CONSUMER PREFERENCES FOR AUTOMATED PUBLIC TRANSPORTATION SYSTEMS

Don P. Costantino and Thomas F. Golob, General Motors Research Laboratories; and Peter R. Stopher, Northwestern University

This paper investigates the attitudes of a cross section of residents of a metropolitan area toward 3 automated transportation systems. Respondents to a home interview survey evaluated their satisfaction with each system according to 12 attributes such as travel time, comfort, automatic control, and privacy of the vehicle. Respondents also evaluated their overall satisfaction for each system and projected their possible use of these systems. In the first phase of the analysis, the interrelations among the respondents' perceptions of the system attributes are examined. Five latent factors are determined through factor analysis to describe the attribute satisfaction ratings: level of service, comfort and privacy, degree of automatic control, out-of-pocket cost, and options and amenities. These factors are consistent for both work and shopping trips. In the second phase, reported overall satisfaction for work and shopping trips is explained in terms of the attributes through the use of linear additive models. Level of service is a significant descriptor of overall satisfaction for work trips; comfort and privacy and options and amenities are added descriptors for shopping travel. The final phase of the analysis uses a nonlinear estimation technique to explain the allocation of work and shopping trips by the respondent. This technique revealed, as did the linear additive model, that satisfaction with a mode is dependent on trip purpose.

•KNOWLEDGE of the perceptions displayed by individuals toward alternative designs and operating strategies of existing and proposed transportation systems can be important to the successful planning, implementation, and operation of the systems. This study is an attempt to advance information on peoples' attitudes, specifically within the realm of models for automated urban public transportation systems.

The models developed here are concerned with a better understanding of how peoples' attitudes with respect to certain attributes (i.e., waiting time, comfort, and fare) affect their perceived overall satisfaction for 3 proposed automated transportation systems. The knowledge of those attributes that influence the attitudes of an individual toward a particular transportation mode are desirable inputs to both the design of system components and the planning of specific applications. The primary purpose of this study is not to develop a demand model per se for automated transportation systems but to construct models that will identify those attributes perceived by the respondents as important for determining their satisfaction for particular modes.

The 3 automated urban public transportation modes and the guideways on which they operate are described in the next section. The questionnaire and subsequent data base are also presented in that section, and the 12 attributes used to describe each mode are detailed. The results of the factor analyses of the interrelations among peoples' perceptions of these attributes are presented in the following section. Linear regression models are developed in a third section to explain the overall satisfaction rating given each mode by the respondents. Perceived differences in overall satisfaction between modes are also examined in that section. In the final section, the allocation of trips among the modes is explained in terms of the attribute ratings through the use of a binary-choice logit model.

DATA BASE

The sample of observations for this study came from a survey assessing attitudes for hypothetical new urban transportation modes designed to serve the arterial transportation needs of a large metropolitan area. The survey is detailed by Dobson and Kehoe (3). Three transportation modes—dual-mode transit (DMT), people mover (PM), and personal rapid transit (PRT) are the subject of the research reported here. The personal rapid transit mode involves a small vehicle that individuals can use on a private basis. It remains on the guideway at all times and holds as many as 4 people. PRT vehicles are designed to provide comfort, privacy, and to a large extent the flexibility of the private automobile. They are routed from origin to destination with no stops, and passengers must board and disembark at transit stations. The people mover is a vehicle designed to accommodate approximately 25 passengers. It resembles a bus, but operates exclusively under automatic control on a guideway. PM operates on a regular schedule and stops to load and discharge passengers along the route. Dual-mode transit operates under driver control on regular city streets or by automatic control along the guideway. The dual-mode transit vehicle holds about 12 people and resembles a small bus in appearance. In manual mode, the DMT vehicle operates as a demand-responsive bus. Thus, in order to use DMT, a person places a call to a dispatcher and requests a DMT vehicle. The vehicle operates along regular streets picking up and discharging passengers and then enters a guideway, where it is controlled automatically without a driver.

Specifically the survey provided respondent evaluation for the 3 automated transportation modes. Socioeconomic and demographic characteristics of the respondents were also collected. The survey was implemented in the form of an in-home interview of approximately 1-hour duration. The final sample consisted of approximately 500 respondents systematically sampled from the population of the Detroit Standard Metropolitan Statistical Area (as defined in the 1970 Census of Population).

The interviewer first ascertained whether the pre-selected respondent made 1 or more work trips per week. If so, a work trip questionnaire was presented. Otherwise, a shopping trip questionnaire was administered. After receiving an explanation of the design and operation of each mode through the use of diagrams and scenarios, respondents were asked to give a satisfaction rating of 1 to 7 for that mode on each of 12 attributes. These attributes are shown in Figure 1. In addition, respondents were requested to evaluate their overall satisfaction with each mode. The respondents were also asked to allocate 10 hypothetical trips among the public transportation modes of the Metro Guideway and their present means of transportation. Figure 2 shows the question that requested the allocation of trips. To keep the interview and questionnaire within the attention span of the respondent, each questionnaire was directed to only 2 of the 3 modes. All respondents were asked to answer questions relating to DMT, but only about either PM or PRT, not both. This limited the sample sizes for much of the analyses reported here to approximately 250 observations (one-half of the total survey sample of 500). Additional data items from this survey have also been analyzed (4).

SATISFACTION RELATIONS

Factor analyses were performed on the data matrices of satisfaction ratings for the 12 system attributes shown in Figure 1. Analyses were conducted separately for each of the 3 automated modes and for each of the 2 travel purposes of work and shop. The objectives of these 6 factor analyses were twofold. The first objective was to identify the latent or underlying dimensions (i.e., linear combinations of the original attributes) that best describe the interrelations between satisfaction ratings. The second objective was to select a relatively independent subset of the original 12 attributes for use in models designed to explain respondents' overall satisfactions and modal choices (10).

From an examination of the variance accounted for by successive factors, it was decided to retain 5 factors for interpretation in each of the 6 analyses. Two factor analyses were performed for each mode: one for a work trip and the other for a shopping trip. Selection of the number of latent factors was accomplished through subjective evaluations of a number of statistical criteria (7).

Figure 1. Response form for judgments on dual-mode transit.

I think I would be this satisfied with this feature if I made my usual trip in a dual mode transit vehicle:	Extremely Satisfied	Very Satisfied	Somewhat Satisfied	Neither Satisfied Nor Dissatisfied	Somewhat Dissatisfied	Very Dissatisfied	Extremely Dissatisfied	
The ability I think I would have to get where I want to go on time	7	6	5	4	3	2	1	9
The safety I think I would have from harm by others and from vehicle accidents	7	6	5	4	3	2	1	10
The room I think there would be for strollers and wheel chairs	7	6	5	4	3	2	1	11
The ability I think I would have to get to many places in the Detroit area using the guideway	7	6	5	4	3	2	1	12
The ability I think I would have to buy refreshments and news-papers at the transit stations	7	6	5	4	3	2	1	13
The amount of control I think I would have of the temperature in the vehicle	7	6	5	4	3	2	1	14
The time I think I would have to wait for the vehicle	7	6	5	4	3	2	1	15
The time I think it would take to get to where I'm going	7	6	5	4	3	2	1	16
The fare I think I would have to pay	7	6	5	4	3	2	1	17
How comfortable and quiet I think the ride would be	7	6	5	4	3	2	1	18
The automatic control feature of the vehicle	7	6	5	4	3	2	1	19
The amount of privacy I think would have in the vehicle	7	6	5	4	3	2	1	20
Over-all, taking everything into consideration, how satisfied do you think you would be if you make your usual trip in a dual mode transit vehicle?	7	6	5	4	3	2	1	21

Figure 2. Instructions read to respondent for mode-choice task.

22. Still thinking about the future, assume that you could choose among the types of transportation we have been talking about. . . (LAY OUT BLUE CARD FOR EACH OF THE FOLLOWING). . .

Card #4
(Dup 1-8)
2 9

The type of transportation I use now, but with longer travel times

Dual mode transit

Personal rapid transit

Here are 10 cards. Each one of these cards represents one of your usual trips (to work/to go shopping). Please divide up these 10 trips the way you think you would make them by each of these types of transportation (POINT TO BLUE CARDS). You may take all of the trips using the same type of transportation or you may take some trips with one type and some with other types of transportation. Just show me which types of transportation you think you might use for 10 trips if you could choose any of these.

	Number of Trips
Present type	______
Dual mode transit	______
Personal rapid transit	______
Total Trips:	10

10			11
12			13
14	–	–	15
16			17

Tables 1, 2, and 3 give the rotated factor loadings matrices for the 6 analyses. The factor loadings are correlation coefficients that relate each original attribute to each latent factor. The absolute value of each loading is thus proportional to the degree of correspondence between the factor and the attribute. Only loadings with absolute value greater than 0.50 are given in the tables. The tables also give the commonalities for each variable. These commonalities are coefficients of determination, R^2, expressing the proportion of variance of each variable that is explained by the latent factors taken together. The average of the commonalities for each of the 6 analyses ranged between 0.75 for DMT work trips to 0.82 for PM work trips. Thus, in all 6 cases a linear combination of 5 latent factors accounted for a large proportion of the variance in the original 12 attribute ratings.

Most of the factors are readily interpretable and are consistent across the 6 analyses. Consequently, a common set of 5 factors was chosen to represent the interrelations in the respondents' satisfaction ratings. Thus, the structure of perceptions toward the attributes for the 3 automated modes is relatively similar for both trip purposes. The 5 factors (and attributes chosen to represent each) are then as follows: (a) level of service (waiting time for vehicle), (b) comfort and privacy (comfort and quietness of ride/amount of privacy in vehicle), (c) degree of automatic control (automatic control feature of vehicle), (d) out-of-pocket cost (fare), and (e) options and amenities (temperature control in vehicle).

COGNITIVE STRUCTURE OF ATTITUDES

In theories relating attitudes to behavior, an important role is played by an individual's overall conscious, subjective feeling toward an object or set of objects. The concept of such an overall feeling, or overall satisfaction as it is measured in the present survey, is thoroughly developed in the psychological literature. The research reported in this section deals with the testing of specific hypotheses that relate individuals' overall satisfactions with a transportation mode to their beliefs about the attributes that define the mode. Kotler (15) defined such descriptive attributes for market research purposes as "a bundle of physical, service and symbolic particulars expected to yield satisfaction or benefits to the buyer." This division into attributes, moreover, provides a direct linkage to the new economic approaches to consumer theory (16) in which the objects of utility (benefit to the individual) are specified as the properties of the consumer good, as opposed to the good itself.

A multiple regression approach for explaining overall satisfaction in terms of separate attribute satisfaction scores has been introduced (22). This model is similar to the cognitive summation theories advanced in the field of psychology (4, 20). However, a number of issues involving conceptualization and measurement differentiate various versions of these psychological theories employed in market research. A recent paper (29) summarizes many of these issues. The form of the attitude hypotheses tested here is

$$A_j \cong \sum_{k=1}^{h} B_{jk}S_{jk} + \text{constant}$$

where

A_j = overall satisfaction associated with mode j,
S_{jk} = satisfaction associated with attribute k for mode j, and
B_{jk} = regression coefficient of the kth attribute for mode j.

Linear regression models were calculated for each mode. The attributes chosen to be used in the regression analyses were obtained from the factor analyses in the previous section of the paper. Responses to these satisfactions were solicited on a 1 to 7 semantic differential scale (1, 5, 24, 27).

The results of the regressions of overall satisfaction on the 5 attributes representing the latent factors are given in Tables 4 and 5. b refers to the actual regression

Table 1. Rotated factor loadings for dual-mode transit satisfactions.

	Work Trips						Shopping Trips					
	Factor						Factor					
Variable	1	2	3	4	5	Common-alities	1	2	3	4	5	Common-alities
Waiting time			0.85			0.84	0.76					0.77
Travel time			0.81			0.84	0.75					0.78
Fare		-0.68				0.64	0.87					0.79
Comfort	0.65					0.73		-0.77				0.75
Automatic control					-0.84	0.86					0.89	0.89
Amount of privacy	0.76					0.71		-0.65				0.68
Arriving on time					-0.60	0.66		-0.61				0.80
Safe from harm					-0.79	0.74						0.68
Room for strollers	0.60					0.80		-0.59				0.70
Able to get places				0.82		0.85				-0.78		0.81
Refreshments	0.78					0.68			0.90			0.84
Temperature control	0.76					0.65			0.55			0.67
Proportion of variance	0.23	0.18	0.17	0.10	0.09	75.00	0.22	0.19	0.13	0.13	0.10	76.60

Table 2. Rotated factor loadings for people-mover satisfactions.

	Work Trips						Shopping Trips					
	Factor						Factor					
Variable	1	2	3	4	5	Common-alities	1	2	3	4	5	Common-alities
Waiting time	0.62		0.55			0.78	-0.81					0.84
Travel time			0.73			0.85	-0.81					0.88
Fare			0.84			0.85					0.84	0.92
Comfort				0.71		0.86	-0.60					0.72
Automatic control					0.85	0.91				0.90		0.90
Amount of privacy				0.83		0.87		0.72				0.74
Arriving on time	0.82					0.85	-0.72					0.75
Safe from harm	0.65					0.78	-0.78					0.79
Room for strollers		0.83				0.77		0.55				0.73
Able to get places	0.78					0.78	-0.67					0.73
Refreshments		0.78				0.77		0.86				0.76
Temperature control		-0.71				0.74			0.73			0.83
Proportion of variance	0.22	0.19	0.17	0.14	0.11	81.90	0.31	0.17	0.12	0.10	0.10	80.00

Table 3. Rotated factor loadings for personal rapid transit satisfactions.

	Work Trips						Shopping Trips					
	Factor						Factor					
Variable	1	2	3	4	5	Common-alities	1	2	3	4	5	Common-alities
Waiting time	0.89					0.85	-0.80					0.76
Travel time	0.87					0.83	-0.71					0.72
Fare					-0.82	0.91	-0.84					0.76
Comfort	0.53	0.52				0.64		0.59				0.74
Automatic control				0.92		0.92		0.76				0.74
Amount of privacy		0.86				0.80		0.76				0.81
Arriving on time	0.89					0.84			0.69			0.79
Safe from harm	0.69					0.66		0.64				0.61
Room for strollers			0.86			0.82					0.86	0.90
Able to get places	0.69					0.79			0.67			0.71
Refreshments		0.60	0.62			0.87				0.77		0.84
Temperature control		0.76				0.74			0.64	0.60		0.81
Proportion of variance	0.33	0.18	0.12	0.10	0.08	80.60	0.21	0.19	0.14	0.13	0.10	76.80

Table 4. Results of regression analysis.

Mode	Variable	Work b	Work t	Work Beta	Shop b	Shop t	Shop Beta
DMT	Wait time	0.32	5.7	0.34	0.36	6.3	0.34
	Fare	0.22	4.0	0.27	–	–	–
	Privacy	–	–	–	0.12	2.3	0.13
	Automatic control	0.14	3.2	0.19	0.16	4.0	0.21
	Temperature control	–	–	–	0.14	2.8	0.15
PM	Wait time	0.24	2.4	0.24	0.42	5.3	0.39
	Comfort	0.27	2.8	0.26	–	–	–
	Privacy	–	–	–	0.27	3.9	0.27
	Automatic control	0.25	3.1	0.29	0.16	2.2	0.17
	Temperature control	–	–	–	–	–	–
PRT	Wait time	0.50	5.9	0.50	–	–	–
	Fare	–	–	–	0.27	4.5	0.30
	Comfort	–	–	–	0.25	3.0	0.21
	Privacy	0.17	2.3	0.19	–	–	–
	Automatic control	–	–	–	0.27	5.2	0.34
	Temperature control	–	–	–	0.15	2.6	0.16
DMT-PRT	Wait time	0.48	5.6	0.49	0.24	2.8	0.24
	Fare	–	–	–	0.20	2.7	0.22
	Automatic control	–	–	–	0.21	2.8	0.22
	Arriving on time	0.26	3.0	0.27	–	–	–
	Temperature control	–	–	–	0.20	2.5	0.19
DMT-PM	Wait time	0.29	3.5	0.32	0.39	4.8	0.24
	Privacy	–	–	–	0.29	3.8	0.29
	Automatic control	–	–	–	0.16	2.3	0.16
	Room for strollers	–	–	–	0.15	2.1	0.16
	Temperature control	0.32	3.0	0.28	–	–	–

Table 5. Statistical tests of regression analysis.

Mode and Purpose	Constant	R	R^2	F-test	Number
DMT					
Work	1.74	0.60	0.36	36.65	194
Shop	1.25	0.64	0.41	46.83	280
PM					
Work	1.21	0.58	0.34	19.83	96
Shop	0.78	0.67	0.45	39.77	149
PRT					
Work	1.65	0.56	0.32	22.60	98
Shop	0.20	0.73	0.54	29.33	131
DMT-PRT					
Work	0.35	0.46	0.21	12.82	96
Shop	0.27	0.63	0.40	23.29	149
DMT-PM					
Work	-0.11	0.56	0.31	21.26	98
Shop	-0.11	0.62	0.39	20.33	131

coefficient, and t is a statistical test to determine whether the regression coefficient differs significantly from zero. The set of explanatory attributes for each regression model reported in the table is limited to that set of independent variables that are significant at the 0.05 level or higher. Beta is a measure of the relative contribution the variable makes toward accounting for the variation, or R^2. The F-test is a statistical test on the regression equation designed to accept or reject the null hypotheses. Disaggregation by trip purpose was incorporated into the analyses, for it was postulated that a person's perceived attitude toward a particular mode would differ according to the function of the trip. In this study the choice of trip purpose is a binary one: work or shop.

The attribute exhibiting the greatest importance in explaining overall satisfactions for both work and shopping trip purposes on DMT was waiting time. The concept of door-to-door service probably resulted in the respondents' attaching a high level of importance to the attribute that measured the unique in-home wait at one end of a trip. The only other variable found to be important in both trip purposes on DMT was automatic control. DMT is the only one of the 3 modes that is not fully automated since the demand-responsive portion of the DMT trip is operated manually. Consequently, one possible reason for the level of importance given automatic control is that respondents tended to feel uncomfortable with a totally automated system and preferred a mode that they can observe being operated for a portion of the trip. This high level of importance could also be traced to the flexible routing and scheduling of the DMT system, for respondents might have equated the level of automatic control associated with DMT to the desirable door-to-door service provided by such routing and scheduling. The question of how a respondent perceived automatic control calls for further research into perceptions toward this attribute-system relation. The only other variables that entered significantly into the DMT model were fare for the work trip and privacy and temperature control for the shopping trip. These results suggest that the work trip purpose is indeed perceived as being different from the shopping trip purpose for DMT. The significant attributes in the work trip were those concerned with level of service and cost. However, for the shopping trip, those variables representing additional conveniences, such as privacy and temperature control, were highly important.

The perceptual differences between the trip purposes for people movers were less evident. As with DMT, a high level of importance was attached to waiting time for both trip purposes. Comfort was perceived as important for the work trip and privacy for the shopping trip. Both privacy and comfort, however, are measures of the same factor. There is a slight distinction between the 2 variables, and in the case of PM comfort is perceived as more important for the work trip and privacy for the shopping trip. Automatic control entered the PM model for work trips because it was perceived as a service variable, and temperature control was included for shopping trips. For people movers, respondents' perceived differences between trip purposes were not extreme. However, the somewhat different variables for each trip purpose suggests that amenities such as temperature control are perceived as more important for the shopping trip.

In the case of personal rapid transit, the 2 trip purposes were considerably different. The only explanatory variables included in the work trip were waiting time and privacy, where the latter attribute accentuates the small vehicle, personal destination control of the PRT. The lack of importance with regard to automatic control is somewhat perplexing. For the PRT shopping trip, all variables were significant with the exception of waiting time. This was the only instance in which the waiting time attribute was not an important explanatory variable.

A large difference in the percentage of variance explained by the 2 PRT trip purpose models was also evident. A conclusion is that the work trip model was underspecified. This would suggest that variables of importance for the perceived PRT work trip are not included in the model, and further research is needed to uncover these variables.

The results suggest that the respondents perceived work and shopping trips differently, regardless of mode. A high level of importance was allocated to the level-of-service variable for all work trips, while other variables such as temperature control and privacy or comfort were consistently significant for shopping trips. The implication is that the amenities plus convenience might play an important role in designing systems that will attract shoppers; such amenities are not so significant as level-of-service performance for the work trip.

A second set of attitudinal hypotheses tested dealt with the respondents' perceived differences between modes. It was postulated that

$$\Delta OS_{ij} \cong \sum_{k=1}^{n} B_{ij,k}(\Delta S_{ij,k}) + \text{constant}$$

where

ΔOS_{ij} = difference in overall satisfaction between mode i and mode j,
$S_{ij,k}$ = difference between satisfaction rating given attribute k for mode j for each individual, and
$B_{ij,k}$ = regression coefficient for difference in satisfaction rating between mode i and mode j for attribute k.

These multiple regression models attempt to explain the difference perceived by the respondents in overall satisfaction between pairs of modes: DMT-PRT and DMT-PM. The independent variables consituted the differences between the scaled ratings assigned to each attribute by the respondents for DMT-PRT or DMT-PM, while the dependent variable served as the difference in overall satisfaction. The results of these regressions are also given in in Tables 4 and 5. As before, only those variables that revealed significance at the 0.05 level or higher were included in the final model.

The 2 work trip variables that the respondents perceived to differentiate between DMT and PM were waiting time and temperature control. The waiting time might be explained by the advantage in service that DMT has over PM: DMT provides door-to-door service. For PM, the rider must have a means of transporting himself to a station to board the vehicle. However, the DMT-PM work model is less fully specified and, therefore, substantial conclusions on perceived differences between these modes cannot be drawn.

Waiting time, comfort, and automatic control were all perceived as important attributes for differentiating between DMT and PM for shopping trips. These attributes can be associated with physical differences in waiting time and automatic control between the 2 modes and also with a physical comfort difference. The comfort difference is more subjective, however, probably ranging from the nature of the at-home pickup (via station pickup) to vehicle design and operation variances. Another attribute that affected the perceived difference between DMT and PM was room for strollers. For PM, as opposed to DMT, a person with a stroller still faces the problem of getting to and from the station.

A much larger multiple correlation coefficient was associated with the shopping trip when compared to the work trip. Waiting time was the only variable common to both trip purposes. Amenities and convenience and room for strollers entered to a much larger extent in the shopping model.

The final regression model expressed the overall satisfaction difference between DMT and PRT. By releasing the constraints of the 5 latent factor variables, the work trip model had 2 significant variables: waiting time and arriving on time. As with the DMT-PM model, the DMT-PRT work model was underspecified, and additional attributes beyond the 5 latent-factor ones were necessary to explain the perceived difference between DMT and PRT for the work trip. Arriving on time was found to be an important differentiating variable.

The DMT-PRT shopping trip model included waiting time, fare, automatic control and temperature control, and arriving on time. These 5 variables are perceived to differentiate between DMT and PRT. These attributes differentiate between the 2 modes on the basis of their physical characteristics. PRT is a totally automated personal vehicle, and amenities and on-time performance can be considered prominent features of a PRT system.

As with the DMT-PM model, there were significant differences between the 2 trip purposes in the DMT-PRT models. Only level of service and arriving on time were significant in the work model, but other variables such as temperature control and automatic control were perceived as having the differentiating effect between DMT and PRT in the shopping model. This relation is similar to the DMT-PM model and to the overall satisfaction models.

CHOICE MODELS

For the purposes of application to transportation planning, it is important to attempt to establish a link between individuals' affect and their likely use of a new mode of travel. By this means, the information obtained from the psychological measurements, discussed thus far in this paper, may be used in determining the likely acceptability and use of a new mode of travel. This would add a much needed tool to those currently available to the transportation planner and would also provide a procedure to assist in system design.

Such a tool will require a 2-stage process. First, since the travel mode in question is not likely to exist as a fully operational system, data can be gathered only on the behavioral intentions of people in relation to use of the system. This behavioral intention should be related to the measurement of satisfactions with various attributes of the system. Second, actual behavior would be related to behavioral intention. This second step would need to be carried out after one or more systems were introduced. This research collected information on behavioral intention, and this part of the research is concerned with attempting to relate behavioral intention to measured satisfactions with system attributes.

The intention of the analysis reported in this section was to determine the extent to which the respondents' allocation of trips between alternative modes could be explained by differences in satisfaction ratings revealed for various attributes of the 2 modes. The hypothesis was that the relation between choices and differential satisfactions of attributes would be nonlinear in a form identical to recent disaggregate mode-choice models (13, 19, 25, 28). This form is the multiple logistic function: a sigmoid curve relation between probability of choice and a linear function of satisfaction differences. (Linear models were tried but were abandoned after interpretations of the results showed that a significant nonlinear effect was present in each case as hypothesized.)

The measure of behavioral intention employed was an allocation of 10 hypothetical trips among the respondents' present mode of travel, dual-mode transit, and either people mover or personal rapid transit (Fig. 2). Although the trip allocations included the respondent's existing mode, satisfactions for the existing mode on the 12 attributes were not obtained. Hence, the choice models were concerned with the allocation of trips only between DMT and either PM or PRT. Each trip allocation was considered to represent 1 observed choice. Thus, if the probability in the choice model is defined as the probability of choosing DMT, a respondent who allocated 3 trips to DMT and 5 trips to PRT (and 2 trips to his or her existing mode) would be considered as having been observed on 8 occasions, yielding 3 observations with a choice value of 1 and 5 observations with a choice value of 0 (the 2 trips to the existing mode being omitted).

Using this form for the dependent variable, we sought 4 binary-choice models: DMT versus PRT and DMT versus PM for each of work and shopping trip purposes. The 5 attributes identified by the factor analysis were used as explanatory variables to construct 4 models (Tables 6 and 7).

Some variables in each of these models are not significant, suggesting that the models constructed are not optimal. (Since a stepwise procedure is not available for logit models, a systematic exclusion of nonsignificant variables is not readily achievable.) However, all models are significant at the 95 percent confidence level (the 95 percent chi-square distribution table value with 5 degrees of freedom is 11.07). The pseudo-R^2 measure has a maximum value that is different for each model and is generally substantially less than 1.0. (The departure of the maximum value of the correlation coefficient indexes from 1.0 is a measure of the degree of nonlinearity in the model as well as the goodness of fit.) Therefore, the pseudo-R^2 serves only as a comparative measure between models.

Table 6. Results of logit analysis.

	Work				Shop			
	DMT-PRT		DMT-PM		DMT-PRT		DMT-PM	
Variable	Coefficient	t-score	Coefficient	t-score	Coefficient	t-score	Coefficient	t-score
Five set								
Wait time	0.276	3.67	0.356	4.58	0.111	1.68	0.134	2.16
Fare	0.243	-3.40	0.052	0.66	0.251	3.69	0.157	-2.76
Privacy	0.059	0.87	0.088	-1.11	0.195	3.02	0.082	-1.14
Automatic control	0.060	0.99	0.057	-0.83	-0.120	-1.81	0.230	4.56
Temperature control	-0.151	-1.93	0.171	2.78	0.363	4.56	0.136	2.22
Final set								
Wait time	–	–	–	–	–	–	-0.181	-2.36
Travel time	0.343	3.94	0.293	3.94	–	–	0.439	4.64
Fare	0.344	-4.34	–	–	0.301	4.90	-0.151	-2.59
Automatic control	–	–	–	–	-0.105	-1.61	0.285	5.45
Privacy	–	–	–	–	0.175	2.77	-0.245	-3.10
On time	–	–	–	–	0.244	2.96	–	–
Strollers	–	–	–	–	–	–	0.139	2.54
Temperature control	-0.182	-2.37	–	–	0.385	4.86	–	–
Retirement	–	–	0.300	3.63	–	–	–	–
Safety	0.244	3.18	–	–	–	–	–	–
Able to get places	0.216	2.31	–	–	–	–	–	–

Table 7. Statistical tests of logit analysis.

Mode and Purpose	Constant Coefficient	Constant t-score	Pseudo-R^2 Coefficient	Chi Square Coefficient	Chi Square t-score	Number
DMT-PRT						
Work	0.521	5.68	0.042	19.73	5	98
Shop	0.408	4.94	0.134	87.84	5	131
DMT-PM						
Work	0.937	9.63	0.097	41.36	5	96
Shop	0.675	9.08	0.056	41.34	5	149
Final						
DMT-PRT						
Work	0.484	5.30	0.109	52.10	5	98
Shop	0.390	4.76	0.130	84.97	4	131
DMT-PM						
Work	0.945	9.81	0.116	49.77	2	96
Shop	0.687	9.12	0.121	91.59	7	149

Given the poor statistical performance of most of these models, constraints on the variable set were relaxed, and more significant models were sought through the inclusion of additional attributes. These are also shown in Tables 6 and 7.

These models show a high degree of heterogeneity, with a range of 2 through 7 significant variables. In terms of both inclusion of variables and signs of coefficients, little consistency is found among the models. For shopping trips, DMT is superior to PRT for fare, privacy, and temperature control, but inferior for automatic control; for work trips, DMT is superior to PRT for travel time, safety from harm, and ability to get places, but inferior for fare and temperature control. Clearly, the modes are perceived differently for different purposes.

Similarly, for work trips, only travel time and refreshments are significant for comparing DMT and PM, both apparently favoring DMT; for shopping trips, 7 variables are needed to compare DMT and PM, and all but fare, waiting time, and privacy favor DMT. Of the signs on the attributes in this model, only the negative sign for privacy appears to be inconsistent with expectations and may be due to intercorrelations among the explanatory variables. This is a topic for further research, for the effects of interrelations among variables in logit models have largely remained uninvestigated.

As with the linear models of overall satisfaction differences, automatic control is a consistent variable of importance in the shopping trip models, but does not appear in the work trip models. Unlike the linear models, waiting time appears to have little importance in these models, entering significantly in only one model. On the other hand, fare and travel time, both of which were of little or no significance in the overall satisfaction models, appear in 3 of the 4 choice models. Room for strollers appears as a significant variable for the DMT-PM choice for shopping trips, as it did for the overall satisfaction differences for the same trips.

All of the choice models show evidence of considerable underspecification, which is demonstrated by the size and significance of the constant term. In the logit formulation, the linear function (the function specified in Tables 6 and 7) must be 0 for indifference between 2 alternatives. When satisfactions with all significant attributes are equal for each model pair, a significant constant yet remains, giving a non-0 value to the linear function. For no difference in satisfactions in each of the 4 models, the probability of choosing DMT will be 0.619, 0.598, 0.722, and 0.667 respectively for the 4 models. Hence, it may be concluded that additional variables are needed in the models to specify more fully the behavioral intention of the respondents and to remove the bias indicated by the significant constant terms.

In conclusion, it may be stated that mode choices can be explained by an examination of differences in satisfactions with various attributes. However, there is considerable scope for further development of such models. Such developments would include improvement of the specification of the models, estimation of more useful statistical measures of the models (e.g., the correlation ratio and associated F-statistic), and investigation of the effect of demographic characteristics on the choices (25).

CONCLUSION

This paper has presented a series of models concerned with the effect attitudes have on explaining overall satisfaction with a particular mode, perceived differences between modes, and trip allocation among modes. It was hypothesized that an understanding of the preferences and perceptions of individuals toward proposed forms of urban transportation is important to the successful implementation and operation of those systems. This study examined the respondents' perceptions toward 3 proposed automated systems: personal rapid transit, people movers, and dual-mode transit.

Interrelation among respondents' satisfactions of the attributes yielded 5 latent cognitive factors when factor analysis was applied: level of service, comfort and privacy, degree of automatic control, out-of-pocket cost, and options and amenities. The factors were stable for both shopping and work trips.

The findings developed from the regression models explaining overall satisfaction with the modes suggested that people perceive trip purposes differently. For the work trip associated with each mode, the level-of-service variable—waiting time—was perceived to be highly important; for the shopping trip, amenities and added conveniences—temperature control and comfort—were more important. The work trips were not so fully specified as the shopping trips, suggesting that additional attributes be incorporated in the work trip models. The success of the models confirms the validity of recent disaggregate extensions of psychological attitude summation theories to the explanation of consumer behavior.

The extent to which the allocation of trips by the respondent could be explained by differences in satisfactions with various attributes was then determined. A binary-choice logit model was used. As with the regression model, it was found that people perceive trip purposes differently. However, a higher degree of heterogeneity was evident in the choice models than in the satisfaction models. The results of the logit analysis suggest that the attitudinal information collected for the attributes included in the study is insufficient by itself for explaining allocation of trips among modes. The large size and significance of the constant term further imply that the models are underspecified.

These models show that peoples' satisfactions with respect to certain attributes have an effect on explaining overall satisfaction, satisfaction differences between modes, and allocation of trips among modes. However, stratification by socioeconomic and demographic variables, a more thorough process of attribute selection, and a clearer understanding of how the respondents perceived each attribute (e.g., automatic control) would improve the models presented. Improvements in these attitude behavior models are necessary if they are to serve as a basis from which transportation planning decisions are made. This research does indicate, however, that the use of perceptual judgments for generating transportation planning models is both feasible and useful in providing policy information for decision-making.

REFERENCES

1. Brunner, G. A., Hille, S. J., Nash, A. N., Paine, F. T., and Schellenberger, R. E. User Determined Attributes of Ideal Transportation Systems: An Empirical Study. Department of Business Administration, Univ. of Maryland, 1966.
2. Dobson, R. Documentation for the Metro Guideway Home-Interview and Leave-Behind Questionnaires. General Motors Research Laboratories, Warren, Mich., 1973.
3. Dobson, R., and Kehoe, J. F. Disaggregated Behavioral Views of Transportation Attributes. Paper in this RECORD.
4. Fishbein, M. Readings in Attitude Theory and Measurement. Wiley, New York, 1967.
5. Golob, T. F. The Survey of User Choice of Alternative Transportation Models. High Speed Ground Transportation Journal, Vol. 4, 1970, pp. 103-116.
6. Golob, T. F. Attitudinal Models. HRB Spec. Rept. 143, 1973, pp. 130-145.
7. Golob, T. F., Dobson, R., and Sheth, J. N. Perceived Attribute Importance in Public and Private Transportation. Proc., American Institute for Decision Science, Boston, Nov. 1973.
8. Golob, T. F., and Dobson, R. Assessment of Preferences and Perceptions Toward Attributes of Transportation Alternatives. TRB Spec. Rept. 149, 1974, pp. 58-81.
9. Harman, H. H. Modern Factor Analysis. Univ. of Chicago Press, 1967.
10. Hartgen, D. T., and Tanner, G. H. Individual Attitudes and Family Activities. High Speed Ground Transportation Journal, Vol. 4, 1970, pp. 439-467.
11. Hartgen, D. T., and Tanner, G. H. Investigations of the Effect of Traveler Attitudes in a Model of Mode-Choice Behavior. Highway Research Record 369, 1971, pp. 1-14.
12. Howard, J. A., and Sheth, J. N. The Theory of Buyer Behavior. Wiley, New York, 1969.
13. Inglis, P. A Multimodal Logit Model of Modal Split for a Short Journey. Highway Research Record 446, 1973, pp. 12-20.
14. Kaiser, H. F. The Varimax Criterion for Analytic Rotation in Factor Analysis. Psychometrika, Vol. 23, 1958, pp. 187-200.
15. Kotler, P. Marketing Management: Analysis, Planning and Control. Prentice-Hall, Englewood Cliffs, N.J., 1967.
16. Lancaster, K. J. A New Approach to Consumer Theory. Journal of Political Economy, Vol. 74, 1966, pp. 132-157.
17. Lovelock, C. H. Consumer Oriented Approaches to Marketing Urban Transit. Urban Mass Transportation Administration, Rept. UMTA-CA-11-0008-73-3, March 1973.
18. Paine, F. T., Nash, A. N., Hille, S. H., and Brunner, G. A. Consumer Attitudes Toward Auto Versus Public Transportation Alternatives. Journal of Applied Psychology, Vol. 53, 1969, pp. 472-480.
19. Reichman, S., and Stopher, P. R. Disaggregate Stochastic Models of Travel Mode Choice. Highway Research Record 369, 1971, pp. 91-103.
20. Rosenberg, M. J. Cognitive Structure and Attitudinal Affect. Journal of Abnormal and Social Psychology, Vol. 53, 1956, pp. 367-372.
21. Sherret, A. Structuring and Econometric Model of Mode Choice. Cornell Univ., PhD dissertation, 1971.
22. Sheth, J. N. Attitude as a Function of Evaluative Beliefs. American Marketing Association Consumer Workshop, Columbus, Ohio, Aug. 1969.
23. Sheth, J. N. Canonical Analysis of Attitude-Behavior Relationship. 18th International Meeting, Institute of Management Sciences, Washington, D.C., 1971.

24. Sommers, A. N. Toward a Theory of Traveler Mode Choice. High Speed Ground Transportation Journal, Vol. 4, 1970, pp. 1-8.
25. Stopher, P. R., and Lavender, J. O. Disaggregate, Behavioral Travel Demand Models: Empirical Tests of Three Hypotheses. Transportation Research Forum, 1972, pp. 321-336.
26. Thurstone, L. L. The Measurement of Social Attitudes. Journal of Abnormal and Social Psychology, Vol. 26, 1931, pp. 249-269.
27. Wallace, J. P., and Sherret, A. Product Attributes. HRB Spec. Rept. 143, 1973, pp. 146-174.
28. Watson, P. L. Predictions of Intercity Mode Choice From Disaggregate Behavioral Stochastic Models. Paper in this RECORD.
29. Wilkie, W. L., and Pessemier, E. A. Issues in Marketings' Use of Multi-Attribute Attitude Models. Journal of Marketing Research, Vol. 10, 1973, pp. 428-441.