x_{jt} = coordinate of stimulus j along dimension t.

This expression differs from the usual Euclidean distance formula by the inclusion of the weights that represent the importance that an individual associates with a dimension in forming his or her similarity judgment. These weights represent idiosyncratic differences in perception along each axis of the stimulus space. The coordinates of stimuli in the perceptual space and the individual weights are estimated by an iterative least-squares procedure (1). This estimation procedure is designed to maximize the portion of the total variance in representation of dissimilarities that is explained by the stimuli coordinates and individual weights.

The determination of the correct dimensionality of the perception space is based on both the relative fit of the different dimensional solutions and the usefulness or reasonableness of the resultant space in interpreting perceptions.

Phase Three: Identification of Coordinate Axes for INDSCAL Solutions

The INDSCAL procedure provides a spatial configuration of group and individual perceptions for a set of stimuli, but to characterize this perceptual space, its dimensions must be identified. Although technical tools are available to assist in this task, the identification of the underlying dimensions is based, at least partially, on judgment.

One approach to the identification of the dimensions is based on an examination of the configuration of the stimuli in the perceptual space (3). This examination identifies the important characteristics that differentiate the stimuli along each of the dimensions. This approach must be used when there is no other basis for determining the characteristics of the dimensions in the perceptual space, but its effective use depends on the available information on the characteristics of the stimuli included.

In this study, the identification of the dimensions in the group perceptual space was aided by the use of additional information that consisted of ratings of the shopping centers for each of 16 attributes as discussed by Stopher in a paper in this Record. The ratings information was represented by a vector of average ratings of each shopping center for each attribute. A property-fitting program, PROFIT (2), was used to place each of these 16 attribute vectors in the group perceptual space provided by the INDSCAL solution by using linear regression procedures such that the projections of the stimuli in the perceptual space on these vectors most closely match the stimulus values on the attribute vectors. The orientation of the attribute vectors in the perceptual space helps to identify the underlying characteristics of each perceptual dimension.

Phase Four: Comparison Among Perceptual Spaces

Perceptual spaces for the shopping-center stimuli were developed for two independent samples of 100 observations each. The generality of the perceptual space developed was tested by comparison of the perceptual spaces for the different samples. When perceptual spaces to be compared appear to have a common configuration and orientation, a direct comparison may be made by (a) the coordinates of the stimuli in the perceptual space, (b) the rank ordering of the stimuli along each of the dimensions in the perceptual space, and (c) the orientation of the attribute vectors in the perceptual space.

When perceptual spaces to be compared do not have a common orientation, it is first necessary to rotate one of the perceptual spaces. This is accomplished by use of the C-MATCH program (7), which determines the rotation necessary to best match the two different perceptual spaces. After rotation, the perceptual spaces can be compared as described above.

ANALYSIS

The data were collected from approximately 7500 individuals who mailed back questionnaires that were distributed at four shopping centers in the North Shore area of metropolitan Chicago (9). These data were screened to eliminate individuals who indicated that they were not familiar with one or more of the seven shopping locations or who did not respond to all the questions required for this analysis. This left approximately 1600 questionnaires from individuals who had answered all the questions and indicated that they had at least some familiarity with each of the shopping-center stimuli. A further reduction was necessary because the INDSCAL program can analyze simultaneously only up to 100 individuals. Two random and mutually exclusive samples of 100 observations each were selected to develop the required perceptual spaces and to conduct the analysis.

The following procedure was used:

1. Develop and interpret the perceptual spaces for one sample at different levels of dimensionality and select the best on bases of judgment and fit statistics.
2. Identify the perceptual spaces of varying dimensions for the other sample.
3. Compare the perceptual spaces from the two samples and determine the consistency between the samples.

Figure 1. Variance in similarities-data explained.

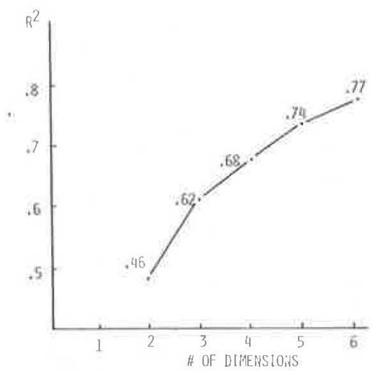
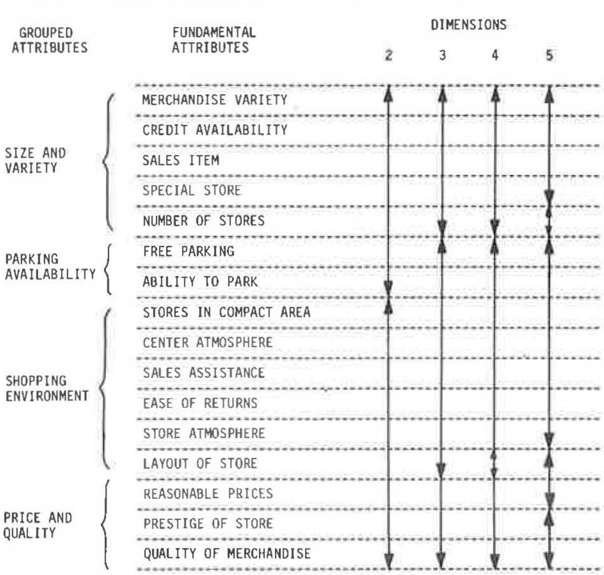


Figure 2. Attribute groupings and perception dimensions.



Perceptual Spaces for Sample One

Perceptual spaces were developed for sample one for two to six dimensions. The portion of the overall variance explained by each perceptual space is described in Figure 1. As expected, the increase in the variance explained by each added dimension decreases. There are elbows (changes in slope) for the three and five-dimensional solutions.

The individual dimensions in the various perceptual spaces were interpreted by fitting the 16 attribute-rating vectors for the seven shopping locations in each of the perception spaces. These vectors of attributes were grouped together for each dimensional space by assigning each attribute to that dimension with which it has the largest vector cosine. Figure 2 summarizes these groupings for the two through five-dimensional spaces and categorizes those attributes that tend to group together. The effect of increasing dimensionality of the perceptual space can be examined by following the changes in groupings.

The two-dimensional solution combines size and variety (group 1) and parking quality (group 2) on one dimension and environment (group 3) and price and quality (group 4) on the second dimension. The three-dimensional solution restructures the clustering of groups to produce a more distinctive pattern of dimensions: One dimension consists of size and variety (group 1) alone; the second dimension combines parking quality (from group 2) with environment (from group 3) and may be interpreted as an overall measure of environment including ease of parking; and the third dimension includes price and quality only. The four-dimensional solution is similar to the three-dimensional solution except that store layout is separated from group three to identify the fourth dimension. This attribute also loads heavily on the same dimension as the other attributes in the convenience group, which suggests that little improvement in perceptual understanding is obtained by use of the fourth dimension.

The five-dimensional solution is similar to the four-dimensional solution except that the fifth dimension was loaded only with number of stores, which was previously included in the size-and-variety group, and price was shifted from the price-and-quality group to the dimension that previously included only store layout. The resulting dimensions do not lend themselves to useful interpretations. The six-dimensional solution was not analyzed as none of the 16 attributes were associated with the sixth dimension.

The ease of interpretation of the three-dimensional perceptual space and the small change indicated by the four-dimensional solution suggest that this space is appropriate to represent shoppers' perceptions of shopping places. The characterization of the dimensions is based on the length of the attribute-vector projections on each dimension.

The selection of the three-dimensional solutions is supported by the elbow in the variance-explained curve at this point (Figure 1). The selection of the three-dimensional solution also is supported by the ability to represent the attribute vectors in this space. The PROFIT model produces Pearson correlations for the goodness of fit of each attribute vector in the perception spaces, which increased markedly between the two and three-dimensional spaces, but little between the three and four-dimensional spaces (Table 1). The locations of the attribute vectors in the three-dimensional spaces are illustrated in the two-dimensional projections shown in Figures 3, 4, and 5.

Perceptual Spaces for Sample Two

Perceptual spaces were developed for sample two for two to four dimensions. The portion of the overall variance explained for the different spaces is almost identical to that for the corresponding spaces for sample one. As with sample one, there is an elbow for the three-dimensional space.

The two and three-dimensional perception spaces are very similar to the corresponding spaces for sample one. The same attribute groups load on the same dimensions. Thus, the interpretations of the two and three-dimensional spaces for sample two are identical to those for sample one. The four-dimensional solution is similar to the three-dimensional solution except that credit availability is separated out to identify the fourth dimension. This attribute also loads heavily on dimension three (price and quality), which suggests again that the fourth dimension does not provide useful additional information. As with sample one, the Pearson correlations for the goodness of fit of the attribute vectors in the stimuli spaces increased markedly between the two and three-dimensional solutions, but little between the three and four-dimensional solutions.

Thus, the analysis of sample two is similar to that of sample one. The two and three-dimensional solutions provide similar interpretations of the perceptual spaces for both samples. The four-dimensional solutions do not produce significant additional information on perceptual structure in either sample and have different structure between samples.

Table 1. Correlation of attribute vectors with perceptual spaces.

No.	Attribute	Dimension of Perceptual Space 2	3	4
1	Layout of store	0.87	0.92	0.92
2	Ease of returning merchandise	0.73	0.94	0.94
3	Prestige of store	0.99	0.99	0.99
4	Variety of merchandise	0.98	0.99	0.99
5	Quality of merchandise	0.98	0.98	0.98
6	Credit availability	0.80	0.94	0.95
7	Reasonable prices	0.80	0.92	0.95
8	Availability of sales items	0.81	0.89	0.94
9	Free parking	0.49	0.94	0.99
10	Stores in compact area	0.78	0.94	0.94
11	Store atmosphere	0.91	0.97	0.97
12	Ability to park	0.64	0.97	0.99
13	Shopping-center atmosphere	0.90	0.96	0.98
14	Sales assistance	0.89	0.97	0.98
15	Availability of special stores	0.96	0.97	0.97
16	Number of stores	0.97	0.98	0.99

Figure 3. Projection on dimensions 1-2 plane.

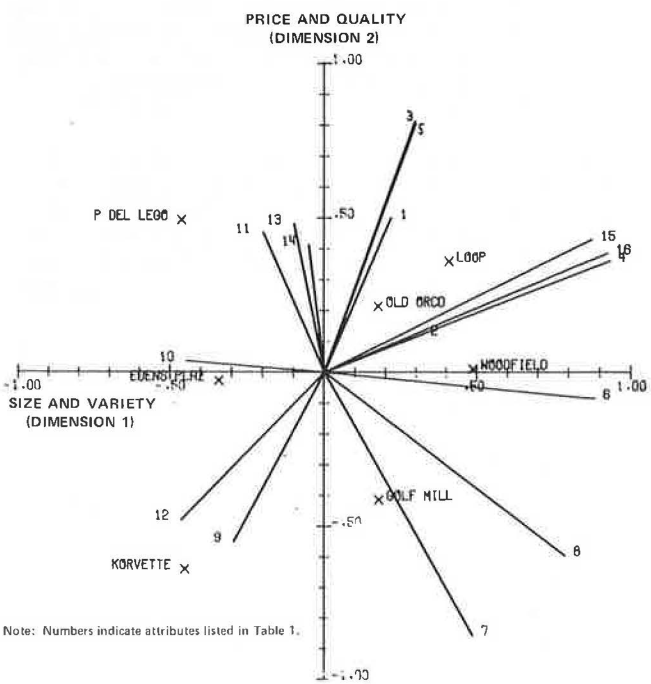


Figure 4. Projection on dimensions 1-3 plane.

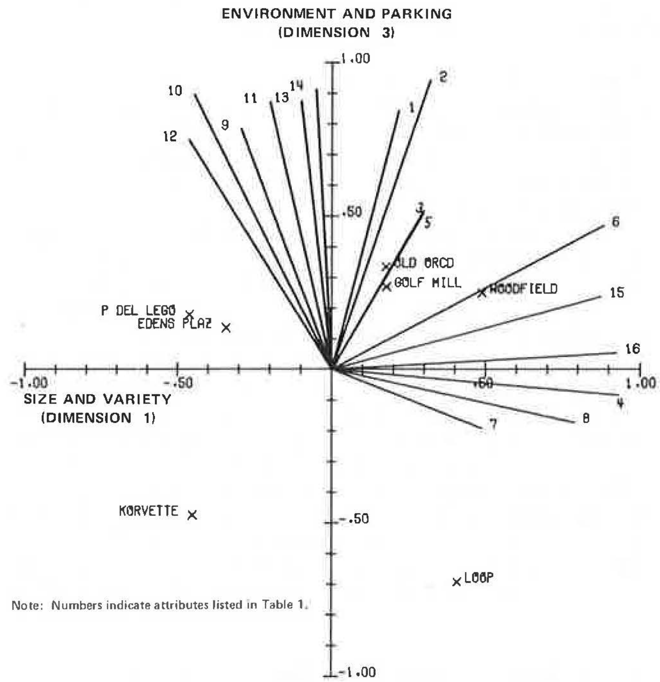
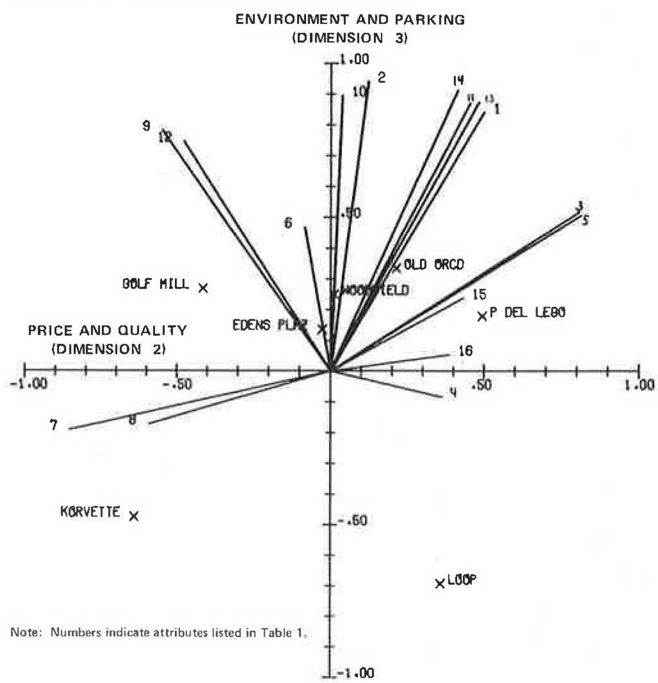


Figure 5. Projection on dimensions 2-3 plane.



Comparison Between Sample One and Sample Two

One of the objects of this research was the determination of the existence of a common perceptual space for shopping centers among residents of the North Shore area in which the sample was collected. One method of testing this hypothesis is to construct perceptual spaces by using independent samples and compare the spaces for consistency. Comparisons were made between perceptual spaces with two, three, and four dimensions for two independent samples. The comparisons are based on

1. Correspondence between the coordinates of the stimuli (shopping centers) in the perceptual space and
2. Correspondence between the directions of the attribute vectors in the perceptual spaces.

These comparisons assume a common orientation of the perceptual spaces developed for the two samples. This parallels the INDSCAL assumption that the perceptual space that is developed has a unique orientation, so that no rotation of the axes is needed to recover the underlying perceptual dimensions.

The common orientation of the perceptual spaces for the two samples was tested by determining the rotation necessary to obtain maximum correspondence between spaces of common dimensionality. The two, three, and four-dimensional perceptual spaces were compared by using the C-MATCH program (7). This procedure takes two configurations of a common set of stimuli, orthogonally rotates either or both of them to obtain the maximum congruence between them, and computes the rotation matrix required to obtain this congruence. The rotations required to obtain the maximum correspondence between each pair of spaces are shown in Table 2. Little rotation is necessary to match the two and three-dimensional spaces between samples (as indicated by the closeness of these rotation matrices to the identity matrices). However, the four-dimensional spaces require substantial rotation to achieve maximum congruence. As was indicated above, the INDSCAL solution is intended to produce a perceptual configuration that represents a unique orientation in the perceptual space. The fact that rotation is required to achieve maximum congruence suggests that there are underlying differences between the perceptual spaces for the two four-dimensional solutions. The lack of correspondence between these spaces is a probable result of increasing the degrees of freedom of the perceptual spaces to the point where the program is fitting the random elements of the particular data set rather than the underlying perceptual structure. That is, the higher dimensionality exhausts the structural information in the data set. Green and Wind (5) have suggested that for metric solutions, the determinancy of the space will be high when the number of stimuli is three or more times the number of dimensions in the perceptual space, and on this basis, the discrepancy between the four-dimensional solutions for spaces based on only seven stimuli is not surprising.

The very small amount of rotation required to obtain maximum congruence between the pairs of two and three-dimensional spaces confirms the common orientation between these pairs of perceptual spaces. The C-MATCH program also produces a measure of the correlation of interpoint distances (which is independent of rotation) between spaces of like dimension. These correlation measures were 0.87, 0.94, and 0.86 for the two, three, and four-dimensional spaces respectively.

Further comparisons of the INDSCAL solutions for the two samples are given for the two-dimensional spaces in Tables 3 and 4 and for the three-dimensional spaces in Tables 5 and 6. Tables 3 and 5 compare the coordinates and rank order of each of the stimuli on each axis in the perceptual spaces. Tables 4 and 6 compare the dominant loadings of the attribute vectors along each axis in the perceptual space. Tables 3 and 4 indicate a high degree of correspondence between the two-dimensional spaces generated by the two samples. The locations of the various shopping centers in the perceptual spaces are similar, although there is some disparity in rank ordering. The dominant loadings of the attribute vectors are similar with the exception of the stores-in-a-compact-area attribute, which loads almost equally in the two dimensions. Tables 5 and 6 indicate a high degree of correspondence between the three-dimensional spaces. The locations of shopping centers is similar, the number of rank differences is less than that for the two-dimensional spaces, and the dominant attribute loadings are very similar.

This analysis indicates an extremely strong correspondence between the three-dimensional spaces developed for the two independent samples. This strong correspondence has two important implications: First, it is possible to develop a perceptual space for a population group based on analysis of data for a small repre-

Table 2. Rotation matrices to obtain maximum correspondence between samples.

Sample 2	Sample 1: 1	2	3	4
Two-dimensional space				
1	0.99	0.11	—	—
2	-0.11	0.99	—	—
Three-dimensional space				
1	0.99	0.04	-0.05	—
2	-0.03	0.99	0.05	—
3	0.06	-0.05	0.99	—
Four-dimensional space				
1	0.94	0.21	0.25	-0.02
2	-0.03	0.82	-0.57	-0.04
3	-0.31	0.52	0.74	0.29
4	0.11	-0.13	-0.25	0.96

Table 3. Sample comparison: stimuli coordinates and rank order (two dimensions).

	Dimension 1				Dimension 2			
	Sample 1		Sample 2		Sample 1		Sample 2	
Shopping Location	Coordinate	Rank Order	Coordinate	Rank Order	Coordinate	Rank Order	Coordinate	Rank Order
Chicago Loop	0.50	1	0.46	1	-0.17	6	0.11	3
Edens Plaza	-0.35	5	-0.13	5	0.10	4	0.01	5
Golf Mill	0.08	4	0.13	3	-0.11	5	-0.30	6
Korvette City	-0.46	7	-0.45	6	-0.76	7	-0.73	7
Old Orchard	0.16	3	0.12	4	0.34	2	0.30	2
Plaza del Lago	-0.40	6	-0.58	7	0.48	1	0.51	1
Woodfield	0.46	2	0.44	2	0.12	3	0.10	4

Table 4. Sample comparison: attribute vector loading along axes (two dimensions).

Attribute	Dimension 1 Sample 1	Dimension 1 Sample 2	Dimension 2 Sample 1	Dimension 2 Sample 2
Layout of store	—	—	0.98	0.93
Ease of returning merchandise	—	—	0.97	0.84
Prestige of store	—	—	0.94	0.90
Variety of merchandise	0.98	0.98	—	—
Quality of merchandise	—	—	0.94	0.92
Credit availability	0.95	0.98	—	—
Reasonable prices	—	—	-0.92	0.75
Availability of sales items	0.76	0.92	—	—
Free parking	-0.96	-0.93	—	—
Stores in compact area	—	-0.80	0.75	—
Store atmosphere	—	—	0.97	0.91
Ability to park	-0.96	-0.93	—	—
Shopping-center atmosphere	—	—	0.99	0.99
Sales assistance	—	—	0.99	0.99
Availability of special stores	0.89	0.89	—	—
Number of stores	0.96	0.93	—	—

Table 5. Sample comparison: stimuli coordinates and rank order (three dimensions).

	Dimension 1				Dimension 2				Dimension 3			
	Sample 1		Sample 2		Sample 1		Sample 2		Sample 1		Sample 2	
Shopping Location	Coordinate	Rank Order	Coordinate	Rank Order	Coordinate	Rank Order	Coordinate	Rank Order	Coordinate	Rank Order	Coordinate	Rank Order
Chicago Loop	0.41	2	0.45	1	0.35	2	0.31	2	-0.69	7	-0.67	7
Edens Plaza	-0.34	5	-0.13	5	-0.03	5	-0.09	5	0.14	5	0.25	3
Golf Mill	0.18	3	0.14	3	-0.41	6	-0.37	6	0.27	2	0.24	4
Korvette City	-0.45	6	-0.44	6	-0.64	7	-0.65	7	-0.47	6	-0.49	6
Old Orchard	0.18	4	0.12	4	0.21	3	0.23	3	0.33	1	0.35	1
Plaza del Lago	-0.46	7	-0.59	7	0.49	1	0.53	1	0.18	4	0.06	5
Woodfield	0.49	1	0.45	2	0.01	4	0.04	4	0.25	3	0.26	2

Table 6. Sample comparison: attribute vector loading along axes (three dimensions).

Attribute	Dimension 1 Sample 1	Dimension 1 Sample 2	Dimension 2 Sample 1	Dimension 2 Sample 2	Dimension 3 Sample 1	Dimension 3 Sample 2
Layout of store	—	—	—	—	0.84	0.80
Ease of returning merchandise	—	—	—	—	0.94	0.95
Prestige of store	—	—	0.80	0.73	—	—
Variety of merchandise	0.93	0.97	—	—	—	—
Quality of merchandise	—	—	0.81	0.77	—	—
Credit availability	0.88	0.75	—	—	—	—
Reasonable prices	—	—	-0.85	-0.76	—	—
Availability of sales items	0.79	0.90	—	—	—	—
Free parking	—	—	—	—	0.78	0.81
Stores in compact area	—	—	—	—	0.89	0.91
Store atmosphere	—	—	—	—	0.87	0.79
Ability to park	—	—	—	—	0.75	0.71
Shopping-center atmosphere	—	—	—	—	0.87	0.88
Sales assistance	—	—	—	—	0.91	0.90
Availability of special stores	0.87	0.87	—	—	—	—
Number of stores	0.92	0.93	—	—	—	—

sentative sample drawn from that group. This means that perceptual representations can be extended beyond the sample of estimation to the population it represents in the same way that choice models are presently extended and implied. Second, in contrast to earlier expectations, it is possible to develop a representative perceptual space with a high degree of determinacy even when the number of stimuli is less than three times the number of dimensions. This is important because the number of relevant stimuli (alternatives) in transportation-choice situations is often small. However, the lack of correspondence between the four-dimensional spaces confirms that there is a close limit to the exploitation of small data sets.

CONCLUSIONS

There were two primary objects of this research. The first was an investigation of the feasibility of constructing a representative perceptual space of shopping locations based on a small sample of individuals by analyzing reported measures of similarity. The second was the identification of underlying perceptions of shopping locations and an understanding of the policy implications indicated by these perceptual aspects.

With respect to the first object, the analysis demonstrated the ability to develop perceptual spaces in two and three dimensions that are subject to reasonable interpretation and similar for two independent sets of observations. These results indicate both that the development of perceptual spaces for destination attractiveness characteristics is feasible, and that the perceptual space developed is representative.

With respect to the second object, the perceptual space that has the best interpretability has the following three underlying characteristics: (a) size and variety, (b) price and quality, and (c) environment and parking. These three characteristics, therefore, suggest themselves as appropriate attractiveness measures to be used in destination-choice modeling. The common practice of representing alternative shopping locations in terms of measures of size and variety (such as retail employment or floor space) alone will define underspecified choice models. The results of this research suggest directions for objective quantification of shopping-location attributes that represent other characteristics that are important in formulating perceptions of shopping locations and provides decision makers with information about present perceptions. Discrepancies between these public perceptions and management perceptions suggest directions for changes in policies that may improve public perceptions. This is particularly critical when lack of information or misinformation causes incorrectly poor perceptions and consequently low utilization. Finally, this research confirmed the potential for measuring characteristics of consumer alternatives that are not measurable by direct or engineering means. Such consumer measurements could provide a basis for extending the scope of transportation policy analysis to include consideration of improvements in subjective characteristics of transportation alternatives.

ACKNOWLEDGMENTS

The work reported in this paper was conducted under a contract from the Program for University Research, Office of the Secretary, U.S. Department of Transportation.

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

Abridgment

Instrumental and Life-Style Aspects of Urban Travel Behavior

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The travel behavior of social groups has been discussed in the literature on the basis of several conceptual approaches. The first, the logistic-operational approach, emphasizes the prediction of flows in constrained transportation networks. Thus, trip-generation models have been developed that account for the trip-making rates of various population groups, which is sometimes referred to as a category analysis of travel demand (9). The second, the spatial-activity approach, relates travel purposes to urban forms and functions. Given the various preferences of social groups in terms of their activity space within a citywide opportunity field, different population groups are presumed to have distinctive residential choices and trip patterns, so as to overcome the friction of distance caused by the spatial differentiation of urban areas (3). The third, the market-segment approach, focuses on the varying needs of special groups in society. In this approach, the travel behavior of the disadvantaged, such as the poor, the aged, or the disabled, is investigated with the aim of identifying potential ways to overcome their mobility deprivation.

This increasing interest in the travel patterns of social groups has been accompanied by a closer investigation of the behavioral aspects of travel demand. Theoretically, travel is considered as an intermediate good, for which the demand is derived from the demand for the activity performed at the trip destination. In a broader sense, this function of transportation is known as the instrumental aspect of travel, where the activity of traveling ought to be related to a set of various tangible needs or requirements of households that necessitate movements between real-world locations. The instrumental aspect of transportation has been widely used in the methodological formulation of travel research, partly because of its obvious linkage to postulates of the theory of consumer behavior (1).

It is common practice to provide an operational definition of the instrumental function of transportation by a classification of trip purposes. Three main categories of trip purposes can be defined on an increasing scale of elasticity:

1. Subsistence trips (i.e., work and business trips) are characterized by their inelasticity in terms of periodicity, time, and location;
2. Maintenance trips (i.e., those for personal affairs and shopping) have more elasticity as far as the need it-

self is concerned, but a somewhat greater flexibility in the choice of destinations, time, and periodicity; and

3. Leisure trips (those for entertainment, social, and sport purposes) are relatively the most flexible, because they are clearly related to discretionary activities (4).

More recently, an argument has been advanced that the instrumental aspect of travel patterns of social groups may be a necessary, but not a sufficient, component of a fully behavioral analysis of travel phenomena. The questions arose from two separate, but converging research efforts. The first was the attempt to formulate the basic constructs of the psychological and social factors that influence the travel behavior of households and individuals living in urban areas (5). The second was the idea that households and individuals may have established life-styles in which transportation or mobility patterns fulfill some ends in themselves. This particular question evolved partly from the inconclusive travel adjustments shown during the energy crisis in 1973-1974 (8).

In this paper, the premise is investigated that the instrumental aspects of travel should be complemented by those of another dimension that reflects the habitual behavior of individual decision makers. This dimension is sometimes labeled the preference pattern or the taste system of persons or households, but it is preferable to call it the life-style aspect. Life-styles are assumed to be shaped by recurrent behavioral responses to socioeconomic conditions, as well as to deeper personal or social attitudes, roles, or values. The specific mechanism of the behavioral response is partly reflected by consumer-behavior concepts in economics; human-development stages, role theory, and decision-making processes in psychology; and concepts of social mobility and household management in sociology.

Four life-style aspects appear to be particularly relevant, either separately or together, to individual or household travel behavior.

1. The level of economic resources available to the household and the propensity to consume—economic resources act as catalysts to travel, not only in overcoming the monetary costs of trips, but also in the increased propensity to consume goods and services at the trip destination.

2. The social engagement-disengagement continuum, which reflects the degree of involvement with people and functions in the immediate vicinity or in the urban environment in general. On one end, there are households with a very low level of engagement (or a high degree of disengagement) with the rest of the world, and on the other hand, there are households with a high involvement with their surroundings.

3. Role differentiation within the household—households with different cultural backgrounds and family sizes will have reached different forms of task allocations, according to the role of the male and female heads of household. Thus, every instrumental need listed above, particularly for nonsubsistence trips, can be performed either by any member of the household or by a specific member, depending on their habitual roles.

4. Control and awareness of time allocation, which is an element that relates to the feasibility that households can plan and order their daily routine or rhythm of life. Some households are likely to have very little control over their routines, while others have a high degree of control and may be in a position to determine whether to perform an activity out of the home or to have other people come to them.

The relation between the life-style aspects—economic resources, social engagement, role differentiation, and control over time—and the instrumental aspects—overall mobility, subsistence, maintenance, and leisure—of travel behavior can be viewed as a matrix. In each cell (i.e., for each combination of both aspects), the interaction can be scaled on a high-to-low continuum.

The main problems encountered in an empirical investigation of the relation between the life-style and the instrumental aspects of travel behavior are associated with the proper selection of the data and the research methodology. Life-style aspects should be regarded as composite and dynamic behavioral constructs, whereas the data collected in travel surveys are usually socioeconomic variables that serve as static proxies for the underlying behavorial mechanisms. Similarly, the research methodology that almost suggests itself is an in-depth household interview, preferably on a longitudinal basis. However, the amount of information required about the background, attitudes, and behavior of each household and its representativeness would probably preclude the collection of a sample that was sufficiently large for significant cross tabulations.

With the limited scope of a single study, a number of simplifying assumptions had to be made, mainly due to the available data. The life-style aspects were supplemented by socioeconomic variables, despite their inadequacy. Thus, reported household income represents economic affluence and the propensity to consume, and social engagement is reflected by age. Role differentiation is shown by focusing on travel patterns of the head of household. Finally, time control may be represented by level of education and vehicle availability. For the research methodology, an existing large cross-sectional survey, rather than a much smaller longitudinal sample, was used. The rationale was that if social groups could be differentiated even on the basis of the inadequate data and research design, a more extensive investigation would be justified.

DATA BASE

The data were collected as a follow-up of the 1972 census. The population sampled included all inhabitants aged 5 and over who had a fixed residence during the survey period in localities with 10 000 or more inhabitants or in smaller localities contiguous to metropolitan areas. The sample was conducted between November 1972 and June 1973 in 70 localities and included 55 000 households. Although only 30 percent of all households have a light vehicle at their disposal, the sample was weighted so that 50 percent of the households included had vehicles.

The methods of data collection were the standard home-interview questionnaires and cordon and screenline surveys. The enumerator visited households in the late afternoon and inquired about trips occurring between 2:00 p.m. on the preceding day and 2:00 p.m. on the day of the visit. Special attention was paid to trip information from each individual member of the household. Since the data were collected only on weekdays, the trip distributions obtained reflect only averages of weekday travel. As in most travel studies, the dependent variable is the reported trip distribution of household heads, where a trip is defined as a movement by means of a motorized vehicle from a point of origin to a destination, including walking for the purpose of reaching the point from which the journey was to start (2).

On the basis of the methodological introduction, the following specific variables were selected for the analysis.

1. Reported annual household income for households that earn salaries or wages (self-employed households were deleted because of the potential bias in their reported income) were subdivided into four groups.

2. The variable selected as a proxy for role, was head of household, who is the shaper and the mobile element of the household's mobility pattern.

3. Vehicle availability in the household refers to private passenger vehicles, commercial vehicles with a load capacity not exceeding 1 Mg (1 ton), or two-wheeled vehicles not used for carrying goods. The proportion of private automobiles was 82.4 percent, and 85 percent of all vehicles were fully owned by the households. Because 95 percent of the families with a vehicle at their disposal have only one, it was not necessary to further subdivide automobile availability by the number of vehicles.

4. Age was represented by the conventional classification of young, middle aged, and old.

5. Education was based on years of schooling.

6. Instrumental aspects were the total trips, which represent overall mobility, and subsistence trips, which include work and business trips. In some cases, maintenance and leisure trips were also included in the analysis.

By a careful selection of the subpopulation, the size of the sample was reduced to about 28 000 observations—14 277 households with automobiles and 13 487 automobileless households—covering the entire urban population of the country and having the characteristics shown below (1 I£ = $0.24 in 1973).

Characteristic	Value	Standard Deviation
With automobile		
Age, years	42.63	8.90
Income, I£	23 225	10 590
Schooling, years	13.24	3.40
Without automobile		
Age, years	44.69	11.10
Income, I£	13 785	8780
Schooling, years	9.22	3.68

INTERACTIONS OF LIFE-STYLE AND INSTRUMENTAL ASPECTS OF TRAVEL

It is commonly recognized that vehicle availability, income, and education act as positive catalysts to household travel and reinforce each other in their effects. Age, on the other hand, particularly old age, is perceived as a barrier to mobility. When travel patterns of household heads are considered (Table 1), the overall results are similar, although a number of specific interactions are noteworthy.

1. The net positive effect of income on overall mobility is higher in the group of automobileless households than in that of families with automobiles. Also,

Table 1. Average daily trips of household heads.

Age (years)	Annual Income (I£)	Automobile Availability	Education (years): 0 to 8 All	0 to 8 Subsistence	9 to 12 All	9 to 12 Subsistence	13 to 15 All	13 to 15 Subsistence	≥16 All	≥16 Subsistence
≤34	≤8 000	Yes	4.1	1.6	3.5	1.4	4.2	1.5	4.7	1.3
		No	2.0	0.8	2.7	1.1	2.7	1.0	3.0	1.1
	8 000 to 16 000	Yes	3.1	1.2	4.1	1.7	4.1	1.5	4.4	1.5
		No	2.2	0.9	2.7	1.2	2.8	1.0	2.7	0.9
	16 000 to 25 000	Yes	3.6	1.4	4.3	1.8	5.1	2.1	4.3	1.6
		No	2.1	0.8	3.0	1.2	3.0	1.2	2.4	0.9
	≥25 000	Yes	2.9	1.1	4.4	1.8	4.2	1.7	4.3	1.8
		No	1.7	0.8	3.4	1.5	2.4	1.0	2.8	1.0
35 to 64	≤8 000	Yes	2.8	1.1	3.6	1.4	3.8	1.6	4.2	1.7
		No	1.8	0.8	2.1	0.9	2.1	0.9	2.4	0.9
	8 000 to 16 000	Yes	3.1	1.4	3.8	1.6	4.0	1.6	4.4	2.0
		No	2.1	0.9	2.3	0.9	2.6	1.2	2.1	0.8
	16 000 to 25 000	Yes	3.1	1.3	4.1	1.8	4.4	2.0	4.1	1.7
		No	2.2	0.9	2.7	1.3	2.6	1.1	2.6	1.0
	≥25 000	Yes	3.4	1.5	4.2	1.9	4.4	2.0	4.1	1.8
		No	2.1	0.9	2.6	1.2	2.7	1.2	2.9	1.2
≥65	≤8 000	Yes	2.3	1.1	1.8	0.6	1.6	0.7	3.4	1.8
		No	1.7	0.7	2.2	0.9	2.2	0.7	1.9	0.6
	8 000 to 16 000	Yes	2.6	1.6	3.3	1.8	1.8	0.9	3.9	1.2
		No	1.8	0.7	2.3	0.9	2.1	0.7	2.5	0.9
	16 000 to 25 000	Yes	2.1	0.9	3.8	1.7	2.3	1.0	2.4	1.1
		No	2.0	0.9	2.2	0.9	2.0	0.7	1.7	1.1
	≥25 000	Yes	3.6	2.7	3.2	1.7	4.0	2.0	3.8	1.5
		No	1.6	0.8	2.6	1.2	2.8	1.1	2.7	1.2

Table 2. Quantitative relations between trip generation of household heads and selected socioeconomic variables.

Dependent Variable	Independent Variable: Education Value	Education t-Statistic	ln Education Value	ln Education t-Statistic	ln Income Value	ln Income t-Statistic	Age Value	Age t-Statistic	ln Age Value	ln Age t-Statistic	Constant Value	Constant t-Statistic	R^2
With automobiles													
All trips	-0.315	0.062	4.570	0.760	0.179	0.057	-0.018	0.004	—	—	-4.439	1.215	0.732
Subsistence trips	-0.208	0.034	2.723	0.422	0.150	0.032	-0.036	0.016	1.453	0.648	-7.816	1.800	0.675
Maintenance and leisure trips	-0.055	0.029	0.977	0.357	—	—	—	—	-0.539	0.070	1.132	0.617	0.717
Without automobiles													
All trips	-0.083	0.043	1.306	0.407	0.197	0.046	-0.011	0.003	—	—	-1.064	0.560	0.787
Subsistence trips	-0.082	0.025	0.926	0.234	0.123	0.026	-0.003	0.001	—	—	-1.251	0.351	0.664
Maintenance and leisure trips	—	—	0.199	0.023	—	—	-0.186	0.032	—	—	0.643	0.144	0.776

the effect increases in both groups with the age of the household head.

2. Age is always a negative factor. This is probably due to the deletion of children and adolescents from the sample, thus removing the lower tail of the usual bell-shaped distribution. Similarly, when only household heads are being included, the difference between the mobility of the various age groups is modest and does not exceed 25 to 35 percent between group averages.

3. The effect of education on travel is not simply additive to that of income. In reality, at higher levels of education and income, some reduction in overall mobility and subsistence travel can be observed.

4. Subsistence trips are the predominant trip purpose, as befits the case of household heads. Education is generally negatively related to this predominance.

To determine the interaction between the life-style and the instrumental aspects of household heads, standard multivariate techniques were used (Table 2).

The quantitative relations shown in Table 2 substantiate the basic premise that three socioeconomic variables—education, income, and age—contribute independently to a large degree of the explained variance of trip generation by household heads. Furthermore, the effect of income is positive, although weak. Age is nearly always negatively related to the various instrumental aspects of travel. Education shows mixed interactions, depending on the statistical formulation of the relations.

The derivation of the elasticities of income, education, and age shown below provides an additional insight to the effects of these variables on the mobility patterns of household heads.

	Dependent Variable		
Independent Variable	Income	Education	Age
With automobiles			
All trips	0.044	0.099	−0.184
Subsistence trips	0.087	−0.020	−0.050
Maintenance and leisure trips	NS	0.284	−0.611
Without automobiles			
All trips	0.085	0.235	−0.218
Subsistence trips	0.126	0.177	−0.154
Maintenance and leisure trips	NS	0.540	−0.506

Three general observations can be made:

1. On the whole, the elasticities of the variables on instrumental aspects of travel are fairly low, with the exception of maintenance and leisure trips.

2. Automobileless families have almost consistently higher elasticities than do households with an automobile available.

3. Income elasticities are positive, but very low; age elasticity is negative, but higher; and educational elasticities, although generally positive, show an interesting exception, namely that of subsistence trips by household heads with automobiles.

Turning now to the behavioral interpretation of the findings, several inferences seem to be appropriate. First, economic resources appear to have only a small effect on either overall mobility (within the observed range) or subsistence travel, probably because of the low costs of the trips relative to their utility or to the satisfaction derived at the trip end. However, the lack of significant results about maintenance and leisure trips should be considered in the light of the availability of weekday travel data without the complementary weekend travel. Second, the engagement-disengagement continuum is reflected by the difference in the travel patterns of young vis-à-vis elderly household heads. Young adults are the most mobile group and make more trips for nonsubsistence purposes, particularly at higher levels of education. This is the age when the basic activity space is being formed, probably through a process of search and an evaluation of the opportunity range offered by the urban environment. Old age, on the other hand, is characterized by a substantial decrease in mobility. These lower levels of mobility of the elderly can be related to both the disengagement and the activity theories of aging (6).

Control and awareness of time are represented by both education and vehicle availability. Lower educational levels are generally associated with occupations that do not permit trips during working hours, whereas higher educational levels presumably allow a greater flexibility in subsistence travel, particularly business trips. However, higher educational levels may also have an opposite effect, because of a greater awareness of time and of the need for planning the use of this scarce resource. In a more detailed analysis, it was found that the income elasticities of maintenance and leisure trips of household heads who have an automobile and belong to the group with the highest education tend to be negative. This suggests that education has a mixed interaction with mobility, positive up to a certain level and then becoming negative, when the number of trips is reduced either by better planning or by a substitution of the person who is performing the trip.

The effect of automobile availability is two-fold: On the one hand, as has been shown above, it reduces the differences among the various variables that represent life-styles. In other words, when they have an automobile available, people with less income have a trip-making behavior more similar to that of people with higher income than they would have without an automobile. The same appears to be true for education and age. This particular effect of the private automobile may be termed an equity effect, in that it overcomes basic differences in socioeconomic characteristics of the traveling population. At the same time, the apparent dissimilarity between the elasticities of automobile-owning and automobileless household heads suggests a divergent propensity to use the opportunity field offered by the urban environment. Such a dual mobility pattern has been observed in a separate study (7) and seems to be reinforced by the findings of the present analysis.

CONCLUSIONS

A comparison of socioeconomic variables and their relations to weekday travel patterns in urban areas of Israel has shown a number of noteworthy variations in the distributions that can be related to a firmer behavioral rationale. This paper attempts to link the choice mechanism to a set of habitual responses inherent in the instrumental nature of travel and in life-style aspects that presumably underlay the preference systems of various groups in society.

Even in a simple cross-sectional analysis of standard household travel surveys, it was possible to isolate several phenomena that are usually missed in the normal category analysis of trip generation: the counter effect of higher education on income in reducing mobility; the existence of a highly mobile age group, young adults, with a travel behavior opposite to that of the better known, less mobile group of the elderly; the equity effect of automobile availability; and finally, the small weight of income on the trip generation of household heads.

These results should be considered as partial and tentative, because of the limitations of the data. These limitations include the lack of independent data on mobility, such as trip lengths or vehicle kilometers of travel by the various social groups. Also, there was no information available on pedestrian movements, which would complement the investigation of instrumental needs that can be fulfilled without making a trip at all.

A number of implications for transportation research and policy may be outlined. First, survey techniques should include specific life-style variables and be administered in panel-type longitudinal surveys, so as to obtain more direct information on travel behavior. Second, a reconsideration of the population to be investigated in such surveys is required, so that subgroups who might respond more rapidly to transportation policy measures could be identified. Finally, the relations shown in this study precede the energy crisis. In view of the high probability that travel costs will increase in the future, the likely effect of this trend on the elasticities of the various socioeconomic variables should be investigated.

ACKNOWLEDGMENT

This research was partly supported by a grant from the Ford Foundation received through the Israeli Foundations Trustees. The assistance of Nurit Strauss in the statistical computations is gratefully acknowledged.

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

Public Attitudes Toward Transit Features and Systems

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An attitudinal survey was made in the Dallas-Fort Worth metropolitan area in 1973-1974 to obtain representative public attitudes toward a comprehensive array of urban public transit features and systems. The sample population surveyed were demographically representative of the area. The questionnaire was structured such that the reasons for some of the attitudes could be deduced. It consisted of a series of questions about transit features or operational elements and a section about whole transit systems. An unbiased, informative audiovisual presentation accompanied the administration of the questionnaire, calling attention to various human factors, aesthetics, economics, and innovations regarding public transit. The questionnaire also incorporated a provision for quantification of attitudes by adding a question about money to be invested in a transit-system feature to the usual qualitative scale of answers. The importance scales were compared to the money-investment scales by using factor analysis, regression analysis, and other techniques. The five transit systems in the questionnaire were improved bus, dual rail, other-tracked vehicle, dual mode, and demand responsive (bus). This type of research is consistent with a contemporary philosophy of system development that emphasizes user-oriented techniques as an approach to enhancing public transit usage.

The initial objects of this research were two. The first was to determine the nature and type of human design factors that the public believe are important and should be incorporated in the transportation system. The second was to determine what type of overall system people prefer. Subsequent aspects of the study involved examining the data and determining any interrelations among the various parameters. The final step was to identify the underlying factors that influence regional attitude and behavior patterns in the public's decision to ride or not to ride any public transit system. Such attitudinal information should allow transit planners to be more sensitive to the desires of the public. This study was sponsored by the Urban Mass Transportation Administration of the Department of Transportation.

The experimental design and the data analysis attempted to determine the answers to a series of propositions about attitudes toward transit in the Dallas-Fort Worth metropolitan region.

The first phase of the research was the development of an attitudinal-survey, or questionnaire, form. This required several exploratory sessions, reviews, interviews, and revisions. The next phase of the research involved the presentation of the questionnaire to a representative sample population. Regional demographic characteristics such as income, sex, age, distance to work, and others have been compared to those of the sample, and the sample is considered to be reasonably representative. Weighting the survey toward those groups of people who were using mass transit was considered, but rejected because such a sample, while yielding certain useful information, would fail to consider potential customers not then using the available transit. The demographic characteristics of the sample were cross tabulated with their attitude and desire categories to determine whether users or nonusers of public transit were demographically homogeneous or not.

Statistical techniques (factor analysis and multiple regression analysis) were applied to the data to determine the interrelations between population attitudes toward public transit and the total range of demographics, human factors in design, preferences for different types of systems, and resultant projected behavior (to ride or not to ride).

Someone will ultimately have to pay for any transportation system selected, whether it is through the farebox or in taxes. The economic-aspects section of the questionnaire attempted to determine attitudes about how a system should be financed. Public opinion is important because these people will be those voting on bond issues and otherwise deciding how to finance new transit systems.

SURVEY METHODOLOGY

The development of the data-gathering methodology was the first task of the research. The first major decision, which had greater importance than originally envisioned, was to use a group-presentation technique rather than a personal interview. The questionnaire was developed over a period of 6 months. A five-person team that included a sociologist, a transportation engineer, a human-factors engineer, and two graduate students met and debated the questions to be asked and their wording and ordering on the questionnaire. After several pilot tests, given to and critiqued by different socioeconomic groups, to reduce the bias of the questionnaire, the final form was developed.

Audiovisual Program Development

During the initial trials of the questionnaire, it was realized that the respondents would need some kind of informative material preceding or accompanying it. This had the potential of reducing the validity of the survey if the presentation introduced bias. The audiovisual presentation consisted of 35-mm slides synchronized with a taped commentary to ensure consistency. The operation was automatic and all respondents were shown the same information in the same manner. The slides were selected of a wide range of both present and proposed transit vehicles and systems. Some slides were prepared by the research team, and others were obtained from system operators and the manufacturers and developers of such systems, vehicles, and equipment. The slides were selected to hold the interest of the viewers, as well as for the presentation of unbiased information. Human-factors considerations were pointed out, but none were labeled as good or bad. Transportation innovations and features were shown that were predicted to be available in the future, as well as those that were currently available. The slides were especially important in explaining the different types of transportation systems. Many of the respondents had not previously seen examples of some types of systems, and a correct interpretation based only on a verbal description would have been very difficult. The audiovisual presentation required that a trained announcer be used for the narrative and that the slides be of high quality and closely follow the subject matter. Consideration was also given to the amount of time the slides were projected on the screen and the moment of introduction of each slide. To lend a more personal atmosphere, personal or live greetings and introductions were included, as well as a question-and-answer period after the session for those desiring more information.

Questionnaire Design

The final version of the survey questionnaire was divided into four sections. The first section—personal information—was designed to obtain personal statistics. The respondents were asked not to identify themselves by name and were assured complete anonymity. Items such as income, age, sex, household questions, and background information about the use of present mass transit facilities were necessary to distinguish answers from special groups, such as the turnpike users.

The second section of the questionnaire dealt with the socioengineering factors of mass transportation systems and was an attempt to determine the more desirable features for future systems. A unique part of this section was the provision of an investment column for dollar amounts to be allocated each year for the development of desired features. This column gave a further quantification of preference and could also serve to test the validity of the answers. It was seriously examined during the pilot studies. Although it did create some confusion, its benefits greatly outweighed its disadvantages, and so it was retained in the final design.

The investment column was set up in a manner that required forced choices, because some features had to receive no money. If the minimum investment was made in each case, a maximum of 20 of the 26 features could receive allocations for development. If strong preferences were shown by the allocation of more than the minimum amount to one or more features, fewer than 20 could receive financial aid. It was felt that this manner of investment was preferable from two points of view. First, it forced the respondent to think and quantify his or her preferences, because it was not possible to just go down the page and distribute money according to the importance given to each feature. Second, it could be used as a finer scale for interpreting the importance ratings, as well as providing a cross reference for validity.

The third section was designed to determine public reactions to transit issues such as maximum walking distance to and from the transit system, maximum waiting time for vehicles to arrive, and maximum costs per unit distance for fares. This section also sought data on the extent of agreement by the public about ownership, fare subsidization, use of public taxes, bond issues, and the desirability of extra service for extra fares (such as first-class airline tickets). The respondents were then asked whether they would use a good transit system if it existed today and whether they thought they would be using one within the next 30 years, and why.

The fourth section—preferences for transportation systems—used a different approach to determining attitudes. Five different transportation systems were described during the audiovisual portion of the presentation and the respondent was asked to bid on each system according to how he or she felt it would serve the needs of the people in the Dallas-Fort Worth area. Slides depicting some features of each of these systems were collected from representative firms and agencies. To eliminate any bias in the slide presentation, approximately the same number and quality of slides were selected to show the features of each system. The five systems selected were improved bus, dual rail, other-tracked, dual mode, and demand operation. The questionnaire contained a brief printed summary of each system to refresh the respondents' recollections. In addition, a combination category was established to determine a combination of any two systems the respondent felt would provide a good overall system for the area. Because great differences exist in the costs of development and installation of each system, it was felt that some kind of cost-range information was necessary. However, exact ranges, if such were available, would probably have had a greater influence on the amount bid than would relative cost ranges such as high, medium, and low. This last section was largely educational; it was designed to acquaint the public with some of the proposals for future transportation development and to measure their reactions to such systems. It was expected that the socioengineering-design questions of the second section would still be fresh in their minds and that they would look for some of these human-factors considerations in formulating their bids for each system.

To keep the questionnaire from becoming too long, all design-related human factors could not be included. In the category of engineering design, noise, illumination, air quality, and pollution have been the subjects of several previous studies, and so they were excluded. By excluding these bioenvironmental factors it was not implied that they were less important, rather that the lack of space necessitated their removal in favor of less studied factors.

The questionnaire was organized so that a minimum of contamination between sections would occur. The sequence was especially important in the last section covering the five proposed systems. The section about investment in transportation systems was placed last in the hope that the human-factors considerations of earlier sections would be remembered and perhaps used in the system selection. The economic and convenience aspects were deliberately placed after the design section to allow more candid answers to the design-features questions without the financial aspects influencing the ranking of importance of the features presented. The general-aspects section was inserted between the design section and the proposed-system section to determine existing attitudes before the introduction of proposed systems.

ANALYSIS OF QUESTIONNAIRE DATA

The problem of determining significant relations was complicated. Because of the large number of variables and relations present in the questionnaire, only selected interrelations were investigated. These included the following:

1. People in this region will be willing to ride an improved public transit system that incorporates public needs and desires.
2. There are certain human factors involved in transit preferences and attitudes that are more important than others.
3. There is a significant relation between the level of importance given to such human factors and the demographic characteristics of a person or group of persons.
4. There is a positive correlation between the importance a person places on any particular feature and the amount of money that person would be willing to invest in achieving its inclusion in a transit system.
5. Certain human factors or other design features are common to all transit systems and do not vary in kind and intensity among systems.
6. There is a positive correlation between a person's attitude toward public transit and his or her personal decision to accept and use a transit system.
7. There is a significant relation between the type of public transit system preferred and the person's socioeconomic or other demographic characteristic.
8. There is general apathy toward mass transit in the Dallas-Fort Worth metropolitan area.

To test these propositions, correlation analysis (largely in the form of contingency tables) and a standard factor analysis were used. These tests were selected because most of the propositions deal with significant relations between the variables at the first level. Simple contingency tables easily show such first-level relations. (A first-order relation assumes that all variables have the same weight, and thus determines the relations between one variable and the others, but not those between a combination of two or more variables and the others.)

Demographic Comparison

The survey was intended to be representative of the voting-age population in the Dallas-Fort Worth metropolitan area. The demographic characteristics of the sample are compared with those from actual census data in Table 1. The sample is slightly weighted towards the upper income end with a mean income of $12 500 (compared with an income of $12 000 for the census-data population). The mean number of persons in the household (3.42) for the sample population is almost identical to that (3.44) of the census-data population. The midcities area is overrepresented, and Dallas is underrepresented; however, growth patterns show the midcities area to be expanding more rapidly than either Dallas or Fort Worth, and the sample fits future population projections. Overall, the survey data are reasonably representative of the area under consideration.

In the study area, 88.3 percent of the working population actually drive to work in an automobile, and in the sample 90.1 percent drove to work. This indicates the minor current role of mass transportation at present. The survey respondents drive an average of 13.3 km (8.3 miles) to work and have an average of 2.17 persons having a driver's license/household and an average of 2.04 automobiles/household. Their replies to questions about other transportation characteristics are shown below.

Question	Response	Percentage of Total
Do you use any kind of public transportation	Yes	29.5
	No	70.5
Do you car pool to work	Yes	10.0
	No	90.0
Do you drive as part of your work	Yes	40.3
	No	59.7
How often do you use the bus	Daily	3.1
	Weekly	4.6
	Monthly	5.5
	Yearly	16.2
	Never	70.6

Essentially, the table above indicates that there is an automobile for every person with a driver's license and that only 13.2 percent of the population ride the bus (the only mass transit mode available in this metropolitan area) more than once a year.

Design Features

The 26 design features measured are listed in Table 2, which also includes the mean values of their importance ratings (on a scale of five for very important to one for very unimportant) and the mean values of the money investments for each.

To interpret the money aspect of the questionnaire, it is necessary to understand the instructions for that portion of it. The following is an excerpt from those instructions:

If you and your community were going to be actively developing public transportation for this urban area, please indicate just how you would be willing to invest a maximum of $2 000 000 toward this purpose.

If you feel that a particular feature is desirable and think that money should be invested for its development, we ask that you invest at least $100 000. To keep calculations easy, please invest in multiples of a 100 000 (for example, $0, $100 000, $200 000, $300 000, and so on). Remember that, because the total amount invested cannot be more than $2 000 000, you are not going to be able to invest in every design feature.

Table 1. Demographic characteristics.

Characteristic	Sample (percentage of total)	Actual (percentage of total)
Age		
<26 years	8.4	18.9
26 to 35 years	31.7	23.5
36 to 45 years	29.5	19.0
46 to 55 years	15.5	16.7
56 to 65 years	9.0	11.3
>65 years	5.9	10.6
Sex		
Male	46.5	47.3
Female	53.5	52.7
Marital status		
Single	13.2	21.3
Married	82.2	71.1
Other	4.6	7.6
Home		
Rent	20.9	37.8
Own	79.1	62.2
Family income		
$0 to $3 000	3.5	7.2
$3 000 to $6 000	8.0	13.3
$6 000 to $9 000	5.8	19.4
$9 000 to $12 000	9.6	20.5
$12 000 to $15 000	15.7	15.4
$15 000 to $25 000	32.9	18.4
>$25 000	24.0	5.7
Geographic location		
Fort Worth	20.9	21.9
Midcities	30.4	11.1
Dallas suburbs	20.3	19.5
Dallas	28.4	47.0

Table 3 shows that the respondents put great emphasis on a safe and efficient system. It also pinpoints some of the design features that are lacking in many mass transit systems, but important to the potential riding public. Features such as a nice and clean vehicle and system, fast routing information, weather protection, and station accessibility are all high on the importance list. On the other hand, the table shows that comparatively few seem to care about passenger privacy, house-to-destination routing, or socially attractive stations.

There are some interesting differences between the importance ratings and the money ratings. This was expected for the following reasons:

1. It was emphasized to the respondents that there need not be correlation between the two.
2. Some people may consider a feature very important, but think that its relative cost is low.
3. Some people may consider a feature very important, but not be willing to spend money on it.
4. Some people may consider a feature not too important and realize that its cost is very high.

Table 3 gives the average money allocated to each feature, based on the total completed questionnaires. There is a large variation, ranging from $214 900 for vehicle-accident safety to $16 100 for passengers helping with the establishment of rules. Several respondents allocated $800 000 (40 percent) or more of their money to the safety design feature. It seems logical that passengers helping establish the rules received a very low money allocation because time, rather than money, would be needed to fulfill this design feature.

Some variables have quite different relative positions on the money allocation scale, as compared to the importance scale. In particular, eight features were rated far higher on the importance scale than on the perceived

Table 2. Ratings for 26 design features.

Design Feature	Importance Rating		Money Investment ($)	
	Value	SD	Value	SD
Trip time (avg speed) is a primary design factor	3.851	0.979	119 200	109 200
Smooth ride (not bumpy, swaying, or jerky) is a necessity	3.833	0.965	94 100	83 200
Comfort inside the vehicle is important (such as comfortable seats, back rest, leg room, and elbow room)	3.662	0.931	91 300	88 000
Vehicle should be extremely safe from accident or collision	4.650	0.652	214 900	159 400
Vehicle should have considerable privacy for its passengers	2.261	1.114	16 700	47 600
Vehicle should have rest-room facilities	2.837	1.370	38 800	60 800
Vehicle must be modern and of the latest design	3.111	1.046	61 000	93 700
Design must easily accommodate the handicapped (be accessible to wheel chairs, crutches, and blind)	4.086	1.007	107 000	95 000
Vehicle must have built-in safety for passengers from hazards such as robbery and assault	3.985	1.065	105 300	119 400
Vehicle must be designed to deal with emergencies of passengers (such as accidents, seizures, and heart attacks)	3.640	1.156	82 800	92 800
Vehicle should be under automatic control (e.g., controlled by a computer)	2.741	1.281	66 100	105 900
Vehicle, its stations, and pathways must fit in with the natural surroundings	3.340	1.065	72 800	91 900
Passenger should have some physical control over the vehicle (e.g., a means to cause the vehicle to stop in case of emergencies and to stop at the passenger's station)	3.312	1.311	51 000	64 200
Vehicle stations should offer protection from the weather	4.246	0.836	92 900	77 800
Vehicle stations must provide safety for patrons from hazards such as robbery and assault	4.092	1.002	93 200	98 500
Vehicle stations should provide route information such as maps and time tables	4.040	1.052	47 600	54 900
Vehicle stations should be attractive socially (i.e., equipped with facilities such as neighborhood meeting rooms, television rooms, and game rooms)	1.880	1.091	17 200	39 400
Transportation system should have fast and easy-to-understand information on routing (e.g., where the vehicle stops and goes and when it arrives)	4.289	0.924	69 400	68 700
Vehicle should pick you up at your house and take you to your destination door	2.140	1.211	20 900	58 200
Vehicle should be extremely dependable and not break down because of mechanical failure	4.333	0.856	157 100	110 800
Vehicles should be extremely punctual	4.016	0.873	60 000	76 000
Passengers should help establish the rules and regulations for the riders	2.767	1.346	16 100	39 800
Vehicle system must be adaptable to changing needs (e.g., it should have the ability to change routes, directions, and number of vehicles easily)	3.658	1.045	78 900	83 200
Vehicles and system property should be kept nice and clean	4.294	0.759	82 100	65 200
If the station is not at my front door, then it should be easy to get to from my residence and from my place of work	4.179	0.937	89 300	116 500
Management of the transportation system must consider the customers, employees, and community when establishing policy and procedures	4.250	1.024	56 700	75 800

cost of providing them. These were (a) nice, clean vehicles and systems, (b) fast information on routing, (c) management considering the community, (d) protection from weather at stations, (e) station accessibility (easy to get to), (f) protection of station patrons from crime, (g) route information at stations, and (h) punctual vehicles. The importance of rest-room facilities, passengers helping establish the rules, and passenger control of the vehicle showed the greatest variability of response.

Transit Issues

The results of the third section of the questionnaire are given in Table 3. These questions dealt mainly with attitudes towards transit issues. It is noteworthy that the sample population definitely agreed that a public mass transportation system would be worthwhile, even considering its limitations and that they might be taxed for its upkeep, and would be willing to use a good system today (and even more so in 20 years). There was average agreement that tax money should be used to keep fares low. People generally desired a system that ran frequently (no more than 7 min waiting) and came close to their home (no more than 2.25 blocks away).

The data were analyzed to determine whether certain features or issues varied significantly with age, sex, or family income. The results found by using a 90 percent confidence limit ($\alpha = 0.10$) are given in Table 4.

Ratings of Transit Systems

The following instructions for rating the five major types of transit systems (improved bus, dual rail, other-tracked, dual mode, and demand operations) were given to the respondents for the fourth section of the questionnaire.

If you (and your community) were now to begin developing an urban public transportation system that would be completed within about 20 years, please indicate your preference for each of the different systems. Bear in mind that the different systems would cost different amounts and that your bidding represents the best offer you are willing to make for each system. For your benefit, a brief description of the basic features of each of the different systems has been provided on the following pages.

The urban public transportation systems listed below are distinctly different. Each, alone, could be developed to provide transportation throughout the city. In fact, citywide travel (rather than longer distance travel between different cities) is the object of each of these different types of transit systems.

1. Improved bus system: This system would involve a citywide system that used new types of buses with improved comfort, lowered door steps, spaces on board for the handicapped, and on-board information services. There would be improved bus stops and stations featuring

Table 3. Attitudes toward transit issues.

Attitude	Mean Response
Longest distance person should have to walk getting to and from vehicle station, blocks	2.25
Longest time person should have to wait for vehicle at station, min	7
Highest cost per kilometer customer should have to pay for transit, ¢	3 to 4
Public transportation systems should be privately (not publicly) owned	Slightly below avg agreement
If system is publicly owned, fares should be kept low by public taxes	Avg agreement
If system is publicly owned, it should be built by tax money (not bonds)	Below avg agreement
Should be first-class section with extra service for those who want it	Below avg agreement
I realize the limitations of a public transportation system and that I may be taxed for its upkeep, but think it will be worthwhile in this area in the next 20 years	Above avg agreement
I believe I would use a good public transportation system instead of an automobile if it were available today	Slightly above avg agreement
If I am living in this area 20 years from now, I think I would use a good public transportation system instead of an automobile	Above avg agreement

Table 4. Variables that varied significantly with age, sex, or income.

Variable	Varied Significantly With Age	Variable	Varied Significantly With Sex	Variable	Varied Significantly With Income
Importance of trip time	Younger find more important	Importance of vehicle accident safety	Females find more important	Importance of vehicle accident safety	Lower income find more important
Importance of passenger privacy	Middle aged find more important	Importance of restroom facilities	Females find more important	Importance of restroom facilities	Lower-middle income find more important
Importance of passenger safety from crime	Older find more important	Importance of accommodating the handicapped	Females find more important	Importance of accommodating the handicapped	Lower income find more important
Importance of automatic control over vehicle	Older find more important	Importance of passenger safety from crime	Females find more important	Importance of passenger safety from crime	Lower income find more important
Importance of looks of vehicles and stations	Middle aged find less important	Importance of handling passenger emergencies	Females find more important	Importance of handling passenger emergencies	Lower income find much more important
Importance of socially attractive stations	Middle aged and older find more important	Importance of weather protection at stations	Females find more important	Importance of passengers helping establish rules	Middle income find more important
Importance of on-time vehicles	Older find less important	Importance of protecting station patrons from crime	Females find more important	Walking distance to and from station	Lower-middle income willing to walk less
Importance of station accessibility	Younger find more important	Importance of route information at stations	Females find more important		
Agree public transportation should be privately owned	Younger disagree more	Importance of socially attractive stations	Females find more important		
Agree to use taxes to keep fares low	Middle aged disagree more	Importance of fast information on routing	Females find more important		
Agree system to be built by tax money	Middle aged disagree more	Importance of passengers helping establish rules	Females find more important		
Agree would use a good transportation system today	Middle aged disagree more	Importance of station accessibility	Females find more important		
		Walking distance to stations	Females find it should be less		
		Agree to use taxes to keep fares low	Males agree less		
		Agree system to be built by tax money	Males agree less		

protection from the weather, good lighting, bus route maps, and free telephone information about routing, schedules, and fares. Express busways would be provided along selected corridors in the city and give rapid or express service. The express buses would operate on exclusive rights-of-way or freeway lanes. The city-wide system would provide feeder service or connections to the express busways.

2. Dual-rail system: This system would consist of a combination of commuter trains, rail rapid transit on exclusive rights-of-way, and trolleys or streetcars on public streets. The characteristics of this system are that the vehicles use the standard two-rail track system, and it is generally not possible to have at-grade crossings on city streets, except for the trolleys or streetcars that provide local service. Construction can be elevated (overhead tracks) or subway (tunnel) as preferences and relative costs dictate. Improved equipment featuring more comfortable cars, on-board attendants, reserved seat sections, and automatic control is incorporated. Terminals or waiting stations would provide protection from the weather, good lighting, and route and schedule information.

3. Other-tracked system: This system would involve transit vehicles that operate with an exclusive track, such as monorail or channel. These special tracks may not be placed at grade with any street system, but must be constructed either over or under the existing street system. The vehicles might be small (5 to 10 passengers), be suspended on a cushion of air or ordinary pneumatic tires, and have electric, turbojet, or conventional gasoline engines. There would be express routes featuring larger vehicles (or several smaller ones connected into a train) that would have fewer stops and higher speeds. There would also be a distribution network of special tracks throughout the city with more frequent stops and lower average speeds. At least some of the vehicles might be automatically controlled. The terminals or station stops would feature the same modern conveniences available to the dual-rail system.

4. Dual-operation system: The dual-mode system consists of small vehicles (similar to automobiles) that are manually operated by the driver on parts of the city street system. There would, however, also be a network of major guideways in the city on which the vehicles could be operated automatically. The driver would drive the vehicle onto the guideway and manually indicate his or her destination, and the vehicle would be automatically operated down the guideway to the exit point. The driver would then operate the vehicle manually to reach the precise destination. Such a vehicle would have pneumatic tires for operation on the city streets and use either those wheels or possibly another set of a different type (rail, for example) for operation on the guideway. Power could be provided by batteries for operation while off the guideway. Electrical power from the guideway could be used to power the vehicle and to charge its batteries while it is operating on the guideway. In the initial development of such a system, a gasoline or diesel engine could be used, and buses (or larger transit vehicles) could operate on fixed routes off the guideway and be powered along the guideway for express bus service.

5. Demand-operation system: This system would involve various sizes of modern buses ranging from small minibuses carrying 5 to 10 passengers to large 50-passenger buses. The buses would pick up passengers at their trip origins while possibly picking up and discharging other passengers en route. The passengers would call the dispatcher and state where they were to be picked up and where they wished to go. The system is controlled by the dispatcher's computer and two-way radio to continuously direct the vehicles. Some deviation from the most direct route is allowed so that the buses may pick up and deliver other passengers. A maximum waiting time for pick up is given the prospective passenger by the computer when the call requesting service is made, and the passengers are assured that their trip will require no more than some stated maximum time. The computer determines the vehicle best situated to fulfill each request without violating any assured times or overloading any vehicle. Because of the nature of its operation, the system acts like a slow, shared taxi service and operates on the city streets.

Indicate your best offer by bidding an annual amount in millions of dollars for each system. Your bid can be as high as 10 million and as low as 0 million (if you think the system would not be worth anything). For example, if you think one system would be fairly good for your city's needs (and your trips as well), you might bid an annual 4 million or 5 million; if you think another system would be very worthwhile for you and your city, you might bid 9 million or 10 million.

The results of the bidding are given below.

System	Cost Range	Avg Annual Amount Bid ($)
Improved bus	Low	4 003 000
Dual rail	High	3 756 000
Other tracked	High	4 221 000
Dual operation	Medium	2 622 000
Demand operation	Medium low	3 235 000

The improved bus system was awarded much higher bids in relation to its costs. Significant amounts were bid for dual-rail and for other-tracked systems, but because of their much greater implementation costs, the improved bus system is considered the clear-cut public preference.

It is possible that one important factor was that people were simply willing to invest the most money in the systems they were most familiar with. Residents of this metropolitan area had seen very little of either dual-mode or demand-operation systems before viewing them during the presentation, and their bids probably reflected this lack of familiarity.

Following the bids on the five major types of systems was an opportunity to bid on any combination of two of the five. The instructions for responding to this question were

Combining your choice of two of the previously described systems, you may provide the desirable transit for your city. Indicate the two systems you prefer to combine.

A probable transit system of the future would be a combination system, not one exclusive type. The responses to this question are shown below.

Combination	Preference (percentage of responses)
Improved bus and demand operation	17.3
Improved bus and other tracked	16.9
Improved bus and dual rail	15.7
Other tracked and demand operation	11.4
Other tracked and dual mode	9.4
Dual rail and other tracked	7.2
Dual mode and demand operation	6.7
Improved bus and dual mode	5.9
Dual rail and demand operation	5.9
Dual rail and dual mode	3.4

An improved bus system combined with either a demand-operation, an other-tracked, or a dual-rail system accounted for more than 50 percent of the responses. This, again, may be partially explained by the fact that these were the most familiar combinations.

CONCLUSIONS

There is a need and a latent demand for a good mass transit system in northern Texas. A large segment of the public wants a system that will approach the convenience of the automobile. Other segments of the public need transit systems that can accommodate their particular set of travel needs. In designing new systems, some features must be given more attention than others. According to this study, punctuality, care for passengers, weather protection, route information, station accessibility, community consideration, and safety are wanted the most. Passenger privacy, socially attractive stations, and house-to-destination routing are far less important.

The population sample used in this study was representative of the Dallas-Fort Worth metropolitan area. Bias in answering the questionnaire was greatly reduced by the use of a prerecorded audiovisual program.

The findings of this research were confirmed through the use of a correlation analysis that used a 90 percent confidence level. The following propositions were found to be true:

1. People in this region will be willing to ride an improved public transit system that incorporates public needs and desires.
2. Certain human factors involved in transit preferences and attitudes are more important than others.
3. There is a significant relation between the level of importance given to such human factors and the demographic characteristics of a person or group of persons.
4. There is positive correlation between the importance a person places on any particular factor and the amount of money that person would be willing to invest in achieving the inclusion of the factor in a transit system.
5. Certain human factors or other design features are common to all transit systems and do not vary in kind and intensity among systems.
6. There is positive correlation between a person's attitude toward public transit and his or her personal decision to accept and use a transit system.

The following proposition was found to be false: There is a significant relation between the type of public transit system preferred and the person's socioeconomic or other demographic characteristic.

The following proposition was found to be probably true: There is general apathy toward mass transit in the Dallas-Fort Worth metropolitan area.

Thus, the planner might realize that, no matter which system is implemented, it will be equally attractive for use by most segments of the population. He or she does not have to worry about implementing one system for one portion of the community and another for a different portion. This argument could be used to overcome political obstacles when extending the transportation system across city and county lines.

There will be an increasing need for mass transportation in the Dallas-Fort Worth metropolitan area. At present, people are unwilling to leave their automobiles, but they generally see the long-term necessity for transit because of pollution, overcrowding, and energy problems. Although people will not be lured from their automobiles to transit by choice, they seem to feel that they may be required to use transit more in the future. The results of this study could be used to determine the most acceptable forms of transit for the future.

There was a slight preference for a tracked-vehicle system or an improved bus system, with a dual-rail system ranking third, as indicated by the money allocations for the five different systems. The costs of the bus system would be significantly less than those of the other systems (for the total urban area system required), and the public's willingness to allocate money for such a system makes it clearly the cost-effective choice.

The proposition that apathy exists towards mass transit is probably true. While no questions dealt directly with this issue and the analysis of the questionnaires cannot prove the hypothesis, the results indicated that it is true. This indicates the need for a publicity campaign to inform the public of the availability of transit now and the important issues that lie ahead for transportation in the urban areas of the future.

Publication of this paper sponsored by Group 1—Transportation Systems Planning and Administration.

**Deceased.*