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INVESTIGATIONS OF THE EFFECT OF TRAVELER ATTITUDES IN A MODEL OF MODE-CHOICE BEHAVIOR

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This paper summarizes the research conducted by using attitudinal data to predict individual mode choice. In this approach, travel is viewed as a form of human behavior to which the appropriate sociological and psychological principles may be applied. A model of individual mode choice is formulated, based on the traveler's attitudes toward qualitative system characteristics. An index is devised to represent the relative quality of transit and automobile to the traveler and is then related to actual mode choice. The choice model is made operational by merging an attitudinal data set with a file of trips based on the characteristics of trips and trip-makers. A series of tests examines the sensitivity of the model to changes in several qualitative system attributes. Finally, recommendations are made for further studies and refinements that are felt to be necessary if the model is to become an operational planning tool.

●THE USES of attitudinal data in understanding individual travel behavior were investigated during the fall of 1969 by the New York State Department of Transportation. Through a review of the literature on household decision-making, activity patterns, and travel characteristics, a heuristic theory of travel behavior was structured around the social and psychological needs of persons and households. Individual travel decisions (destination, choice of mode, and route) were hypothesized to result from an informal household decision-making process that evaluates the needs of members and assigns to each member certain tasks intended to fulfill those needs. Previously prepared papers (1, 2) describe this approach in more detail.

The research described in this paper concentrated on mode choice within this framework. A model of individual mode choice was devised that included components felt to be essential to understanding travel behavior. These are the characteristics of the traveler and his household, described by socioeconomic variables; the types of activities in which individual household members participate; the distribution of activity sites about the household by alternative modes of travel; and the attitudes of travelers toward the quality of alternative modes. It was felt that using traveler attitudes in the model would permit examination of qualitative (and often subconsciously perceived) factors affecting travel behavior such as comfort, convenience, self-esteem, and personal safety. There is growing evidence (3, 4, 5) that these factors are of considerable importance in mode-choice travel decisions and therefore should be included in choice models. In addition, it was felt that the problems of the demand for new modes, whose attributes may be quite different from those of existing modes, are probably most amenable to solution through consideration of traveler attitudes rather than through extrapolation of engineering measurements.

This paper gives a brief statement of the theory and formulation of a mode-choice model developed to incorporate these approaches and considerations. It also presents a series of tests of the model that is designed to reveal both the sensitivity of the

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model's formulation to the qualitative aspects of mode choice and the applicability of attitudinal data to mode choice.

TRAVEL AS A FORM OF HUMAN BEHAVIOR

Each individual has associated with him a set of needs defined by the roles he assumes in his interaction with other persons and groups. Through experience, individuals and groups develop both awareness of and attitudes toward alternate courses of action that may satisfy needs. Through awareness, a person or group recognizes the existence of those particular actions offering some potential for satisfying needs. Attitudes, on the other hand, are the pre-established tendencies for responses toward any of the courses of action identified by awareness. Attitudes and awareness therefore aid individuals by identifying activities and actions that can satisfy needs.

For those activities that require travel for completion, the individual must also consider the characteristics of alternate transportation systems with respect to their usefulness to him. Individual decisions involving travel will depend on this evaluation. In a travel decision, choice of mode, the traveler's view of the transportation systems is particularly important. In studies measuring how persons view transportation modes (3, 4, 6, 7), it is generally agreed that a person's attitude toward new or greatly improved transportation service will be based on his experience with existing service. In other words, he will evaluate new or unfamiliar systems by comparing them with more common ones. This paper suggests a procedure for describing this evaluation. It is hypothesized that the traveler classifies the modes that he perceives to be operating in the transportation system by comparing his attitude toward and awareness of attributes of these modes with his corresponding attitude toward and awareness of attributes of a preconceived ideal (perfect) mode. This allows him to make some statement about the relative quality of alternative modes, both to each other and to the ideal mode. The choice of mode is then determined by evaluating the quality of each mode. Experience from each trip may result in conscious or subconscious changes in the traveler's attitude, thus affecting his subsequent travel decisions.

A mode-choice model based on the previous ideas has been formulated and is being tested. The remainder of this paper deals with the form of this model and some preliminary test results.

MODE-CHOICE MODEL FORMULATION

Recently proposed mode-choice models (8, 9) have suggested that the criteria of traveler mode choice seem to depend on 2 components of perceived system attributes:

1. The importance placed on a given system attribute by a particular traveler for a particular trip (importance expresses awareness); and
2. The degree of satisfaction this traveler has with the ability of each alternative mode to fulfill the requirements of each system attribute (satisfaction expresses attitudes).

The model of traveler mode choice described here is based on the idea that a traveler's attitude toward the modes available for his trip depends on both the importance and the relative quality of a number of aspects of this trip, with each being represented by a number of specific system attributes. The rationale for the model will not be detailed here; the reader is referred to other material (1, 2) for extensive treatment. Put briefly, the model describes a binary choice situation in which the urban traveler chooses between 2 alternative means of travel. The choice is binary because the automobile and transit modes dominate intraurban travel. It is hypothesized that the amount of travel occurring on each mode P_{ik}, for traveler of type k on mode i, is a function of travelers' attitudes toward the quality of alternative modes and the travel times over each network within a particular travel corridor. Travelers' attitudes are measured by an attitudinal index, C_k, whereas the travel times are evaluated by an index of service, SI; therefore, $P_{ik} = f(C_k, SI)$.

The attitude of a traveler toward alternative transportation systems is hypothesized to be a linear combination of his attitude toward each of the factors he perceives to influence his travel decision. In evaluating the modes available, the traveler considers both the relative importance of each factor and his satisfaction with either mode with regard to that factor. This is expressed as

$$C_k = \sum_q I_{qk} \left(1 - \frac{S_{1qk}}{S_{2qk}}\right) \tag{1}$$

where

C_k = attitudinal index for traveler of type k (Table 3);
I_{qk} = importance of a factor q, defined as the greatest importance placed on any of the i attributes encompassed by factor q, for traveler k— $I_{qk} = \max I_{ik}, i \in q$;
S_{1qk} = satisfaction (generalized benefits) that the traveler experiences with factor q, where S_{1qk} is some function of the i attributes encompassed by factor q toward mode 1 by traveler k; and
S_{2qk} = similar conditions as for S_{1qk}, except that this applies to mode 2.

An index of service was constructed to allow the planner to evaluate major system improvements in specific corridors. The transportation planner, unlike the traveler, is interested in a precise description of transportation system characteristics in terms of engineering measurements. Aspects of the transportation system such as headways and capacities aid the planner in examining system capability, determining capital and operating costs, and relating alternative courses of action to changes in specific system attributes. The service index weighted the ratio of over-the-network travel times for 2 modes by the trip-end density at the nonhome end of the trip.

$$SI = \frac{TP}{AP + ATT} \left[\frac{1}{D_k}\right]^{1/2}$$

where

SI = service index,
TP = transit door-to-door travel time,
AP = automobile in-vehicle travel time,
ATT = automobile terminal time, and
D_k = density of trip destinations, for a particular trip purpose, at the nonhome end of the trip.

MODE-CHOICE MODEL IMPLEMENTATION

Trips for this study were stratified by trip purpose, automobile availability, household type, and income. These variables were intended to account for the different importances placed on certain system attributes for different types of trips. The levels of the variables are as follows:

Variable	Levels
Trip purpose	Work-school, other
Automobile availability	Automobile available, no automobile available
Household type	Family, nonfamily
Income	$0-3,999, $4,000-5,999, $6,000-9,999, over $10,000

A discussion of the reasoning behind this structure appears elsewhere (1). Briefly, this combination of variables and levels was felt to be a means of identifying trips by their associate activities. Trip purpose was intended to represent activity purpose, automobile availability was to represent the activity's priority in the household, household type was to represent the idea of hierarchy in household decision-making, and income was to represent the resources of the household.

This trip stratification was then applied to a file of trip data collected by a home-interview survey in Rochester, New York, in 1963. Each trip in the Rochester file was classified according to one of 32 combinations of the variable levels described previously.

Transportation studies have not collected separate data on the traveler's perception of modal attributes in conjunction with data on travel patterns. One study conducted by the University of Maryland in metropolitan Philadelphia was designed to collect these types of linked data. In that study, the respondent was asked to indicate the level at which each of 2 travel modes satisfied a specific attribute. Independently, the respondent was asked to record the level of importance of this attribute to him. Each set of responses referred to one of 33 attributes that ranged from vehicle cleanliness to travel costs. For a particular trip, both measures of satisfaction and importance were recorded along 7-position Likert scales. This information defined the attitude data file. Table 1 gives a typical list of scores for each of the 33 system attributes for the following combination of variable levels: family, income between $4,000 and $5,999, automobile available, and work trip.

Because of their appropriateness, the Maryland survey data were used as a basic attitude source for the current study. Each response was placed into 1 of the 32 cells that described the trip characteristics by using the levels of the 4 variables described previously. Average scores for each of the 33 attributes were then computed in each of these cells.

The Maryland survey staff found that different combinations of attributes tended to describe different factors important to travel. Reliability is an example of a factor composed of 2 attributes—arrive without accident and avoid stopping for repairs. Although these factors were not entirely independent, it was felt that for modeling purposes they could serve to differentiate system attributes. Each attribute investigated by the Maryland survey could be similarly described by a number of transportation system variables.

Table 1 gives the combination of the 33 system attributes into 11 factors for a particular type of trip. Those attributes representing factors were then used to calculate attitudinal indexes according to Eq. 1. Table 2 gives an example of this calculation using the same combination of variable levels as used for Table 1. The entire set of indexes for all 32 cells is given in Table 3.

The attitudinal data devised in this manner were then applied to the analysis of modal-split estimates in Rochester. Because the attitudinal data had been obtained from individuals living in the Philadelphia metropolitan area, it was necessary to relate the observed values from the Philadelphia survey to data from similar trips recorded in the Rochester survey. This was accomplished by assigning the indexes given in Table 3 to trips of a similar type made in the Rochester area. Thus, each trip recorded in the Rochester survey was assigned one of the attitudinal indexes given in Table 3 based on trip and household characteristics.

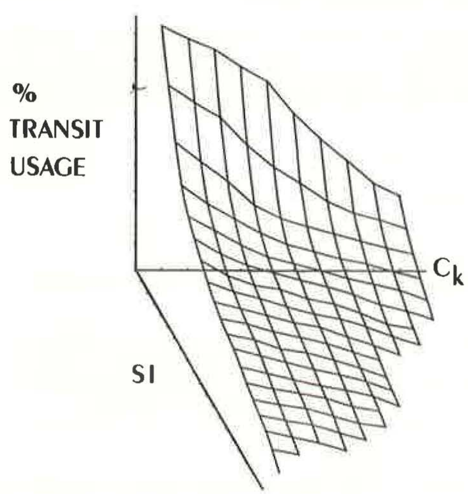

Figure 1. Typical response surface.

The procedure for developing estimates of mode use was based on the concept of response surfaces used in several transportation studies (10). These surfaces can be described as 3-dimensional diversion curves. In general, a response surface is constructed by arraying the percentage of trips by a mode, usually transit, against several demographic, geographic, or system variables, or against all three. Four response surfaces were created for combinations of 2 trip purposes with 2 automobile-availability categories. On each surface the percentage of transit trips was arrayed by the service index and the attitude index as shown in Figure 1.

TABLE 1

SATISFACTION AND IMPORTANCE SCORES FOR SYSTEM ATTRIBUTES BY FACTOR

Factor	System Attribute		Perceived Satisfaction[a]		Perceived Importance[a]
	Number	Description	Transit	Automobile	
Reliability	28	Arrive without accident	6.0	6.1	6.2[b]
	33	Avoid stopping for repairs	5.2	5.5	4.9
Travel time	1	Arrive in shortest time possible	2.5	5.8	5.9
	7	Travel in light traffic	3.9	4.8	4.1
	11	Arrive at intended time	4.4	5.9	6.4[b]
	12	Arrive in shortest distance	4.3	6.4	6.1
	17	Avoid changing vehicle	4.3	6.2	5.0
	18	Ride in safest possible vehicle	5.6	5.9	6.1
	24	Travel as fast as possible	4.3	5.6	6.4
Weather	5	Have protection from weather while waiting	3.0	5.2	5.0
	2	Vehicle unaffected by weather	4.6	6.0	5.6[b]
Cost	3	Total trip cost	4.5	5.7	5.0[b]
	13	One-way cost of 25 cents instead of 35 cents	4.9	5.5	4.2
	22	One-way cost of 25 cents instead of 50 cents	4.6	5.7	4.0
	29	Per-mile cost of 3 cents instead of 15 cents	4.9	5.6	4.5
Vehicle condition	10	Ride in clean vehicle	4.8	5.4	5.6[b]
	20	Ride in new modern vehicle	5.1	5.8	5.1
Personal safety	30	Avoid unfamiliar area	5.0	5.7	4.3[b]
Self-esteem	6	Ride in uncrowded vehicle	4.0	6.0	3.8
	14	Have feeling of independence	4.0	6.2	5.1
	26	Avoid waiting more than 5 min	4.0	6.3	5.8[b]
	27	Ride comfortably	4.8	5.9	5.5
	31	Have pride in vehicle	4.9	4.8	3.6
	32	Avoid riding with strangers	5.0	5.7	4.2
Diversions	4	Listen to radio	5.0	5.5	4.8[b]
	8	Take along family and friends	4.0	6.1	3.9
	9	Ride with people who chat	4.7	5.6	4.0
	15	Look at scenery	4.5	5.6	3.9
	21	Ride with friendly people	4.8	6.4	4.7
	23	Ride with people you like	4.6	6.4	4.3
Convenience	16	Avoid walking more than a block	3.9	6.1	5.5[b]
Packaging	19	Have package and baggage space	4.4	6.2	4.3[b]
Fare payment	25	Need not pay fare daily	5.3	6.1	3.7[b]

Source: University of Maryland Study.

[a]Variable levels: work trip, automobile available, family, income $4,000-$5,999.
[b]Maximum importance within each factor, q.

TABLE 2

EXAMPLE OF ATTITUDINAL INDEX CALCULATION

Factor q	System Attribute	Satisfaction: Transit S_{1qk}	Satisfaction: Automobile S_{2qk}	$1 - \frac{S_{1qk}}{S_{2qk}}$	Importance I_{qk}	Added Value $I_{qk}\left(1 - \frac{S_{1qk}}{S_{2qk}}\right)$
1	Arrive without accident	6.0	6.1	0.016	6.2	0.10
2	Arrive at intended time	4.4	5.9	0.254	6.4	1.63
3	Vehicle unaffected by weather	4.6	6.0	0.234	5.6	1.31
4	Total trip cost	4.5	5.7	0.211	5.0	1.06
5	Ride in clean vehicle	4.8	5.4	0.111	5.6	0.62
6	Avoid unfamiliar area	5.0	5.7	0.123	4.3	0.53
7	Avoid waiting more than 5 min	4.0	6.3	0.365	5.8	2.11
8	Listen to radio	5.0	5.5	0.091	4.8	0.44
9	Avoid walking more than a block	3.9	6.1	0.361	5.5	1.98
10	Have package and baggage space	4.4	6.2	0.290	4.3	1.25
11	Need not pay fare daily	5.3	6.1	0.132	3.7	0.49
Total						11.51[a]

Note: Variable levels are work trip, automobile available, family, income $4,000 to $5,999.

[a]Attitudinal index.

Basically, the model operates by relating a change in some specific system attribute (e.g., vehicle cleanliness) to a change in traveler satisfaction with that attribute. This change in satisfaction may result in a change in the traveler's attitude toward the system, which is measured by the attitudinal index. When applied to the response

TABLE 3

ATTITUDINAL INDEXES BY TRIP CLASS

Household Type	Income (dollars)	Automobile Available: Work	Automobile Available: Nonwork	No Automobile Available: Work	No Automobile Available: Nonwork
Non-family	0-3,999	8.15	14.12	12.14	8.91
(single	4,000-5,999	7.22	15.76	12.97	9.75
persons,	6,000-9,999	5.98	14.29	19.17	10.74
roommates)	10,000+	6.81	18.23	19.77	12.59
Family	0-3,999	13.67	13.95	2.80	3.96
	4,000-5,999	11.51	12.62	6.23	5.55
	6,000-9,999	9.54	12.44	8.41	5.93
	10,000+	9.86	15.38	12.22	9.76

Source: University of Maryland study.

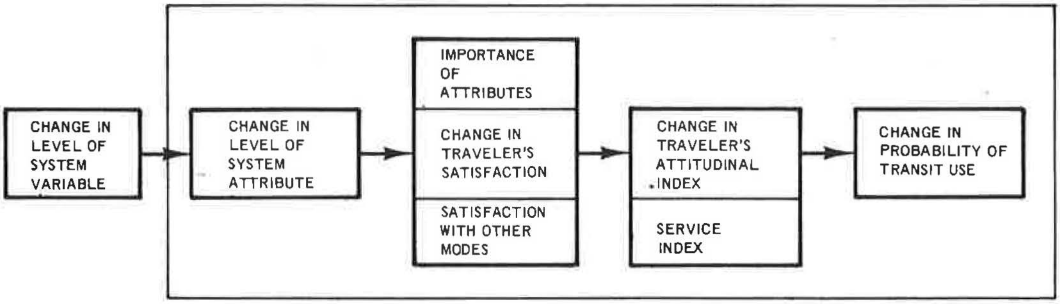

Figure 2. Schematic operation of the model.

surface, this change in the attitudinal index is interpreted as a shift in the trip's position on the surface, resulting in a change in the probability that this trip will be made by transit. When this probability is applied to a large number of trips, the result will be a change in the number of transit users. This process is shown in Figure 2.

The key step in this sequence (Fig. 2) is the description of the relationship between traveler attitude toward a system attribute and the value of specific variables used to describe the attribute. In theory, this may be accomplished by relating specific levels of system variables to attitudinal scores.

There are a number of problems associated with this approach, but foremost is the absence of data that can aid in specifying the relationship between a system attribute and its various variable measures. Therefore, we were forced in the following tests to assume that changes occurred directly in the satisfaction levels of attributes and to use these as the means of inducing attitude change in the model.

A second assumption is inherent in the test implementations of the model. It concerns the acceptability of using attitude data from the Philadelphia survey merged by trip and household characteristics with travel data from the Rochester survey. This second assumption, however, is made in light of some evidence from urban areas that suggests that attitudes are influenced primarily by families and groups rather than by geographic location (11).

Because of the nature of these 2 assumptions, test results are not subjected to any rigorous statistical analysis. Rather, output from the following tests is intended to illustrate the potential of this model form.

DESCRIPTION OF TESTS AND RESULTS

The model as described was applied first to reproducing estimates of mode use as determined by the Rochester survey travel files. Table 4 gives values for transit trips by ring of trip-maker's residence and by ring of trip origin. For purposes of analysis, study areas are described by a series of concentric rings emanating from the CBD. Trips by ring of trip-maker's residence are defined as transit trips that have a trip purpose of either the home as origin or the home as destination in the identified ring. Transit trips by ring of trip origin, on the other hand, are simply those transit trips that originate for any purpose in the indicated ring. Examination of the data given in Table 4 reveals the relative contributions of each of the rings to transit ridership in Rochester as estimated by the model.

Results from the tests are given in Table 5. Table 5 gives the response to hypothetical differences in terms of differences in transit trips by ring of trip-maker's residence and the response by ring of trip origin. These 2 views of ridership response show which residence rings are most affected by the test changes and which ones are affected by travel patterns of the residents.

Test 1

The first test investigates the effect within the model of an assumed increase in the cleanliness of buses (attribute 10, Table 1), as interpreted by an increase in the

TABLE 4

SUMMARY OF MODEL-ESTIMATED TRANSIT TRIPS BY RING OF TRIP-MAKER'S RESIDENCE AND TRIP ORIGIN

Ring	Trips by Ring of Trip-Maker's Residence		Trips by Ring of Trip Origin	
	Number	Percent	Number	Percent
0	2,376	9.2	16,051	17.1
1	4,729	10.4	10,888	11.5
2	30,194	10.8	24,842	8.3
3	28,265	8.3	26,590	6.2
4	18,248	7.3	15,246	5.2
5	5,075	5.1	3,083	2.6
6	3,403	3.5	1,857	1.6
7	1,672	5.1	784	2.9
Total	93,962	8.3	100,358	7.0

satisfaction level of travelers with the cleanliness of the transit vehicle. For this test, the changes given in Table 6 of the percentage of persons satisfied with transit vehicle cleanliness were assumed. (As noted, the figures given in Table 6 result from applying Philadelphia attitudes to Rochester trip data.)

These improvements were assumed to apply to all travelers in the urban area, because bus cleanliness was assumed to be uniform throughout the study area. For each level of system-wide transit vehicle cleanliness, higher income groups express much less satisfaction than lower income groups do. The changes made to the percentage of persons satisfied were based on the assumption that those groups who express the greatest satisfaction with present vehicle cleanliness would be less affected by cleaner vehicles than those groups who registered less satisfaction with this variable.

The percentage of changes in satisfaction resulting from the improvements in vehicle cleanliness were then used in calculating a new set of attitudinal indexes. When the new attitudinal indexes were applied to the response surfaces discussed previously, corresponding increases in transit use resulted. The magnitude and location of the transit use increases are given in Table 5 (Test 1). Most of the resulting increase in transit use developed in this test occurred in rings 2, 3, and 4 because of the high transit potential of the area bordering the CBD. These rings seem to possess the greatest number of 1-car households. On the other hand, the greatest positive percentage differences in transit use are in rings 5, 6, and 7. These outer rings are essentially suburban areas having a substantial number of higher income households that, through the test conditions input to the model, had experienced the greatest increase in satisfaction level. By contrast, the CBD and ring 1, which contain a large number of lower income households, exhibit the lowest response to clean buses, when viewed in terms of percentage difference to initial conditions.

Although arbitrary, the magnitude of these results appears reasonable. One would expect only a small increase in transit use to result from implementing a relatively unimportant attribute such as vehicle cleanliness. Nevertheless, the model does seem capable of evaluating the effect of qualitative components not normally included in other modal-split mechanisms.

Test 2

The effect of a downtown transportation terminal was investigated in a second test. It is felt by some analysts that such a terminal, if well designed, could increase the use of a transit system by providing more efficient service of better quality. In this test, the terminal was evaluated in terms of its effect on system attributes.

TABLE 5

RING SUMMARY OF SIX TESTS

Ring	Calibrated Base	Test 1 Clean Buses		Test 2 Downtown Terminal		Test 3 No Fare		Test 4 New Vehicles		Test 5 Equal Access		Test 6 Equal Satisfaction	
	Volume	Volume	Difference (percent)	Volume	Difference (percent)	Volume	Difference (percent)	Volume	Difference (percent)	Volume	Difference (percent)	Volume	Difference (percent)
	Transit Trips by Ring of Trip-Maker's Residence												
0	2,376	2,453	3.2	2,515	5.9	2,667	12.3	3,007	26.7	3,587	51.0	3,720	56.5
1	4,729	4,864	2.9	4,764	0.7	5,170	9.3	5,629	19.0	6,995	48.0	7,049	49.0
2	30,194	31,577	4.6	30,688	1.6	32,993	9.3	36,959	22.3	44,034	46.0	45,738	51.5
3	28,265	29,865	5.7	28,772	1.8	31,272	10.6	36,116	27.8	45,046	59.5	45,578	61.5
4	18,264	19,515	6.9	18,493	1.3	20,320	11.4	23,908	31.0	27,728	52.0	30,128	65.0
5	5,075	5,449	7.4	5,155	1.6	5,681	12.0	6,721	32.5	9,833	94.0	8,679	71.0
6	3,403	3,639	6.9	3,473	2.1	3,782	11.1	4,401	29.1	7,375	117.0	5,657	66.0
7	1,672	1,807	8.1	1,714	2.5	1,875	12.1	2,166	29.5	4,031	141.0	2,834	69.5
Total	93,962	99,169	5.6	95,974	1.7	103,760	10.4	118,906	26.6	148,629	58.2	149,383	58.0
	Transit Trips by Ring of Trip Origin												
0	16,051	16,482	2.7	16,890	5.2	17,254	7.5	18,806	17.2	17,939	11.8	21,634	34.8
1	10,888	11,311	3.9	10,927	0.3	11,838	8.7	13,204	21.3	15,490	29.8	16,255	49.4
2	24,842	26,120	5.1	25,118	1.1	27,324	10.0	30,938	24.5	41,864	68.5	38,653	55.6
3	26,590	28,220	6.1	26,863	1.0	29,488	10.9	34,089	28.2	48,857	83.8	43,514	62.9
4	15,246	16,373	7.4	15,369	0.8	17,000	11.5	19,974	31.0	24,960	60.1	25,131	64.8
5	3,083	3,335	8.2	3,119	1.2	3,479	12.8	4,157	34.8	7,776	152.0	5,442	76.5
6	1,857	1,988	7.1	1,891	1.8	2,045	10.1	2,394	29.0	4,964	167.0	3,109	67.5
7	784	848	8.2	804	2.5	878	12.0	1,008	28.6	1,877	140.0	1,329	69.5
Total	100,358	105,565	5.2	101,972	1.6	110,153	9.7	125,299	24.8	164,310	63.7	155,777	55.2

TABLE 6

CHANGES ASSUMED FOR TEST 1

Income Level (dollar)	Persons Initially Satisfied (percent)	Persons Newly Satisfied (percent)	Change (percent)
0-3,999	45	50	+11
4,000-5,999	40	46	+12
6,000-9,999	30	40	+33
Over 10,000	25	38	+48

Transit satisfaction levels of certain attributes selected from the list given in Table 1 were assumed to change, as given in Table 7. The justification for selecting these items is as follows: The downtown terminal was assumed to be strategically placed so as to shorten the travel time for the greatest number of people traveling to the CBD. A terminal facility would certainly provide protection from the weather through its structure and possibly through its location, which could eliminate the need for outdoor transfers to reach intended destinations within the CBD. More ridership to the CBD and, because service is kept constant in this test, more crowding of vehicles may be anticipated. Knowing the social safety afforded by a downtown terminal facility, the traveler would be more willing to bring along his family and friends. These ideas are reflected in the changes in the satisfaction levels of the various income groups as given in Table 7.

The new satisfaction levels created as a result of the test changes were then used to develop new attitudinal indexes that led to the resulting increases in transit use as given in Table 5 (Test 2). Examination of both trips by ring of trip-maker's residence and by ring of trip origin reveals that the initial CBD-origin trips increased almost 6 percent. A modest increase occurred in all rings, except in ring 1 that surrounds the CBD. An increase in CBD transit use was expected because CBD travel would be stimulated by the terminal. The lower response found in ring 1 may be due to the penalizing effects of a downtown terminal in increasing walking distances for riders between ring 1 and the CBD. In terms of absolute ridership, increases are most apparent in rings 2, 3, and 4 where the greatest ridership potential exists.

TABLE 7

CHANGES ASSUMED FOR TEST 2

System Attribute		Change in Satisfaction Level by Income Level, percent			
Number	Description	$0-3,999	$4-5,999	$6-9,999	$10,000+
1	Arrive in shortest time possible	5	5	10	10
5	Have protection from weather while waiting	40	50	50	60
6	Ride in uncrowded vehicle	- 5	-10	-10	-10
8	Take along family and friends	10	10	10	10
11	Arrive at intended time	10	15	20	20
16	Avoid walking more than a block	-10	-10	-20	-20
17	Avoid changing vehicle	2	5	5	5
20	Ride in new modern vehicle	10	20	25	30
25	Need not pay fare daily	10	10	5	5
26	Avoid waiting more than 5 min	10	15	20	20
30	Avoid unfamiliar area	20	20	25	30

Test 3

The third test investigates the influence of a no-fare or free transit system on transit ridership. Suppose, it is suggested, that transit fares are reduced while the level of service, in terms of routes, headways, and vehicles, remains constant. In this test the satisfaction of transit riders with fares was maximized. It was assumed that everyone would be highly satisfied with a zero-cost fare. The transit satisfaction level of all riders with all items in the trip cost factor (Table 1) was set to 7.0. A new set of attitudinal indexes was computed and resulted in the increases in transit use as given in Table 5 (Test 3). Overall, transit use increased approximately 10 percent. Comparison of the percentage difference by ring trip-maker's residence and by ring of trip origin shows the CBD resident to be more affected by the omission of a fare than the CBD traveler. Although this condition exists in some other rings, it is to be most expected in the CBD and surrounding area. It is apparent that a fare charge consumes a greater proportion of a lower income salary than a higher income salary; hence, a substantial fare reduction could be expected to have the greatest impact on ridership from the lower income class. In the more suburban rings, the incentive to use transit brought about by the fare reduction is not large enough to influence markedly transit ridership. The outer rings have inferior transit service, and a decrease in fare would do little to reduce the inconvenience of transit riding present in these areas.

Test 4

The fourth test examines the effect of substantial improvement in the vehicle condition of the transit system vehicles. Such an improvement could be made through the purchase and maintenance of all-new, noise-free, pleasant-smelling, clean, highly reliable buses. If such a fleet could be purchased and put into operation at existing service levels, thereby replacing all existing vehicles, some increase in patronage would be expected. These substantial improvements to vehicle conditions would probably be widely recognized, especially if these improvements were combined with an extensive public relations and advertising campaign. The result of this effort would be to make almost all persons very satisfied with the transit vehicle condition.

It was assumed that the test changes could be implemented through the changes to the individuals' satisfactions given in Table 8. We assumed that all riders are completely satisfied with the newness and cleanliness of the vehicles. New vehicles would probably also possess other attributes conducive to ridership. Seats and spacing would be improved over present systems. Confidence in safety and reliability could be expected to increase. Pride in the vehicle could be expected to increase. Finally, because the trend in vehicle design appears to be directed toward the inclusion of larger transparent areas, some increase in the satisfaction expressed by the transit rider with his ability to look at the scenery might be expected.

TABLE 8

CHANGES ASSUMED FOR TEST 4

System Attribute		Change (percent)
Number	Description	
10	Ride in clean vehicle	700[a]
20	Ride in new modern vehicle	700[a]
27	Ride comfortably	60
28	Arrive without accident	50
33	Avoid stopping for repairs	50
31	Have pride in vehicle	40
15	Look at scenery	10

[a]Maximum condition

These changes to the transit satisfaction were applied across all income levels and used to compute a new set of attitudinal indexes. The results of using the test information in the model are given in Table 5 (Test 4). The overall increase in ridership is approximately 25 percent. The CBD and rings 5, 6, and 7 are most influenced by new vehicles. The percentage increase in the outer rings (5, 6, and 7) is above the study area average. The absolute increase in ridership that can be attributed to new vehicles is much lower in these rings than in rings 2, 3, and 4. New vehicles along existing routes with existing system characteristics do little, if anything, to affect accessibility; hence, there is a lower absolute response in the suburban rings (5, 6, and 7).

Test 5

The fifth test is an attempt to view the impact of attitudes toward travel modes on existing transit patronage. This test is accomplished by neutralizing the effect of the travel-time ratio in the service index—setting it equal to unity and creating a condition of equal accessibility (equal time). Automobile availability, trip-end density, and attitude index become the discriminants of transit use when the travel-time ratio equals one. If the 2 modes were perceived equally, the expected modal split would be 50 percent transit and 50 percent automobile. For this test, the resulting modal split can be expected to deviate by some fixed amount from the theoretical 50-50 value, with transit being substantially lower than the automobile (possibly 15-85). The lower use for transit would result from the fact that most people expressed attitudes suggesting that they were more satisfied with the automobile than with public transit for reasons other than accessibility.

This hypothesis was tested by equating system attributes on the service index and observing the model's estimate of the resulting transit use. The results are given in Table 5 (Test 5). As might be anticipated, those rings adjacent to the CBD, predominantly composed of households with 1 automobile, exhibit substantial increases in the number of transit riders. The suburban rings, with higher incomes, more automobiles available, and more pronounced dissatisfaction with transit service, register more modest ridership increases. The overall increased transit use is nearly 60 percent.

Equal access appears to have more of an effect on trips by ring of trip origin than on trips by resident dwelling ring. This is apparent for rings 2 through 6 where there is a marked difference between the 2 respective percentage difference values.

Test 6

For the fifth test, the service index was neutralized. The sixth test investigates the influence of travel time on mode use through the neutralization of the attitude index, creating conditions of equal satisfaction. Equivalency is established by setting the satisfaction of a factor for transit equal to the satisfaction of that same factor for automobile. In this manner each traveler is assumed to have equally favorable attitudes toward both modes. The conditions of equal satisfactions, when summed over all factors in the computation of the attitude index (Eq. 1), result in a value of zero. Structured in this manner, the test studies the effect on transit use of these variables: travel-time ratio, trip-end density, and automobile availability. In this case, the model operated as a diversion curve, based on the respondent's values for time and money.

The results of this test are given in Table 5 (Test 6). In the suburban rings (5, 6, and 7), attitudes appear to have had a more substantial influence on determining transit use than in the inner rings because the greatest percentage increase occurs in this outer area. The overall increase from the total initial ridership is nearly 55 percent. Although the model is used as a diversion curve, this test is not typical of the more commonly accepted diversion curves. The usual diversion curve developed without distinct consideration of qualitative factors had these factors implicit in its construction. The curve used in this test, on the other hand, is devoid of qualitative evaluations and is hinged on cost, trip-end density, and automobile availability. When the components of the service index in this case are examined, the fare cost of transit is less of an influence on mode choice of suburban residents than the time cost of transit travel, which is usually prohibitive.

In all of these tests, trip-end density, although noted, has not been a controlling variable because of a constant trip distribution for all 6 tests.

SUMMARY AND DISCUSSION

The model develops an estimate of expected transit patronage—the proportion of zone-to-zone trips that will use the transit mode—as a function of 4 general factors:

1. Operating characteristics of both transit and automobile systems (such as speed, parking charges, headway, and trip density) as indicated by the service index;
2. Stratification of trips (purpose, automobile availability);
3. Demographic aspects of the region (spatial distribution of households by income, household structure); and
4. Attitudes of travelers toward abstracted system attributes as indicated by the attitude index.

The model tests described were intended to illustrate the potential uses for this tool and to provide insight into the rationality of model response to specific conditions.

In the first 4 tests of the model, emphasis was placed on the effect of attitudes on mode-choice travel behavior. These initial tests were concerned with the impact of various qualitative improvements to the transit system. The tests examined the effect of clean buses, a downtown terminal, no fares, and new vehicles, all of which resulted in increases in transit use. The greatest increases in patronage resulted from the no-fare and new-vehicle tests.

The last 2 tests were intended to operate the model near its tolerable limits. These tests examined the influence of equal access and equal satisfaction. Increased transit mobility, or equal access (Test 5) appeared as a stronger patronage stimulant than fare reduction (Test 3). This observation is in agreement with the result of at least 1 public transportation demonstration project (12). Creating more favorable attitudes toward transit (Test 6) appears to be nearly as important as increasing transit accessibility (Test 5). This observation is based on a comparison of the percentage differences of Tests 5 and 6 (Table 5).

Through incorporation of the traveler's attitude toward the transportation system, the planner may "see" the systems from the traveler's viewpoint, and (theoretically) relate these attitudes to specific quantifiable physical variables that are of concern to the system designer.

A model of the type presented in this paper is also capable of estimating the patronage that may be attributed to new modes by extending present attitudes toward abstracted features of existing modes and projecting them to their new mode counterpart, which is much in the same manner that a person relates past experience to his analysis of the future.

Successful application of the model to this problem would, of course, require knowing the relation between satisfaction levels and levels of specific system variables describing new modes. As in most mode-choice models, the formulation and tests described represent many compromises and are therefore somewhat less than ideal. The data on which the model is based only allow operation of the model as a valuable but limited research tool. It is not possible, at the moment, to apply the model with confidence to actual planning situations. With these comments in mind, one may identify the shortcomings of the model with 2 major areas—model formulation and available data.

Examination of all the assumptions made concerning the formulation of the model would be appropriate. A few key areas that should be examined in greater detail are the relation of travel to activities and household needs, which is the mechanism that governs travel decisions, and the travelers' perception of transportation system attributes.

Similarly, there are many pieces of additional data that should be gathered. Improved data would set the stage for examining the sensitivity of the model to changes in input parameters. On the surface, the model appears to react in a credible manner, but considerably more testing must be done before the model is applied to the problems of a particular city. Two immediate requirements are to gather engineering and attitude data together in various cities to gain knowledge of the relationship between system operations and traveler attitudes and expand the 33 specific items to permit the consideration of a greater number of problems. One can hope that the result would be improved understanding of travel as a behavioral phenomenon.

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