TOWARD THE DEVELOPMENT OF MEASURES OF CONVENIENCE FOR TRAVEL MODES

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This paper describes a research project aimed at investigating the effect on disaggregate, behavioral, modal-choice models of the inclusion of 2 alternative measures of convenience. The 2 measures investigated compare a proxy variable for convenience, which could be included in many existing models without further data collection, and a scale index that was developed from the use of psychological scaling techniques, which will require longer term development and additional data collection. Both measures correlated highly with travel mode choices, although data limitations prevented any actual model building with the scale index. The proxy variable for convenience was found to add significantly to the explanatory power of a modal-choice model and to improve substantially the specification of the model. This paper describes the data sets used to generate these results and discusses the analytical processes used to derive scale information from preference and attitude data. A survey of previous work in the topic area, which is also included, shows that this paper reports on one of the first successful attempts to incorporate a measure of convenience in an urban modal-choice model.

•THIS PAPER describes a research task concerned with providing 3 products relating to measures of convenience for urban travel modes. The first product is an inventory of previous work concerning both comfort and convenience and an assessment of the effectiveness of such efforts in producing a quantifiable convenience variable for inclusion in a travel demand model. Second, the research is intended to provide a theoretical basis for defining and quantifying convenience. Third, the research is to produce prototypical measures of convenience. One of these measures would be of immediate practical use, and another would require a longer time to develop but might provide a more conceptually satisfying and more accurately measured convenience variable. During the research, some data collection was carried out and detailed analysis was performed on some preexisting data sets.

A search of the literature revealed that previous attempts to postulate comfort and convenience variables can be grouped into 3 general categories. The first category does not lead directly to the definition of a variable per se, but is rather a mechanism for determining whether comfort and convenience are important variables. This is done by asking open-ended questions designed to elicit information on the level-of-service characteristics that individual travelers consider to be important. Such questions, however, lead to unstructured responses and a tendency to produce superficial attitudes and opinions rather than stable preferences. Nevertheless, a number of the early studies used this approach. Stopher (23) provided an open-ended question in his survey of faculty and staff of University College, London. From this, using a simple counting procedure (order of reporting of attributes was considered to be irrelevant), he defined time, convenience, cost, and comfort as being the most important

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modal attributes affecting choices of travel modes for the work trip. Because there were no techniques at that time to handle convenience and comfort in a quantitative model, this study developed models in terms of costs and times of travel only. Similarly, Bock (1) established, by this mechanism, that both comfort and convenience were among the most important modal attributes affecting choices between travel modes, but was unable to include quantities relating to these attributes in a travel demand model. Sommers (20, 21) also used the same technique, but then went on to use the second category approach.

This second approach is a simple ranking procedure in which a number of travel mode attributes are presented to the survey respondent, who is asked to rank order those attributes in the context of a specific mode use. This technique is better structured and provides less encouragement to a superficial response than the open-ended question. However, it depends for its worth on the analyst's listing of qualities or attributes and the nonambiguity of the description of those terms. There is also a tendency to lead the respondent to a bias because of the inclusion or omission of specific attributes and because of the order in which the attributes are presented to the respondent. The technique, similar to the first category approach, was used only to estimate the order of importance of various attributes. For example, Sommers (22) found the rank order of attributes to be time, convenience, comfort, safety, weather reliability, cost, noise, and mechanical reliability. It is interesting to note the similarity between this ordering, which was obtained for the author's workplace in the northeast United States, and the ordering from Stopher's survey at a university in central London. Neither study, however, leads to a quantification base for comfort or convenience.

The third category of approaches to working with modal attributes stems from the nonquantification from the first 2 categories already described. This category may be summarized as the application of psychological scaling techniques to modal attributes. A large number of approaches and techniques are available within this general category, and many of these are in their infancy both in general and in specific applications to transportation. The most extensively used data collection technique for scaling models in transportation applications is the semantic differential. This technique involves questioning respondents about a quality and requesting an answer on a numerical scale representing the range between 2 extreme adjectival phrases. In general, the scale is divided into 5 or 7 intervals; the central interval denotes impartiality, lack of preference, or indifference. The following might be a response scale for a typical question, How do you rate the level of service offered by your local bus service?

1	2	3	4	5	6	7
very satisfactory				very unsatisfactory		

This technique has been used extensively in attempts to quantify travel attributes or at least to rank order them. The earliest application appears to have been by Sommers (20) in an attempt to determine the market for a short-haul air service based on V/STOL. However, no quantification of hitherto intangible mode attributes was reported from this study; rather, the technique was used to produce rankings of attributes only. At the same time, a national survey was conducted for the Highway Research Board (8) of attitudes about modes of travel. Again, the semantic differential was used both for degree of satisfaction with each of the automobile and public transportation modes for 15 transportation attributes and for ranking these same attributes in order of importance. Convenience, per se, was not included in the list of attributes. The 7 most important attributes were found to be safety, reliability, independence, transfers, protection from weather, crowding, and comfort. In all of these attributes, the automobile scored more satisfactorily than public transportation.

A further use of the semantic differential technique was at the University of Maryland (16) in a survey that was designed originally to determine the most important modal attributes. To this end, attributes were ranked and factor analysis was performed on the attribute rankings. This led to the definition of major factors relating to reliability, travel time, weather exposure, cost, convenience, unfamiliarity, and state of the vehicle. This same data set was subsequently used by Hartgen and Tanner (7) to quantify attitudes and incorporate them in a modal-choice model. They hypothesized that modal choice is determined by a traveler's degree of satisfaction with a modal attribute, weighted by his order perception of the importance of that attribute for the specific trip. Because of limitations in the data base, the model was not conspicuously successful. However, the results obtained were sufficiently good as to suggest that further investigations along this approach would be worthwhile and also that work should be done to relate engineering and attitudinal measures.

If the semantic differential is used to provide the type of indexes postulated by Hartgen and Tanner, the following assumptions must be made: The respondent has knowledge of the absolute position of an attribute on the psychological continuum, the questions on attitude and the adjectival phrases used on the scale are unambiguous to all respondents, and the same scale extremes are used for all attributes since different adjectival phrases cannot be equated. The first of these assumptions is not theoretically acceptable, and the second and third present operational problems.

A second data collection technique—paired comparisons—has also been applied to transportation modeling. Like the semantic differential, this technique has been used primarily for unidimensional scaling models. (The difference between unidimensional and multidimensional scaling is discussed later in this paper.) With this technique, a respondent is asked to make a series of trade-offs between pairs of specific qualities of some entity, such as a trip or a travel mode. The technique has had little use, so far, in transportation work; the primary instance, which is discussed later in this section, was by Golob et al (6). There are several variations on this technique, but all have a similar analytical interpretation. In the simplest case, a respondent may be asked,

> In respect to this bus ride, which would you rather have (assuming you could have only one):
>
> A faster trip or a more frequent service?
> A quieter ride or a wider seat?

Some researchers, as noted by David (4), have claimed that bias may arise because of the ordering of the elements of a pair and of the set of pairs. Therefore, the ideal questioning procedure would provide every permutation of the attributes, taken 2 at a time and in random order, where the random order may be different for each respondent. Whether or not this avoidance of bias is elected, all combinations of the attributes should be included in the overall design. [A note on paired-comparison designs is included in this paper. Torgerson (29) presents several methods of treating incomplete data matrices by Thurstone's law of comparative judgment.] A rank ordering can then be obtained by determining how many times one attribute is preferred over others and how many times it is rejected. Using all permutations permits consistency checks and bias checks to be made for each respondent. Rank orderings are best obtained for aggregate groups rather than for individuals.

Questioning may also be carried out by generalizing for an attribute and questioning on mode preference, e.g.,

> In terms of quietness of ride, which do you prefer:
>
> Automobile or bus?
> Subway or elevated?

The same remarks apply as before concerning the structuring of the pairs and the initial analysis. Fuller details of the analytical procedures used for obtaining scale intervals are discussed later in the paper.

Golob et al. (6) used semantic differences and paired comparisons to assess the importance of the attributes of a new service (or mode)—the jitney taxi—to a specific community. No attempt was made in this research to quantify comfort or convenience parameters or to build forecasting models. Its major impact on the present research into convenience is the innovative use of unidimensional scaling in a transportation choice problem.

A number of other scaling techniques are available, particularly in multidimensional scaling. Since none of these techniques has been used thus far in transportation applications, they will not be discussed in this section. However, some note was taken of them in following the research reported here, and some discussion of them is given in a later section on the methodology adopted in this study.

Apart from the studies already mentioned, a number of researchers have noted an intuitive expectation that comfort and convenience are likely to be important factors in transportation demand analysis, and some have put forward suggested procedures for quantifying these attributes. Claffey (3) hypothesized that both attributes would be important in mode choice and suggested that serious consideration be given to research in this. More recently, Lave (11) and Hoel and Demetsky (9) reiterated this sentiment and put forward suggestions for how to do it. The suggestions of Lave are particularly pertinent and comprise a prescription for simultaneous measurement of traveler attitudes and corresponding physical and engineering attributes in an attempt to develop variables of comfort and convenience that may be computed from the physical specifications of a travel mode. Lansing, Mueller, and Barth (10) implicitly recognized the importance of comfort and convenience by including questions relating to them in their journey-to-work survey. They did not carry out any analytical work on these attributes, however.

Some further attempts at quantifying comfort and convenience should be noted. Bock (1) used integer values as dummy variables to describe the comfort and convenience of modes of travel. The values used were based partly on attitudinal survey results and partly on intuition; they are 1 for automobile, 2 for railroad, 3 for subway, and 4 or 6 for bus. The effectiveness of these values in the modal-split models was minimal. Lave (11) and Parker and Clark (17) attempted to add comfort and convenience through an implicit value of travel time by permitting (or forcing) this implied value to be different for different modes of travel. The disadvantages of these 2 approaches are the arbitrariness of the values used and the lack of responsiveness to service quality changes or new travel modes. Finally, Watson (31) proposed a convenience measure, comprising the number of journey units in a trip. A journey unit is defined as being each separate modal usage, walk, or wait involved in a trip (where each occasion of mode use, walking, or waiting is counted with a value of unity). In his intercity study, Watson found the journey-unit difference to be one of the most significant variables for explaining mode choice, more significant than cost difference and generally equal to time difference.

DEFINITIONAL PROBLEMS

There are at least 2 reasons for the general lack of success, so far, in quantifying comfort and convenience attributes of travel modes. First, the techniques used to date have been somewhat inappropriate or unresponsive to the requirements of quantification. Second, a comprehensive definition of either convenience or comfort has been lacking. It is most probable that each individual respondent to a transportation survey defines comfort and convenience in an individual fashion. Consequently, those studies that used the terms "comfort" and "convenience" without prior definition have, in fact, gathered data on ambiguous qualities of transportation. Therefore, the apparent failure of past efforts to quantify comfort and convenience and to include these quantities in travel demand models are very likely due to this lack of definition of the attributes.

Claffey (3) defines convenience as being "greatest when users least have to adjust their personal plans and living habits to use transit, and when the difficulties of getting to transit stations and aboard transit vehicles are minimized." Sommers (20, 21, 22) does not explicitly define convenience in any of his papers. However, he implies quite strongly that he defines convenience as the number of origin and destination connections, i.e., a function of the number of transfers. Bock (1) cites convenience as being made up of "convenience; inconvenience; flexibility; mobility; independence; no schedule; easy, simple, practical; lack of flexibility; lack of mobility; and lack of independence." Most of these terms, however, are still broad and ambiguous and provide little help in defining convenience.

Solomon et al. (19) summarize numerous studies that are concerned with determining factors that affect travel choices. By averaging overall studies, these authors determine the most important factors to be safety, reliability, time savings, and convenience respectively. They define convenience as comprising waiting, transferring, parking, and fare collection. Hartgen and Tanner (7) noted that the University of Maryland data, which they used, defined convenience as "avoiding walking more than a block." Golob et al. (6) define convenience as being made up of "having a seat, calling without delay, shelters at pickup, choose pickup time, easy fare paying, more phones in public places, ability to ask questions of a system representative, and coffee, newspapers, andthe like on board." These authors also define a level-of-service variable that comprises "arriving when planned, no transfer trip, less wait time, longer service hours, less walk to pickup, direct route, and dependable travel times." Finally, Watson (31) defines convenience as the number of journey units in a trip, i.e., as a function of the number of transfers.

Clearly convenience has not been defined in unambiguous terms and with adequate breadth to cover all situations. An attempt to provide such a definition was made in this study. Modal attributes are defined in the following manner. A trip may be considered to possess 4 principal attributes: safety, cost, comfort, and convenience. Safety relates to the likelihood of harm from accidents while the traveler uses the system; cost is the monetary outlay by the traveler; comfort refers to the environment in which the trip is made, the extent to which a trip may be enjoyed or not; and convenience refers to the efficiency and effectiveness with which a person can be transported from origin to destination.

Thus, convenience includes all time attributes of a trip (access, egress, line-haul, walking, waiting), reliability (the variance associated with travel time), and level of service (number of transfers required, availability and proximity of parking or boarding points). Since conventional travel models have included travel times as explicit quantified variables, the primary concern of this research was to provide a means of assessing the remainder of this definition of convenience and to attempt quantification of reliability and level of service as defined here.

RESEARCH APPROACH

The task of determining a convenience measure may proceed on at least 2 levels. The first level is to propose a simple proxy measure of convenience, which may be readily determined in new data collection or from existing travel data and which may be incorporated immediately in travel-choice models. Because of the breadth of the convenience definition already put forward, such an approach must be suboptimal with respect to the content of the variable. However, it may be optimal in terms of both cost and ease of use. The second level is to use psychometric scaling methods with survey responses to define an index of convenience and then incorporate such a measure in future model building. Both of these approaches have been adopted in this research task.

In the first-level definition of convenience, the journey-unit measure proposed by Watson (31) was adopted. As mentioned before, this measure comprises simply a count of the number of journey units in one complete trip, where a journey unit is defined as each part of a trip that involves a change of mode or travel activity. Thus, a trip that comprises a walk to the suburban station, a commuter train ride, a downtown bus ride, and a walk to the office has the following journey elements: walk, wait, rail ride, walk, wait, bus ride, walk. The total number of elements is 7, and this would be the value of the journey-unit variable for this trip. Compared with this, an automobile trip might comprise walk, car ride, park, walk. Thus, the automobile trip has a journey-unit variable value of 4.

The convenience rating is one that increases with decreasing convenience, and might more appropriately be labeled an inconvenience factor. In the intercity study conducted by Watson, the journey-unit difference was found to enter the modal-choice models significantly and provided a high degree of "explanation" of the variance of actual travel choices. This research is the first test of this variable in an intracity context. The journey-unit difference, however, may produce a variable that, rather than measuring just inconvenience, measures discomfort, additional time taken, and inconvenience of transfers.

The second approach is based on the use of psychometric scaling techniques to provide the data needed to derive an index of convenience. The precise way in which scaling techniques are used to do this is described in the next section.

It is hypothesized that the traveler's decision process regarding choices, particularly of travel modes for a particular trip, is based primarily on his or her perception of the differences between alternative modes with respect to specific attributes, weighted by his or her perception of the relative importance of each attribute for the particular trip. It is further postulated that the relative ranking of modes on the basis of some modal attribute is a function of a real difference that exists between the modes. In other words, it is assumed that perceived differences are a function of real differences. It is also assumed that the perceived importance of the attributes themselves will be a function of personal characteristics of the traveler and his or her trip purpose.

On the basis of these assumptions, an index can be defined for measuring the relative importance of 2 or more modes, or other choices, with respect to a generalized attribute of convenience. Such an index could be expressed mathematically as

$$I_m^i = \sum_j w_j^i x_{jm}$$

where

x_{jm} = scale value of mode m along the continuum of rankings of all the modes for the jth attribute and is a function of x_{jm}^*, where x_{jm}^* is some measurable system attribute that affects the perception of the relative ranking of the modes (11);

w_j^i = weight that individual i attaches to attribute j relative to other attributes of the travel modes; and

j = attribute number, taken from a limited set of attributes.

Thus, the convenience index is defined for each individual i as being the sum over all attributes of the products of the attribute weight and the attribute rank for each mode. Within the modal-choice model, or other travel-choice model, the indexes for 2 modes could be entered as ratios, as differences, or in any other relative mathematical form desired by the analyst.

The task of the research is to determine the values of w and x in the above formulation. The formulation implies that the weight assigned to an attribute, w_j^i, is independent of the mode, m, and the ranking of the attribute, x_{jm}, is independent of the individual, i. These are somewhat important fundamental assumptions that are necessary in order to be able to proceed further.

SCALING METHODOLOGY

Two primary scaling approaches could be considered for this research: unidimensional and multidimensional. In simple terms, unidimensional scaling is based on the assumption that the stimulus (convenience in this case) may be represented as point values on a line, where each mode or submode has one value. In other words, convenience is represented as a 1-dimensioned attribute like cost or time. In contrast, multidimensional scaling assumes that the stimulus (convenience) is represented as a point in a space of several dimensions. Thus, it is assumed that the stimulus may vary simultaneously in several dimensions. Regardless of which method is used, the index product will be formulated identically. In fact, it is possible to generalize and say that multidimensional scaling is an extension of unidimensional scaling, which provides more information about the stimulus by relaxing dimensionality constraints. Dobson et al. (5) demonstrated that, in at least one practical application, the unidimensional solution was consistent with a multidimensional solution, thus demonstrating that the methods are complements rather than competitors.

Nevertheless, the multidimensional scaling approach involves a more extensive data analysis phase. Therefore, the simpler and more efficient (from the analysis viewpoint) method of unidimensional scaling was used for this research task. Unidimensional scaling generally requires the use of semantic differences and paired-comparison questions to provide the attitudinal data from which scale values will be derived. Multidimensional scaling is used generally for similarity (or dissimilarity) questions, such as,

> In terms of quietness of ride, which of these 2 pairs of travel modes are more alike:
>
> Automobile and bus or subway and railroad?

Thus, it is clear that further research into multidimensional approaches to quantifying convenience can be conducted and still use the results of this present work.

Although the questioning procedures for paired comparisons have already been described, the derivation of scale values from the results of the questions has not been discussed. Before that discussion, however, some further points concerning survey designs using paired comparisons should be considered.

Modal rankings and scale values are required for the unidimensional approach used in this research. Although rankings can be derived easily from paired comparisons, it is advisable to obtain rankings also with a technique such as semantic differences. This provides an important consistency check on the results. There are then several versions of the paired-comparison method, whose applicability depends on the subject of the survey. Two basic designs are possible—complete and incomplete. A complete design is one in which all possible permutations of attributes, or objects, taken 2 at a time, are judged. An incomplete design is one in which some subset of permutations is not included. In this application, each order of each pair represents a separate permutation. The case in which all combinations of attributes taken in pairs are judged is a special instance of an incomplete design. In addition to the design, response sampling may also be single judgment or multiple judgment. In single-judgment sampling, each judge (or respondent) is asked to compare a single ordered pair of attributes; in multiple-judgment sampling, each judge is asked to compare a set of pairs, as specified by the design. In the use of paired comparisons for the type of work involved in this research, only multiple-judgment sampling is practical.

In a multiple-judgment sample, the problem of respondent fatigue becomes important. Bock and Jones (2) suggest that an upper limit of 50 judgments should be anticipated, even for highly motivated respondents. Beyond this limit, although responses may still be obtained, irrationality of decision will become evident and the responses will be worthless. This maximum number of comparisons implies a maximum of between 9 and 10 attributes for a complete design. Therefore, one of the major uses of incomplete designs is to provide a means by which a population of judges can be asked to provide comparisons on a larger set of attributes than this limit implies for complete designs. Specification of the appropriate design for a particular study is, however, highly dependent on the application and the number of attributes to be considered. David (4) gives an excellent discussion of incomplete designs.

The results of a paired-comparison survey can be converted into a linear scale by a number of techniques, based on Thurstone's law of comparative judgment (28, 29). A number of cases have been developed from this law. They make various assumptions about the homogeneity of the population and the distributions of expected responses to paired-comparison questions. The most well-known cases are documented by David (4) and Bock and Jones (2). However, without additional information on choice responses, the only feasible case that can be applied is case V.

The application of case V to paired-comparison data requires that 2 basic assumptions be made about the individuals who are surveyed.

1. The sample population is homogeneous with respect to its familiarity with the stimulus, and
2. The discrepancy in preference among individuals in the placement of the stimulus along the continuum is due to fluctuation in the discriminal process of the group (this

fluctuation is assumed to be normally distributed with a mean value located at the scale value of the stimulus along the continuum).

It is, therefore, clear that the scale values derived are aggregate values for a population or subgroup of a population and cannot readily be derived for single individuals, unless they are asked to repeat judgments on several discrete occasions.

To use the method of paired comparisons requires that, to fulfill the assumptions of Thurstone's case V, a survey population be selected that is relatively homogeneous with respect to both perception of the relative importances of the attributes and perception of the mode ranking for each attribute. Since it is also assumed that mode ranking for each attribute is a function of some real difference in the modes themselves, one may argue that individuals who have used the same modes are homogeneous in their knowledge of the characteristics of these modes. Therefore, the sample must first be grouped on the basis of a commonality of knowledge about a particular mode before a paired-comparison survey is undertaken.

The assumption was also made that attribute ranking is based on the characteristics of the individual making the comparisons. This poses somewhat greater problems for adequate measurement. However, selection of a common trip purpose and socioeconomic grouping of the individuals should effectively provide homogeneous groups for the analysis of attribute weightings. In the full-scale application of this methodology, the analysis may have to be refined at some point by investigating in more detail the extent of homogeneity of responses among different socioeconomic groups within a single trip-purpose category, and the disparities between trip purposes may also have to be determined.

"WATSON" METHOD

The intention of the task reported in this section was to determine the feasibility of "reconstructing" journey-unit data for existing data sets and to determine the usefulness of a journey-unit difference in a modal-choice model for existing data sets. Two data sets were chosen for this work: the Greater London Council journey-to-work data, collected by Stopher (26) in 1966, and the Skokie journey-to-work data, collected by Lisco (12) in 1964. The London data set comprised 1,315 usable observations, and the Skokie data yielded 211 usable observations.

For each observation of each data set, the reported and alternative trip details were analyzed and journey units were assigned on the basis of one for each of the separate elements, as defined earlier. Original survey information was available for the Skokie data so that journey units could be determined in an accurate manner. For the London data, however, it was necessary to infer from transportation maps the most probable trip structure that conformed with the reported trips. Thus, the journey units assigned to that data set are likely to be somewhat inaccurate for some respondents. Furthermore, the home addresses of those respondents (i.e., the trip origins) were coded to London traffic districts, containing an average population of 40,000. Thus, some considerable aggregation error is likely to have been incurred in calculating journey units for those data.

For each data set, several models were constructed by using the logit form [Stopher and Lavender (27) give a description of the logit method and a justification for its selection]. These models were based on variable sets with the same data sets as used previously in earlier research followed by the same sets with the journey-unit difference variable added. The standard statistical goodness-of-fit measures produced directly from logit analysis were used, and the correlation ratio and F-statistic were also computed for each model. The results for the Skokie data are given in Tables 1 and 2 and those for the London data in Tables 3 and 4. For the Skokie models, the table value of t is 1.652 for 95 percent confidence and 2.344 for 99 percent confidence. The 95 and 99 percent confidence values for F are 1.93 and 2.52 respectively; the chi-square values vary with the different degrees of freedom. However, all computed chi-square values are much larger than the 99.9 percent table values. Thus, all the Skokie models are highly significant, and the journey-unit difference is statistically significant in each model. The inclusion of the journey-unit difference consistently reduces the significance of the constant.

Table 1. Results of analysis of Skokie data with and without journey-unit difference.

Model	Constant	Time Difference	Cost Difference	Journey-Unit Difference	Income	Age	Stage in Family l.c.
Variable Coefficients							
I	-2.629	-0.062	-1.97	—	2.295	0.236	2.54
II	-1.687	-0.072	-2.03	-0.21	2.07	0.240	2.53
III	-2.42	-0.048	-2.01	—	1.91	0.215	—
IV	-1.534	-0.058	-2.08	-0.204	1.73	0.216	—
V	-1.42	-0.044	-1.81	—	—	—	—
VI	-0.32	-0.058	-1.911	-0.267	—	—	—
t-Scores							
I	3.51	2.89	3.42	—	3.28	3.14	3.49
II	1.82	3.16	3.45	1.70	2.90	3.15	3.49
III	3.38	2.38	3.62	—	2.86	2.96	—
IV	1.75	2.69	3.66	1.72	2.54	2.93	—
V	2.29	2.38	3.54	—	—	—	—
VI	0.41	2.90	3.61	2.35	—	—	—

Table 2. Statistical analysis of Skokie data.

	χ^2			F	
Model	Value	d.f.	η^2	Value	d.f.
I	68.32	5	0.306	9.851	9,201
II	71.31	6	0.315	10.273	9,201
III	50.46	4	0.223	6.39	9,201
IV	53.49	5	0.253	7.584	9,201
V	24.72	2	0.124	3.186	9,201
VI	30.49	3	0.148	3.871	9,201

Table 3. Results of analysis of London data with and without journey-unit difference.

Model	Constant	Time Difference	Cost Difference	Journey-Unit Difference	Income 1	Income 2	Income 3	Income 4	Income 5	Income 6
Variable Coefficients										
I	1.096	0.0491	0.033	—	-0.11	0.002	0.253	0.095	0.753	-0.153
II	0.966	0.0489	0.033	-0.094	-0.13	-0.035	0.197	0.050	0.71	-0.18
III	1.128	0.0484	0.033	—	—	—	—	—	—	—
IV	0.953	0.0483	0.033	-0.0998	—	—	—	—	—	—
t-Scores										
I	2.51	10.36	7.55	—	0.24	0.005	0.54	0.20	1.24	0.19
II	2.19	10.29	7.52	2.73	0.29	0.077	0.42	0.103	1.18	0.22
III	14.99	10.40	7.58	—	—	—	—	—	—	—
IV	10.125	10.32	7.55	2.904	—	—	—	—	—	—

Table 4. Statistical analysis of London data.

	χ^2			
Model	Value	d.f.	η^2	F
I	287.4	8	0.279	56.08
II	294.9	9	0.291	59.46
III	279.3	2	0.280	56.41
IV	287.9	3	0.285	57.81

For the London models, the table value of t for 99.5 percent confidence is 2.583. The 95 and 99 percent confidence values for F are 1.90 and 2.43 respectively, and all chi-square values obtained for the models are far larger than any table values. Again, all the models are highly significant, and the journey-unit difference is statistically significant in each model in which it was entered. The effect of entering the journey-unit difference is to reduce the statistical significance of the constant, though less markedly than in the Skokie data. The inclusion of the journey-unit difference in both data sets improves the statistics of the total models while having little effect on the coefficients and t-scores of the cost and time differences. In all cases, the journey-unit difference enters with the correct sign (each model having been constructed such that an increasing positive journey-unit difference should lead to a decreasing probability of choice).

The significance of the reduction in the value and statistical significance of the constant lies in the properties of the logit model formulation. If 2 modes are identical in all respects, then a potential traveler should be indifferent in his or her choice; i.e., the traveler should have a choice probability of 0.5. This can only arise if the linear function (detailed in Tables 1, 2, 3, and 4) becomes 0 when modal attribute differences are 0. When the model contains system attributes only, this implies a 0 constant. When the models contain socioeconomic variables, it implies that the constant must equal the negative of the contribution to the function of all the socioeconomic variables. This latter instance is more difficult to determine, but is also the result of a less behavioral formulation of the models (27). The results from the Skokie models V and VI and the London models III and IV show a significant reduction in the size and significance of the constant term when the journey-unit difference is introduced. This suggests that the addition of this variable improves substantially the specification of modal attributes since a large, significant constant term in models of the form of Skokie V and London III implies serious lack of specification of modal attributes. Also, the fact that the significance of the coefficient of travel time does not change suggests that the time taken to transfer is not being confounded with the inconvenience of transferring.

PSYCHOMETRIC METHOD

The second approach explored in this research is the use of psychometric scaling techniques to define convenience and to permit the evaluation of a convenience index, as described earlier in this paper. To investigate the feasibility of this approach, it was necessary first to hypothesize a set of unidimensional attributes to be considered as convenience attributes. Based on earlier research and intuitive reasoning, the following attributes were put forward as constituent elements of convenience:

1. Ride in a safe vehicle,
2. Arrive at the intended time,
3. Avoid stopping for repairs,
4. Arrive in the shortest time,
5. Avoid changing vehicles,
6. Avoid a long wait for the vehicle,
7. Avoid a long walk,
8. Ride in a vehicle that is unaffected by weather,
9. Pay as little as possible for the trip,
10. Avoid having to leave early to be on time for work,
11. Have the station easily accessible to home,
12. Avoid traveling in undesirable areas,
13. Avoid paying daily for the trip,
14. Have easy-to-understand schedules and routes, and
15. Have a choice of departure times.

It was then necessary to design a survey form and select a sample for the purposes of testing the usefulness of the scaling approach. Some small samples were selected from the Chicago area; the commute trip was used, and a captive audience of respondents was obtained by surveying at the place of work. The questionnaire was designed in 4 parts. The first part requested details of the journey to work on the day on which the respondent received the questionnaire. Detailed questions were included on the elements of the trip so that the findings of this exploratory research could be refined in subsequent work. Information was also requested about alternative modes that the respondent considered he or she could have used. Questions were also included to determine mode captivity.

Part 2 comprised 42 paired-comparison questions on the convenience attributes. On the basis of pretest results, the safety attribute (1 on the list above) was omitted from the set of attributes. An incomplete design was used so that all 14 attributes could be examined without seriously overtaxing a respondent. Ten attributes were presented in part 3, and the respondent was asked to select the mode of travel that was most accurately described by the stated attribute. Respondents were given a choice only among automobile, public transport, and no difference. In addition, respondents were asked to list the 3 most important characteristics of a transportation system, without restriction on the attributes to be considered. Finally, part 4 contained questions on the demographic characteristics of the respondent, including age, sex, marital status, income, and education.

A total of 150 questionnaires were sent to employees in 2 Chicago CBD locations, and 97 usable replies were obtained. For the purposes of this research, the primary analysis was the use of the Case V program to produce scales of convenience. The respondents were grouped by age and then by sex, and scales were derived for each grouping. Unfortunately these groups become very small so that results become statistically less reliable.

Figure 1 shows the scale values for the entire sample. The 4 attributes clustered at the top of the scale all relate to travel time and traveler effort. These are conformal with the prior hypotheses of convenience put forward at the beginning of this research. Figures 2 and 3 show the scales for females and males respectively. The same 4 attributes appear at the top of the scale, although the ordering is somewhat changed. Having understandable schedules remains as the 0 point of the scale in both cases. Grouping by age shows greater variability in response (Figs. 4 through 7), but some of the group sizes are now quite small. Avoiding a long wait and arriving in the shortest time continue to appear among the top 4 attributes on all the scales, and having understandable schedules remains close to the bottom of the scale. However, the group aged 25 and under has paying as little as possible among the top 4 attributes, while all the previous scales showed this to be near the halfway point or below. For the group aged 35 to 45, the avoidance of transfers moves to fourth place and an easily accessible station drops to seventh place. The scale for the group aged 45 and over shows a cluster of 5 attributes some distance below the overriding attribute, arrive at the intended time, this latter being an attribute with a much lower scale value in all other groups.

Based on the scales, the responses on the importance of attributes, and the ratings of automobile and public transit on selected convenience attributes, convenience indexes were computed for survey respondents. In this case, the x_{j_m} were the scale values of the attributes used, and the w_j^i were assumed to be either unity or 0 according to whether the respondent did or did not consider the mode best with respect to attribute j. After captive riders and those who gave insufficient cost or time data on usual and alternative modes were excluded, a sample of 49 respondents was left for analysis. This sample contained 17 automobile preferrers and 32 transit preferrers. The sample was judged insufficient for modeling purposes, so an analysis was made of the extent to which each of the convenience index difference, time difference, and cost difference conformed in sign with the preference of mode. The cost difference conformed in sign for 37 of the respondents, the time difference for 16 of the respondents, and the convenience index difference for 32 respondents. In only 8 cases did all 3 variables simultaneously conform with the preference. The index was computed from 5 attributes, ranging down the full length of the scale:

1. Arrive at the intended time,

Figure 1. Case V scale values for all respondents (97 in sample).

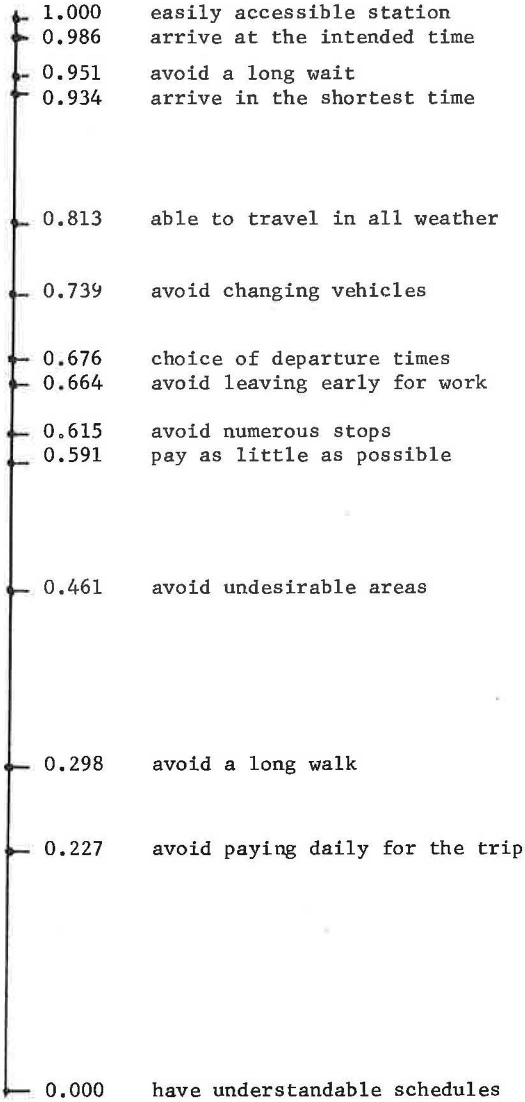


Figure 2. Case V scale values for female respondents (22 in sample).

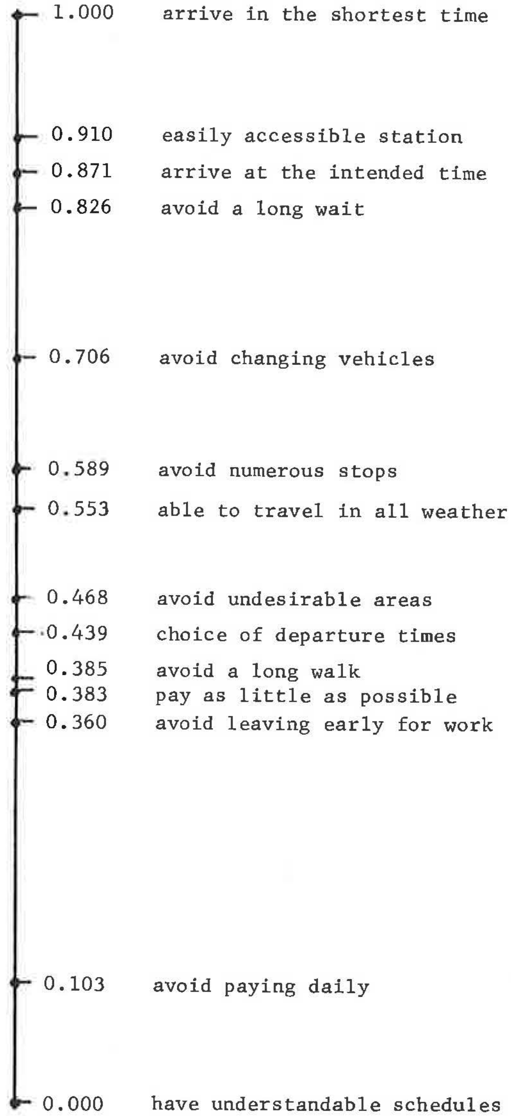


Figure 3. Case V scale values for male respondents (75 in sample).

1.000	easily accessible station
0.991	arrive at the intended time
0.971	avoid a long wait
0.914	arrive in the shortest time
0.891	able to travel in all weather
0.784	avoid changing vehicles
0.782	avoid leaving early for work
0.736	choice of departure times
0.608	pay as little as possible
0.580	avoid numerous stops
0.382	avoid undesirable areas
0.232	avoid paying daily
0.224	avoid a long walk
0.000	have understandable schedules

Figure 4. Case V scale values for respondents aged 25 and under (16 in sample).

1.000	easily accessible station
0.935	avoid a long wait
0.918	pay as little as possible
0.916	arrive in the shortest time
0.816	able to travel in all weather
0.784	choice of departure times
0.776	avoid leaving early for work
0.774	arrive at the intended time
0.680	avoid numerous stops
0.631	avoid changing vehicles
0.388	avoid undesirable areas
0.276	avoid paying daily
0.231	avoid a long walk
0.000	have understandable schedules

Figure 5. Case V scale values for respondents aged 25 to 35 (45 in sample).

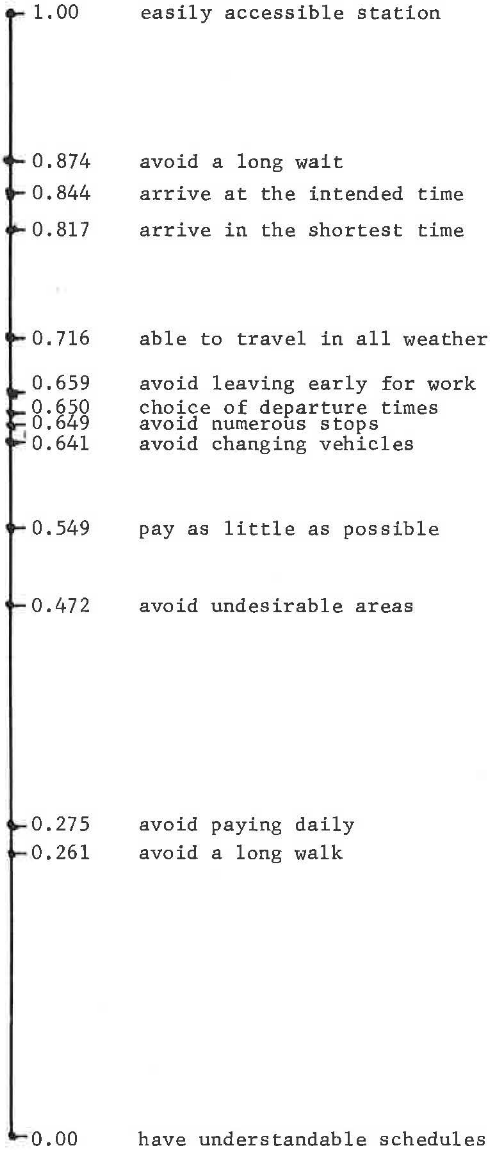
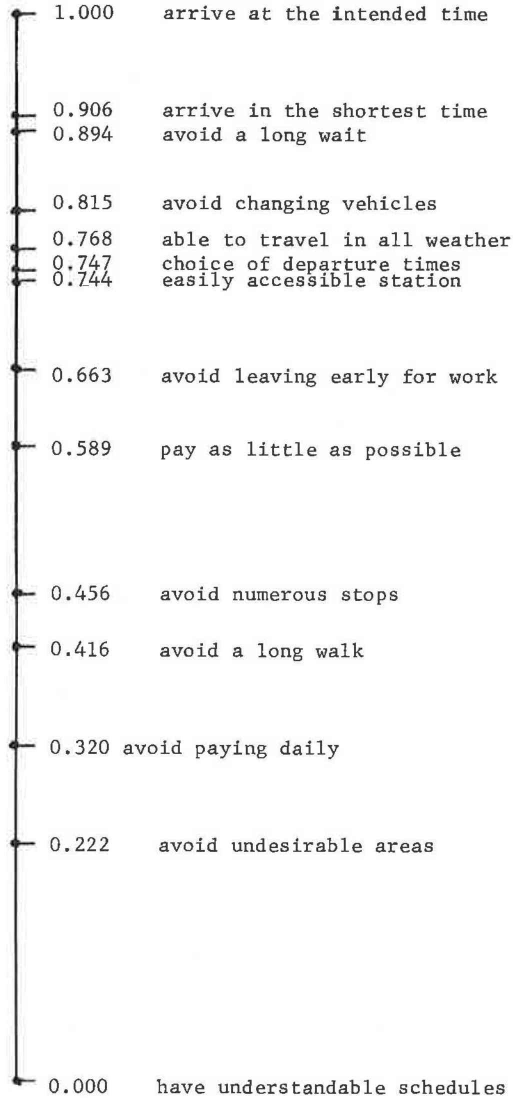


Figure 6. Case V scale values for respondents aged 35 to 45 (15 in sample).



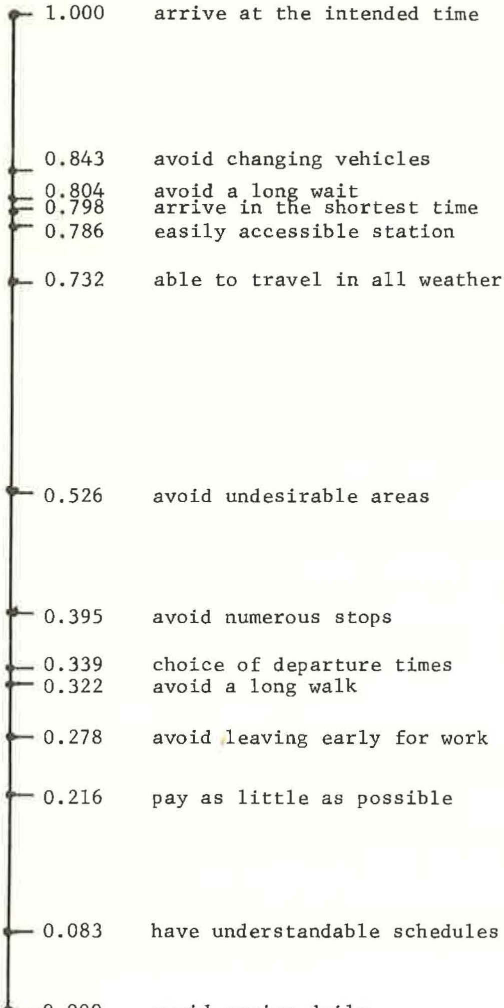


Figure 7. Case V scale values for respondents aged 45 and over (21 in sample).

2. Able to travel in all weather,
3. Avoid numerous stops,
4. Avoid a long walk, and
5. Avoid undesirable areas.

Separate indexes were computed based on the different population groupings, but no significant differences in conformance of signs was detected. Since no models were built, and the size of the differences was not computed, definitive statements cannot be made about the effectiveness of the convenience index in modal-choice modeling. However, the extent of the apparent correlation between the convenience index and the modal preference suggests that it is likely to be of significance in modeling mode choice.

CONCLUSIONS

Both approaches used in this research produce useful results toward the inclusion of a measure of convenience in travel demand models. From a policy standpoint, however, the journey-unit difference appears to be less useful, for it provides the decision-maker with one additional policy variable only—the number of transfers—and may also be confounded with some aspects of trip time. In contrast, the psychometric scaling approach requires the collection of some fairly extensive new data on preferences and attitudes of travelers and requires much more detailed and involved analysis before a measure is produced. The convenience scales produced for the small sample used in this exploratory study also suggest that convenience could possibly be quantified by defining additional time variables in a model. Over the total sample, an easily accessible station (i.e., access time), arrival at the intended time (i.e., travel time variance), avoidance of a long wait (i.e., waiting time), and arriving in the shortest time (i.e., overall travel time difference) appear to be the most important measures of convenience. Thus, a comparative analysis on the same data sets in which the journey-unit difference, the psychometric convenience index difference, and the specification of the 4 travel time parameters listed above are used appears to be worthwhile.

In conclusion, this research has lent support to the hypothesis that the convenience of travel modes can be quantified for the purposes of travel demand modeling. However, it is not possible to state, on the basis of this research, which is the most effective method to use to carry out this quantification. The results obtained in this research provide indications that the pursuit of further research in this area is worthwhile and is likely to lead to more accurate travel demand models and to the adding of important policy variables to the models.

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