MODAL-CHOICE AND ATTITUDE PATTERNS FOR A MEDIUM-SIZED METROPOLITAN AREA

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The purposes of this study were to evaluate the factors that jointly influence the use of a public transportation system and to develop techniques of analysis and prediction that will assist the planning of future transit needs. A sampled population of employees of downtown firms in Denver was asked to complete a questionnaire. The factors that may reasonably have important influence on modal choice were analyzed. Statistical frequency distribution functions were fitted to survey data for several factors. Correlations among a number of variables were determined. The relation between certain intervals of a variable (called the conditioning variable) and data levels for other variables (called the conditioned variables) are also determined. A number of variables that would jointly have an effect on the choice of mode were used in the development of modal-choice prediction models.

•THE NEED for an adequate understanding of the factors at work in the use of multimodal transportation facilities within urban areas is particularly acute. The great and increasing degree of urbanization in the United States makes the planning of transportation facilities and the use of public transit to serve the populations of large metropolitan centers particularly urgent. Recognition of the importance of the problem by local, state, and national governments and by private organizations has led to extensive activity in collection and analysis of the present facts of urban transportation, conduct of transportation experiments under actual conditions, and investigation of alternative approaches to provision of future facilities. A major facet in understanding the needs and determining the approaches is best described as the factors influencing modal choice, the subject of this research.

BASIC ASSUMPTIONS AND OBJECTIVES

The following basic assumptions and objectives have provided the framework for this study:

1. The ultimate purposes of the research are to provide insight into the main factors that jointly influence the use of public transportation systems and to develop techniques of analysis and prediction by which the planning of future transit needs may be aided.
2. Methods of analyzing and predicting modal choice should be applicable, as far as possible, to situations differing widely in the transportation alternatives that are available or proposed and the demand that is to be satisfied.
3. It is unrealistic to expect that a high degree of precision is attainable in predicting individual behavior with respect to choice of modes and routes of travel, particularly in future or hypothetical situations. The variability and multidimensionality of choice are integral parts of the nature and heritage of Americans. However,

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recognition of the underlying factors that operate to produce roughly similar patterns of travel, independently to some extent of time and place, provides the only solid foundation for long-range planning.

4. Estimates of the effects of important factors, considered jointly, on choices among alternative modes and routes of travel must be derived and tested by application of appropriate analytical methods to a suitably large sampling of the population.

5. Although the Chicago study (1) forms a good basis, the people of Denver have different needs that can only be determined empirically.

6. The objective, then, is to determine what policies will be most effective in drawing large numbers of downtown workers away from their private automobiles and to the Denver Metro Transit (DMT) system.

BACKGROUND OF DENVER'S BUS SYSTEM

The situation in Denver closely parallels that of many American cities—the demise of public transportation. Until recently, ridership had decreased to the point where the privately owned transit firm was forced to sell the entire bus system to the city of Denver. The city has since turned the technical and management operations of the system over to a consulting firm composed of professionals in the various required areas. Ridership increased dramatically in the first 18 months of operation, and public relations activities have turned the average worker's head and at least focused his attention.

Only a satisfactory resolution of the one remaining major problem, that of having a profit ensured before a run to the suburbs is begun, stands in the way of a vastly increased ridership on the transit system. The time is surely right; ecology is a major issue, for the downtown area is covered almost daily with smog from automobile exhausts.

DATA COLLECTION

A questionnaire was prepared and distributed to employees of downtown firms. The response was excellent, partly because the questionnaires were distributed through the Downtown Denver Improvement Association and then through the appropriate personnel staffs of the individual firms.

A total of 10 CBD firms participated in the survey. Those firms were well diversified in function and size (Table 1). Adequate dispersion exists among the means for several variables to provide for objective analysis of modal choice—for example, the average annual salary as sampled was 1.64 and 1.49 ($6,600 and $6,200) for firms 02 and 10 respectively and 3.06 ($10,000) for firm 08.

MODEL FORMULATION

Model formulation proceeded from the following premises:

1. The individual trip in its entirety from origin to destination, possibly by way of specified intermediate points, is the basic unit of travel.

2. Mixed-modal trips (i.e., trips composed of segments on differing modes) are particularly important. That point of view contrasts with the usual concept of a modal split, which leads to an assignment of trips to one or another mode exclusively. The concern here is in any tendencies for travelers to switch modes either during a trip or for the total trip.

3. Various characteristics of the transportation network and characteristics of the users interact in the selection of modes and routes.

4. Estimates of the effects of important factors, considered jointly, on choices among alternative modes and routes must be derived from actual data by suitable statistical methods.

5. The analysis of factors influencing travel decisions must ultimately be based on specific information concerning decision-makers, the travel options available to them, and the decisions actually made.

6. People will usually answer questions in the proper frame of honesty; and, when the reverse is true, a rather simple analysis of the questionnaire will reveal this discrepancy so that the form can be corrected or discarded.

7. Aggregation of the data will not in itself cause any inconsistency or inaccuracies.

ANALYSES

The central purpose in the data analyses that were undertaken was to investigate basic questions concerning factors that may reasonably have important influence on modal choice.

Results of the work-trip survey made during the study are first presented in terms of characteristics of the respondents and the spectrum of kinds of trips reported. Summary values characterize the different classes of trips, such as number of trip reports, weighted frequency of occurrence, average reported travel distance, travel time, and cost. In addition, factors stated to be determinative with respect to the type of trip taken, or to be favorable or unfavorable, are listed, and the frequency of citation is given by trip class. Individual factors are grouped into more general factors—travel cost, time, convenience, comfort, and safety—and comparisons are made among trip types on the basis of relative frequency of factor citation. The reasons why persons had switched, one way or the other, between predominant use of the private automobile and predominant use of public transportation for work trips were analyzed in a similar manner. Statistical frequency distribution functions have been fitted to survey data on travel distance, travel time, and proportion of trips using public transportation. Correlations were determined among a number of the variables. In addition, the relation between certain intervals of a variable (called the conditioning variable) and data levels for other variables (called the conditioned variables) has been sought. Proportionate use of public transportation was examined in relation to selected variables taken one at a time: salary level, car driver, car ownership, distance from home to public transportation, overall travel distance, and several other factors. The proportionate use of public transportation was analyzed within the framework of multivariate regression analysis; a relatively large number of independent variables were tested. Finally, attitudes toward park-and-ride, minibus service at or near the doorstep, shuttle service from a metropolitan stadium to the downtown area, and free bus service were investigated.

Types of Trips

Nine modes of travel were selected, and each trip was categorized according to one of those modes.

Type of Trip	Category
Walk	1
Car driver	2
Car passenger	3
Bus	4
Car-pool member	5
Walk-bus (dual mode)	6
Car driver-bus (dual mode)	7
Car passenger-bus (dual mode)	8
Car-pool member-bus (dual mode)	9

Relation of Variables

A list of 29 of the variables that were included in the survey is given in Table 2. The table gives mean values for each firm surveyed and the number of applicable answers, arithmetic means, and standard deviations for the total survey.

Yearly salary levels were requested in 4 categories as follows:

Level (dollars)	Category
Under 5,000	1
5,000 to 7,500	2
7,500 to 10,000	3
Over 10,000	4

Approximately 8 percent of the respondents refused to divulge their yearly salaries. Because salary level is considered by most researchers to be correlated to personal car use, an analysis of divergent salary levels may form the basis for evaluation of several variables. Firm 08 respondents had an average salary level of 3.06 and are the only group that is significantly higher than the mean. Firms 02 and 10 each had significantly lower wages ($2,500 below the mean), and firms 03 and 04 are considerably below the norm.

The number of cars per household is also frequently considered an important variable to modal choice. In the Chicago study, the average number of cars owned per household was 1.2; in the Denver survey, the average was 1.7, a significant difference. The number of households owning various numbers of cars in the 2 cities is given below. If a weighted figure is used, far more Denverites have 2 or more cars than Chicagoans. This could explain the decline in bus ridership that took place in Denver.

Number of Cars	Chicago	Denver	Denver Weighted
0	58	62	34
1	435	478	263
2	187	556	306
3	21	139	76
4		31	17
5		7	4
6		1	1
Total	701	1,274	701

Correlation of Variables

Two distinct correlation matrices were obtained. The first included 9 variables regarding general opinions about public transit. That matrix is given in Table 3. There are no significant correlations among the distance to work (4) or the distance to DMT (11) and the other variables, except there is fairly good correlation between distance to work (4) and DMT use (12), an expected negative value (-0.26). When salary level (1) and DMT use (12) are compared, there is a -0.22 correlation, which is one of the higher values but still not a strong correlation.

The second correlation matrix is a more general review of modal choice and is given in Table 4. Several of the correlations were related by definition; others that are expected although not mandatory include distance to work (4) and distance to bus stop (11), 0.682; parking cost (15) and bus cost (16), -0.538; travel time to work (3) and distance to work (4), 0.349; number of licensed drivers (7) and number of cars (8), 0.718; total cost (34) and distance to work (4), 0.603; total cost (34) and use of a car pool (9), -0.375; and total cost (34) and log of the distance to work (30), 0.546. Of potential value to the users of the study results are several correlations including total cost (34) and use of DMT (12), -0.326, which reflects the economy of the DMT even when compared with out-of-pocket costs of only 5 cents/mile to drive; total cost (34) and frequency of DMT use (13), -0.314; total cost (34) and distance to the bus (11), 0.443; and total cost (34) and salary level squared (32), 0.590. The last item indicates a strong willingness by those having higher salaries to spend more time traveling and, conversely, by those having lower salaries to optimize costs. The salary level squared (32) is also positively correlated with travel time to work (3), 0.354; distance to work (4) in a very strong manner, 0.934; and distance to DMT (11), 0.635. The conclusion is that the lower salaried worker will optimize costs and the more highly paid worker will live farther away and will be less concerned about costs.

Table 1. Data source.

Firm	Sample Size	Total Downtown Employment	Kind of Business
01	446	1,100	Bank
02	85	—[a]	Dry goods
03	23	285	Bank
04	34	750	Bank
05	10	81	Bank[b]
06	362	3,808	Public utility
07	164	1,368	Bank
08	53	1,400	Public utility
09	44	150	Savings and loan
10	59	—[a]	Dry goods
Total	1,280	—	—

[a]Not available. [b]Combined with firm 07 for analysis.

Table 3. General preference correlation.

Variable	Variable 4	9	11	12	23	25	26	17	1
4	1.000	0.099	0.682	-0.261	-0.011	0.059	0.059	0.116	0.210
9		1.000	0.101	-0.216	0.010	0.064	0.069	-0.004	0.048
11			1.000	-0.262	-0.048	0.040	0.070	0.119	0.166
12				1.000	0.121	0.082	0.063	-0.038	0.216
23					1.000	0.200	0.178	0.133	-0.122
25						1.000	0.896	0.224	-0.023
26							1.000	0.237	0.008
17								1.000	0.069
1									1.000

Table 2. Relation of variables.

Number	Variable	Firm (mean) 01	02	03	04	06	07-05	08	09	10	Total Mean	Standard Deviation	Size
1	Salary range	2.78	1.64	2.27	2.16	2.65	2.73	3.06	2.64	1.49	2.60	1.10	1,179
2	Starting work hour	0800	0840	0810	0825	0915	0740	0750	0800	0900	0836	2.2	1,256
3	Travel time, min	39	42	43	34	50	41	43	40	42	43	17	1,184
4	Distance to work, miles	8.7	6.9	10.3	7.5	8.9	9.0	7.7	7.3	7.6	8.6	6.1	1,264
5	Can leave work on time	0.73	0.81	0.78	0.76	0.90	0.79	0.96	0.77	0.90	0.82	0.39	1,274
6	Licensed to drive	0.95	0.84	0.96	0.97	0.91	0.96	0.91	0.95	0.86	0.93	0.26	1,280
7	Number in family licensed	1.96	1.67	1.83	2.12	2.02	2.12	1.98	2.02	2.02	1.99	0.86	1,278
8	Number of cars in family	1.69	1.29	1.78	1.59	1.75	1.90	1.83	1.68	1.54	1.71	0.87	1,275
9	Car-pool member	0.24	0.24	0.17	0.35	0.21	0.33	0.30	0.18	0.15	0.24	0.43	1,280
10	Occupancy in car pool	2.4	2.4	2.3	2.3	2.7	2.3	2.7	2.0	3.0	2.3	1.0	330
11	Distance to bus stop, blocks	15.2	8.1	25.5	14.4	14.8	14.9	17.0	9.8	7.9	14.3	23.9	1,197
12	Use DMT	0.33	0.54	0.30	0.38	0.45	0.37	0.23	0.48	0.58	0.39	0.49	1,279
13	Frequency of use, days	15	18	20	16	18	17	16	16	21	17	7	502
14	Parking distance, blocks	2.9	2.1	3.3	1.2	3.0	2.7	3.2	1.7	3.5	2.8	2.6	810
15	Parking costs, dollars/month	13	19	12	13	14	16	17	17	15	14	9	809
16	Transit costs, dollars/month	12	14	16	13	14	13	12	12	16	13	6	509
17	Do park and ride	0.03	0.07	0.17	0.03	0.05	0.06	0.04	0.05	0.09	0.05	0.21	1,273
18	Percent of park-and-ride trip by bus	48	47	65	—	67	42	47	—	51	55	28	60
19	Switched modes	0.23	0.25	0.36	0.27	0.33	0.33	0.25	0.25	0.21	0.28	0.45	1,243
20	Switched mode to DMT	0.58	0.82	0.50	0.78	0.56	0.47	0.08	0.55	0.47	0.57	0.50	346
21	Aware of cost from mile-high stadium	0.76	0.73	0.87	0.76	0.87	0.77	0.78	0.93	0.64	0.80	0.40	1,203
22	Aware of free passengers on mile-high shuttle	0.61	0.60	0.41	0.59	0.65	0.62	0.57	0.84	0.48	0.62	0.49	1,177
23	Would use mile-high shuttle if stopped close to work	0.16	0.29	0.09	0.21	0.11	0.11	0.11	0.19	0.15	0.14	0.35	1,153
24	If so, how often, days	18	21	22	16	20	17	22	15	19	19	6	159
25	Would use minibus service	0.72	0.75	0.82	0.70	0.73	0.74	0.44	0.62	0.69	0.71	0.45	1,192
26	Would pay a moderate fee	0.75	0.67	0.81	0.70	0.76	0.73	0.47	0.59	0.65	0.72	0.45	1,168
27	Would use park-and-ride	0.39	0.28	0.65	0.39	0.39	0.41	0.34	0.33	0.22	0.37	0.48	1,047
28	Use free bus—same service	—	0.71	—	—	0.58	—	—	—	0.69	0.66	0.47	148
29	Use free bus—better service	—	0.85	—	—	0.86	—	—	—	0.69	0.84	0.37	146

Table 4. Correlation of values used in multistep linear regression equations.

Variable	Variable 2	3	5	4	6	7	8	9	11	12	13	17	15	16	1	30[a]	31[b]	32[c]	33[d]	34[e]
2	1.000	0.172	0.061	-0.018	-0.074	-0.020	-0.038	-0.051	-0.003	0.027	0.043	-0.053	-0.006	0.044	-0.087	-0.025	-0.011	-0.027	-0.051	0.009
3		1.000	0.040	0.349	-0.017	0.071	0.095	-0.020	0.241	0.056	0.112	0.122	-0.078	0.119	0.097	0.351	0.072	0.354	0.078	0.148
5			1.000	-0.096	-0.076	0.011	-0.034	0.040	-0.055	0.134	0.144	0.080	-0.156	0.152	-0.202	-0.114	-0.004	-0.105	-0.063	-0.172
4				1.000	0.121	0.172	0.233	0.099	0.682	-0.261	-0.228	0.084	0.108	-0.198	0.180	0.840	0.176	0.934	0.157	0.603
6					1.000	0.297	0.226	0.059	0.062	-0.220	-0.261	0.017	0.212	-0.252	0.199	0.147	0.143	0.129	0.124	0.128
7						1.000	0.718	0.102	0.140	-0.094	-0.107	0.055	0.087	-0.077	0.093	0.247	0.672	0.211	0.009	0.097
8							1.000	0.082	0.198	-0.222	-0.224	0.039	0.215	-0.211	0.126	0.299	0.938	0.269	0.592	0.222
9								1.000	0.101	-0.216	-0.283	-0.015	0.066	-0.280	0.040	0.116	0.059	0.102	0.009	-0.375
11									1.000	-0.262	-0.234	0.088	0.114	-0.212	0.134	0.533	0.172	0.635	0.130	0.443
12										1.000	0.876	0.270	-0.471	0.848	-0.208	-0.249	-0.169	-0.271	-0.219	-0.326
13											1.000	0.278	-0.538	0.967	-0.235	-0.216	-0.165	-0.241	-0.215	-0.314
17												1.000	-0.133	0.274	-0.033	0.109	0.018	0.101	0.015	-0.081
15													1.000	-0.538	0.172	0.191	0.162	0.157	0.229	0.569
16														1.000	-0.224	-0.194	-0.154	-0.214	-0.222	-0.264
1															1.000	0.210	0.145	0.190	0.116	0.177
30[a]																1.000	0.218	0.957	0.197	0.546
31[b]																	1.000	0.202	0.457	0.171
32[c]																		1.000	0.175	0.590
33[d]																			1.000	0.213
34[e]																				1.000

[a]Log of distance to work. [b]Cars squared. [c]Salary squared. [d]Car-driver ratio. [e]Total cost.

A review of the highest salary firm (08) and two low-salary firms (02 and 10) results in a verification of the general results.

Multistep Regression Analysis

The purpose of the multistep regression analysis is to assess the effects that a number of variables acting jointly have on modal choice. In particular, characteristics of persons and households are treated in conjunction with properties of the transportation choices available to them in order to clarify the complex of causes impinging on modal choice in the Denver area. The variables investigated include, as far as practicable, those that seem likely, either a priori or on the basis of substantial evidence from previous studies, to have impact on modal choice. The firms were evaluated individually and collectively. The evaluation constitutes a test, carried out with new data, of a collection of factors indicated, on grounds of inherent reasonableness or prior evidence, to be potentially useful predictors of modal choice.

The method used here is that of multivariate linear regression analysis. Only one model is formulated for each firm, with a single dependent variable (use of public transit) and several independent variables. The general model is of the form

$$Y = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n + \epsilon$$

in which Y is the dependent variable, $x_1, \ldots, x_n$ are the independent variables, β_o, β_1, $\ldots$, β_n are the unknown coefficients of the model, and ϵ represents the net effect of contributions to the value of Y other than those specified by the first n + 1 terms on the right side.

The actual calculations were performed by a CDC 6000 computer and a stepwise regression program wherein one independent variable is added to the regression equation at each step.

The complete set of independent variables, from which multiple-regression models were developed is given in Table 5. The empirical values of the variables consist of data from the work-trip survey except as otherwise noted in the following. The definitions of most of the variables are self-explanatory; additional comments follow.

Dependent Variable—The only dependent variable studied was the use of DMT (x_{12}) as a relation between transit versus all other trips.

Independent Variables—The independent variables in group B are mathematical combinations or variations of selected group A variables and were formed to represent possible interactions among them. Each of the variables is adequately defined except x_{26}, total cost, which was derived as follows:

$$\text{Total cost} = \left\{ \frac{[(\text{distance to work}) \times (\text{cost per mile to drive car}) \times (2 \text{ trips/day}) \times (22 \text{ days} - \text{DMT use})] + (\text{parking costs})}{1 \text{ or (number in car pool)}} \right\} + \text{transit costs per month}$$

$$x_{26} = \left\{ \frac{[(x_5)\ (0.05)\ (2)\ (22 - x_{13})] + (x_{17})}{1 \text{ or } x_{10}} \right\} + x_{18}$$

Results—Results are given in Table 6 for all 9 individual evaluations and for the total survey. For a majority of the analyses, 15 independent variables were entered into the equation. For the total survey, the residual variance (mean square error) of x_{12} is 0.166 with 1,264 degrees of freedom. The regression mean square is 6.382 with 15 degrees of freedom. The multiple correlation coefficient R is 0.5598, and R^2 is 0.31. Thus, 31 percent of the total sum of squared deviations of the dependent variable from its mean is accounted for by the effects of the independent variables in the equation. The standard error and F ratio to remove the variable are given in Table 6 for the total survey only. Some of the individual firms have very high R^2 values indicating little deviation from the equation.

Interpretation—A number of substantive findings emerge from the multivariate statistical analyses that have been described.

First, there is structure in the data in the sense that there is overwhelming evidence for the existence of functional relations between the dependent and independent variables. The ratio of regression to residual mean squares F is 38 for the equation estimating transit use. The expected value of F is 1 under the assumption that the independent variables have no systematic effects on the dependent variable.

The independent variables exerting major influence on the dependent variable, as measured by the individual F values, are relatively few in number. There are 15 independent variables in the regression equation of Table 6 for the total sample. There are 25 candidate independent variables.

Examination of the independent variables not included in the regression equations is of equal interest with the examination of those included. There are 8 independent variables outside the equation in every case. The following basic variables are not represented in any equation in any form: the number of riders in a car pool, frequency of public transit use, use of a park-and-ride, parking distance from work, parking cost, bus costs, mode of travel, and split between bus and car.

Exclsuion from the regression equations does not mean that the variables are totally without effect, but it does mean that the effects of the included variables are dominant. Examination of those variables would result in concurrence that they should have little or no effect on the modal choice decision.

The equation for each firm is included so one may select an equation to fit a specific set of circumstances. For instance, a successful campaign by DMT to increase ridership in dry goods companies (02 and 10) may be completely unsuccessful in other firms.

Conditioning Variable Analysis

For this analysis, the cases were separated into groups based on specified intervals of one variable, the conditioning variable. For the selected groups, computations were performed on a number of other variables that can be designated as conditioned variables. Different mean values of the conditioned variable for the different intervals of the conditioning variable would indicate a relation.

Five conditioning variables were selected: salary level, distance to work, ability to leave work on time, distance on the public transit stop, and use of DMT. This analysis was not performed for the total of all firms because the program case limits are 700 and the total sample was 1,280 cases. The analysis is based on individual firms, usually only using the larger sample sizes in order to have adequate occurrences in each of several conditioning variable intervals. Results are presented in terms of the conditioning variable.

Salary level—As salary level increases, travel time, car pool use, parking costs (with walking distance after parking down), awareness of the mile-high shuttle service, and awareness of the free passenger ride on the mile-high shuttle all increase dramatically. There is also some increase in travel time to work and number of vehicles in the family. There exists some trend toward less willingness to use the mile-high shuttle and a definite downward trend in the use of DMT. No significant correlation exists between salary level and potential use of the minibus or payment of a moderate fee for that service.

Distance to work—The distance from place of residence to work was selected as the second conditioning variable with the following intervals: <2.1, 2.1 to 5.1, 5.1 to 10.1, 10.1 to 20.1, 20.1 to 30.1, 30.1 to 50.1, and >50.1 miles (insufficient data cases exist for distances of more than 20 miles). As distance increases, travel time to work and distance to a DMT stop both increase as expected. The increased use of a car pool, higher salary, and some increased willingness to use the park-and-ride are other directly related variables. A general but not very significant reduction in use of DMT was noted, and the mile-high shuttle and minibus questions show no correlation.

Leave on time—The ability to leave work on time was opposed to not being able to leave on time and compared with 3 selected public transit modes. About twice as many (percent) use the DMT if they can and do leave work on time, probably partly as a result of having nonmanagement positions and earning less money (hence, increased ridership) and partly as a function of assurance of the availability of the public transit.

In general, almost none of those who must stay late views the park-and-ride concept as a viable option, but 8 percent of those who can leave on time would use it. Conversely, those who cannot or do not leave on time favor the minibus concept more than the others.

Distance to DMT—The distance, in blocks, to the nearest DMT stop was selected as a conditioning variable with 8 intervals: <0.1, 0.1 to 1.1, 1.1 to 2.1, 2.1 to 3.1, 3.1 to 4.1, 4.1 to 10.1, 10.1 to 20.1 and >20.1. As distance increases, the use of a car pool increases and the use of DMT increases then decreases after a few blocks. Although there is no trend in the current use of park-and-ride, there is an upward trend in willingness or desire to park-and-ride from the suburban shopping centers.

Use DMT—DMT use was divided into those who do (at least some) and those who do not, and 9 conditioned variables were evaluated. From 10 to 20 percent fewer respondents who have valid drivers' licenses use DMT, and there are about 0.3 fewer cars in the family of DMT users. Travel time to work trends upward but not significantly. There is no trend in awareness of the mile-high shuttle concepts, but there is a general trend to use mile-high shuttles and the minibus concepts (10 percent increase) if DMT is used. Park-and-ride from shopping centers seems uncorrelated.

Factors Cited as Important in Evaluation and Selection of Modes of Travel

Basic Data—Responses to 2 questions in the survey on the factors influencing modal choice are summarized in this section. The single set of factors and factor codes was set up after an initial listing was made of all the various answers given to these questions. The factors were arranged in 20 groups for convenience of coding and reference.

The 2 parts of the primary modal-choice question are repeated here to show the influence placed on the responder by a list of several potential reasons.

> Why do you take DMT? For example, safety, travel time, economy, comfort, convenience, chance to read, others need car, or bad weather.
>
> Why do you not take DMT? For example, travel time, comfort, privacy, convenience, like to drive, car needed at work, waiting, transferring cost, or exposure to weather.

As many as 4 reasons were keypunched for each respondent. If the respondent listed more than 4 reasons, a general preference code was usually keypunched. Frequently, for those who use DMT only part of the time, the factors may be both favorable and unfavorable.

The second question was answerable only if the person had switched to or from predominant use of public transportation for his work trips while maintaining his present places of employment and residence. The questionnaire heading under which replies were written read, "Main reasons for the switch." Once again, as many as 4 reasons per respondent were keypunched and are included in the analysis.

Frequencies of cases for each modal choice are shown below (from a possible 1,280 total cases).

Response	Frequency
Do not use DMT	775
Use DMT	505
Use DMT full time	293
Use DMT less than full time	212
Switch to DMT	196
Switch from DMT	150

Frequency and Aspect of Citation of Some General Travel Factors in Relation to Trip Mode—The basic data could be considered from many points of view. The approach taken is to compare various kinds of trips with respect to the frequency of citation of some of the general factors or qualities most often used to assess relative merit of travel alternatives. The factors are general preference or absence of real alternatives,

travel time, cost, convenience, comfort, effort and strain of travel, danger or safety, and effects of weather. In each of the 8 citations, frequencies are given separately for the various trip classes.

The number of factor citations for each trip class or combination is divided by the number of trip reports of that class to give the relative frequency of citation (expressed as a percentage). If a factor is determinative of choice of a particular type of trip, it may also be said to be favorable or unfavorable for any specific case, so citations under the aspect of determinative can reasonably be combined when the contrast between favorable and unfavorable assessments is emphasized.

General Preference and Lack of Real Alternatives

The number of citations of the factor "general preference and lack of real alternatives" was roughly proportional to the number of trip reports in the various trip classes. There was a tendency for those who use DMT full time not to complete the rest of the questionnaire, and that may explain the 9 percent for DMT users as opposed to 6 percent for nonusers. These factors were considered as determinative of choice of travel mode rather than as favorable or unfavorable.

Travel Time

The travel time factor was cited 201 times (26 percent) by the 775 cases that do not use DMT. Of those who use DMT full time, 18 (6 percent) cited travel time as favorable. As expected, the travel time in private transportation is considered favorable and shows the willingness of many workers to drive to work in order to save a very few minutes.

Travel Cost

The travel cost factor was stated to be determinative of choice in 19 percent of all trip reports. Of non-DMT users, 53 or 7 percent cited economy as the reason for not using DMT. Many of those have free company-paid parking or are members of car pools. Of the DMT users, there were 202 citations (40 percent), of which 193 were favorable. Cost, or conversely, economy is a very strong positive factor for those using DMT.

Convenience

Convenience (Table 7) is the general travel factor most often cited in the survey. In terms of the component code groups combined under the general names, there are 421 references to convenience in the data. That total is considerably larger than the totals for any other general factor. For those who do not use DMT at all, 32 percent cited the convenience of private transportation or the inconvenience of public transportation. For those who use DMT, at least part time, the convenience factor is also very strong; 31 percent cited the convenience of public transportation.

Comfort

Comfort, specifically, was declared to be determinative of choice in 5 percent of trip reports. The general category of comfort and amenities within the vehicle was cited 175 times or about 14 percent of the time (some respondents cited more than one of these areas that would reduce the percentage slightly). Automobile users cited crowding or congestion of buses and privacy as the prime amenities. For DMT users, the ability to read, study, or work drew a large response with 43 citations (9 percent of the DMT users).

Effort and Strain of Travel

The physical and mental effort and strain of travel are covered by this general factor. Very few of the respondents (2 percent) listed this as a factor in choice of travel mode. There is a sharp contrast between driving and DMT trips with respect to this

factor. A total of 25 DMT users cited this general category; that agrees with findings in the Chicago study. Of those who switched to DMT, 14 percent cited this category as the reason.

Danger or Safety

Danger or safety was rarely named as a factor by those who drive, the largest concern being safety at night (1 percent). Safety was discussed by 10 percent of those who use DMT at least part of the time. Of those who switched to DMT, 9 percent cited safety, and only 3 percent who switched from DMT listed it.

Weather

Vulnerability to weather is, to a greater or lesser extent and in various ways, a characteristic of all types of trips. Personal exposure to weather is a particular drawback for some kinds of trips, and hazardous driving is for others. Of those who do not use DMT, 50 (6 percent) cited exposure to weather; of those who use DMT, 67 (13 percent) cited bad weather driving as the undesirable aspect. Many respondents indicated that the only time they use DMT was in inclement weather.

Some Additional Specific Factors Related to Modal Choice

Detailed data on a large number of specific factors that survey respondents considered important with respect to modal choice are also analyzed. These specific factors are in addition to the more general factors treated in the preceding section. Those specific factors cited most frequently in connection with the various classes of trips are pointed out there.

Car unavailability, on the one hand, and car necessity, on the other, were very frequently cited specific factors determining nondriving and driving trips respectively. The specific factors with their frequency of citation under car unavailability are as follows:

Factor	Frequency
Car not available or not operable	24
Do not have car	30
Car needed at home	55

The specific factors under car necessity are as follows:

Factor	Frequency
Car needed or better for errands	20
Car needed for work	75
Work nonstandard hours	13

Those factors were also cited heavily in the Chicago survey. Of those who do not use DMT, 10 percent stated a need for a car at work.

"Like walking" was stated to be a desirable property of walking trips by 33 non-DMT users, and "less walking" was cited by 9. "Like to drive, do not mind driving" was a factor cited in 10 percent of the reports of driving trips in Chicago and only 3 percent in Denver. "Ecology" was cited by 36 respondents who use DMT and by 19 who switched to DMT.

"Car pool availability" was cited in a fairly large number of cases (40) along with a "ride being available" (24). The need to "pick up or discharge others," usually children, was mentioned by nearly 4 percent of the drivers.

On the unfavorable side, 10 percent of all 1,280 sampled indicated the DMT was too far away; 11 percent of those who do not use DMT cited poor DMT scheduling as the reason. An even larger number, 14 percent of the non-DMT users, disliked the waiting for late buses, and 4 percent disliked transferring. Many who have switched from DMT cited scheduling (27) or waiting (17) as the reason.

Switches Between Major Modes of Travel

There were 346 instances in which the person responded affirmatively to the question on switching major mode of travel while working in the CBD and residing at his or her present address. In 57 percent of these cases, the switch was to greater use of public transportation facilities; in the remaining 43 percent of the cases the switch was in the opposite direction. This represents a significant reversal from the situation in Chicago, where 67 percent switched away from public transit. Some further analysis is warranted and is given in Table 8 for both Chicago and Denver surveys. The specific factors from the survey are grouped into 10 classes of reasons. The frequencies of citation of reasons in each class are given separately for mode changes in the 2 directions. Frequencies are expressed as numbers of citations of factors in each class and also as a percentage of the number of switches.

Ease was cited in 53 percent of the switches to public transit in the Chicago study and in only 13 percent in the Denver study. In Denver, the largest factors influencing a switch to DMT were cost (38 percent), convenience (25 percent), and availability (18 percent). The major explanations for the difference in the percentages switching to public transit appear to be cost and convenience. For the switches from public transit, time, convenience, and availability of private transportation were predominant. The "switch-from" responses were very closely correlated between the 2 surveys.

SUMMARY AND CONCLUSIONS

The subject of the present research project, factors influencing use of the various modes of transportation in trip-making within urban areas, is highly relevant to basic decisions concerning the character of future metropolitan travel facilities. The importance of making sound decisions in the shaping of metropolitan transportation networks is now generally recognized in view of the continuing growth of population and its increasing concentration in the urban areas of the country. Transportation technology has provided a variety of feasible means and modes of urban travel including the minibus and fairly fast bus transit systems. However, intelligent evaluation of alternative possibilities in transportation planning requires that many factors other than purely technical ones be taken into account. The way a complex of transportation facilities of various modes will be used depends as much on characteristics of the population and the geographical distribution of activities as on the characteristics of the network itself. The interplay of the diverse factors that affect modal travel patterns requires for its elucidation both penetrating methods and adequate data.

The measures of effectiveness of a public transit system relate to how well and how efficiently the system serves the travel needs of the population of users. Freedom of choice among alternative ways of traveling complicates the problems of valuation and prediction; at the same time, it makes it possible to investigate empirically the factors that are important to travelers in the making of travel decisions. Research on the present project has used appropriate conceptual models in conjunction with data on travel through multimodal urban transportation systems in order to identify the main factors influencing modal choice and to quantify the effects of those factors operating jointly. Travel patterns in the large are, after all, the result of a multitude of personal choices. The best approach and one that permits both depth of causal analysis and breadth of population coverage is the statistical treatment of detailed information on a large number of individual cases. That course has been followed to the extent possible.

In conclusion, relatively few factors can explain a sizable portion of the modal choices. Although some of those are not alterable, others are and should be approached to assist in additional public transit use.

The mean number of drivers per household is 1.99 in the work-trip survey. The effect on transit use of varying the number of drivers per worker's household is certain. As the number of drivers increases, the worker is more likely to use public transportation. That is the relation to be expected because of competition for a limited number of cars.

There is also a strong effect of number of cars per household on transit use by workers. The mean number of cars owned by members of the household is 1.71 in

Table 5. Independent variables for multistep regression analysis.

Group	Variable	Symbol
A	Zip code of home address (not used in regression)	x_1
	Starting work hour	x_2
	Travel time to work, min	x_3
	Can or cannot leave work on time	x_4
	Distance to work, miles	x_5
	Are or are not licensed to drive	x_6
	Number in family licensed to drive	x_7
	Number of cars in household	x_8
	Member of car pool	x_9
	Number of riders in car pool including respondent	x_{10}
	Distance to nearest bus stop, blocks	x_{11}
	Frequency of use of DMT, round trips/month	x_{13}
	Currently use park-and-ride (dual-mode car and public transit)	x_{14}
	Location of parking for park-and-ride (not used in regression)	x_{15}
	Parking distance from work, blocks	x_{16}
	Parking cost per month, dollars	x_{17}
	Public transit cost per month, dollars	x_{18}
	Mode of travel (not used in regression)	x_{19}
	If dual mode, percentage of trip by public transit	x_{20}
	Salary level	x_{21}
B	Logarithm of distance to work = log (x_5)	x_{22}
	Square of number of cars in household = $(x_8)^2$	x_{23}
	Square of salary level = $(x_{21})^2$	x_{24}
	Car-driver ratio = (x_8/x_7)	x_{25}
	Total cost, dollars/month	x_{26}

Table 6. Multivariate regression analysis results.

Variable	Firm Values									Total	Standard Error	F Ratio
	01	02	03	04	06	07,05	08	09	10			
All	0.983	1.12	0.07	3.403	0.987	1.125	1.869	11.28	0.017	0.93	—	—
x_2	-0.0003	-0.0002	-0.0003	-0.0015	—	-0.00005	-0.0014	-0.102	-0.0002	-0.00007	0.00005	1.9
x_3	+0.0024	+0.0009	-0.0022	+0.0114	+0.0022	+0.0035	+0.0086	+0.0099	+0.0021	+0.0026	0.0006	15.9
x_4	+0.0073	-0.1212	+0.3289	+0.1698	+0.1521	+0.0491	+0.2088	+0.2344	+0.4531	+0.0513	0.0302	2.9
x_5	+0.0186	+0.0214	+0.2726	-0.2193	+0.0348	+0.0277	+0.1695	+0.0874	—	+0.0260	0.0064	16.4
x_6	-0.3489	-0.1356	-0.1336	—	-0.1389	-0.1560	+0.0604	-0.4726	+0.0636	-0.2467	0.0489	25.5
x_7	+0.1098	-2.066	+0.7489	-0.5487	+0.0750	-0.0911	—	-0.5783	+0.030	+0.0707	0.0321	4.9
x_8	-0.1033	+0.3527	-1.313	+0.5406	-0.3027	-0.0851	-0.2728	+0.1357	-0.181	-0.1223	0.0710	3.0
x_9	-0.3258	-0.5822	-1.081	-0.4099	-0.6689	-0.2788	-0.0354	-0.4409	-0.9492	-0.4427	0.0333	176.9
x_{11}	-0.0020	-0.0045	-0.0028	+0.0042	-0.0012	—	-0.0021	-0.0131	-0.0051	-0.0017	0.0007	6.0
x_{21}	-0.0194	+0.0908	+0.1574	+0.1570	-0.1377	-0.0512	-0.1156	-0.0342	-0.1538	-0.0373	0.0097	14.8
x_{22}	+0.6337	+0.6676	+2.456	-1.087	+0.2836	+0.0760	-0.5752	-0.7979	+1.174	+0.5020	0.1528	10.8
x_{23}	-0.0071	-0.05	+0.1583	+0.0827	+0.0492	+0.0091	+0.0276	+0.1800	+0.0443	+0.0081	0.0109	0.6
x_{24}	-0.4616	0.3463	-4.1793	+2.627	-0.4319	-0.4175	-1.471	-0.4692	-0.5813	-0.5024	0.1471	11.7
x_{25}	-0.0718	-0.2033	+0.8760	-1.887	+0.0924	-0.2135	-0.1000	-1.8784	+0.1241	+0.0204	0.0705	0.1
x_{26}	-0.0132	-0.0193	-0.0437	-0.0179	-0.0196	-0.0138	-0.0021	-0.0098	-0.0139	-0.0146	0.0012	152.9
R^2	0.27	0.43	0.93	0.58	0.43	0.31	0.49	0.59	0.68	0.31	—	—

Table 7. Frequency of citation of convenience as a factor in modal choice.

Trip Class	Trip Reports	Citation Aspect: Determinative Number	Determinative Percent	Favorable Number	Favorable Percent	Unfavorable Number	Unfavorable Percent
Do not use DMT	775	175	23	0		71	9
Use DMT	505	150	30	6	1	18	3
Use DMT part time	212	54	26	0	0	17	8
Use DMT full time	293	96	33	6	2	1	0
Switch to DMT	196	42	21	10	5	0	0
Switch from DMT	150	15	10	0	0	7	5

Table 8. Stated reasons given in Chicago and Denver work-trip surveys for switching to or from predominant use of public transit.

Reason for Switching	Chicago: To Transit Number	Chicago: To Transit Percent	Chicago: From Transit Number	Chicago: From Transit Percent	Denver: To Transit Number	Denver: To Transit Percent	Denver: From Transit Number	Denver: From Transit Percent
Availability of means of transportation	14	27.4	37	37.4	36	18.3	36	24.0
General preference	0	0.0	14	14.1	9	4.6	6	4.0
Cost	9	17.6	8	8.1	75	38.3	12	8.0
Time	4	7.8	37	37.4	12	6.1	35	23.3
Convenience	9	17.6	24	24.2	49	25.0	49	32.7
Comfort	6	11.8	16	16.2	4	2.0	13	8.7
Ease (less effort, strain, road congestion)	27	52.9	7	7.1	25	12.8	9	6.0
Safety, health	3	5.9	1	1.0	13	6.6	1	0.7
Environment, weather	1	2.0	5	5.0	6	3.1	3	2.0
Auxiliary activities	6	11.8	4	4.0	5	2.6	0	0.0

Denver and only 1.24 in Chicago. That factor alone explains a fair part of the past demise of Denver's public transit. There is a large decrease in transit use when 1 car is owned, and a further decrease when the number of cars owned increases to 2 and 3.

Time spent waiting for vehicles was found to have a significant effect on transit use. Many respondents indicated a long waiting time for delinquent buses.

There is a strong indication toward a willingness to use public transportation in one or more of its newer forms. More than 70 percent of the respondents indicated a willingness to use minibuses, and 37 percent indicated a willingness to use park-and-ride from outlying shopping centers. Unsolicited but welcome comments to each of those concepts were overwhelmingly favorable. They will not switch overnight, however.

As a final conclusion, all concrete results of this project, in terms of the factors that are indicated to be most influential in travel decisions, seem to be consistent with the Chicago results and with reasonable human responses to the transportation alternatives that are available.

On the basis of the research performed and the results achieved in the present project, the following recommendations are made:

1. Results of the present project show that relatively uncomplicated modal assignment models can incorporate nearly all the predictive power inherent in a fairly extensive set of independent variables. It is recommended that the variables found to be jointly most effective in the work done here be further tested in other cities or tested again in Denver after a few years of successful operation of the DMT.
2. The continuing public relations campaign of the DMT will bring results especially if accompanied by on-time service and consideration of the customers.
3. The park-and-ride concept from suburban shopping centers will meet with the same success as the Blue-Streak project in Seattle, if the buses are comfortable and express.
4. Minibus service, for free or with a moderate fee, will gain considerable ridership.

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