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ATTITUDINAL MEASURES IN MODELS OF MODE CHOICE

H.P. BROWN

ABSTRACT: *A complete specification of a choice model should include all factors that are relevant to that choice process, including qualitative aspects of the transport system characteristics. In the present state of knowledge an appropriate method of including these is by attitudinal measures of the characteristics. The inclusion of attitudinal variables in mode choice models has been shown to considerably improve both the performance of the model, and the estimates of value of time that can be obtained from it.*

The ability of individuals to respond consistently to attitude questions is examined, with evidence supporting the usefulness of attitude measures in a planning context. The problem of bias in reported attitude with its implications for the measurement of perceived levels of system variables is treated.

The application of attitude measures to choice models is only one area in which these techniques can be of use. Evidence is reported to suggest that only in special and rather rare circumstances are choice processes compensatory (ie, involve a trade off). Attitudinal research has already achieved considerable success in isolating the likely effects and impacts of policy changes, and is shown to have great potential for further advances.

1. INTRODUCTION

The development over the last decade of models of travel behaviour based on theories of individual choice has considerably improved the ability of transport analysts to predict future travel demands. These disaggregate probabilistic models have been extended from their origins as models of mode choice to include joint mode and destination choice (Richards & Ben-Akiva (1974)), levels of car-ownership (Lerman & Ben-Akiva (1975)), and most recently to a complete system of models of household mobility and travel decisions (Ruiter and Ben-Akiva (1977)) Whether or not the predictive ability of such a complete model system is greater than that of the conventional models which they replace has yet to be fully documented. The fact that they are structured so as to directly incorporate the factors influencing choice, however, makes them particularly suitable for the analysis of the effects of short term policy options, in marked contrast to the capabilities of conventional models. Of particular relevance in this area are models of mode choice, as the question of mode switching in response to changes in the travel environment is central to most urban policy issues

Choice models must accurately reflect the decision processes of the individual, as it is these processes, based on perceptions of the travel environment, that underly travel behaviour. Despite the very significant advances hinted at above, more work remains in the determination of the exact nature of the processes involved, and in the measurement of the individual's perceptual structure and its relationship to characteristics of the travel environment. Analysis of travellers' "attitudes" towards the transport system is receiving increasing attention, and a number of related issues have emerged. This paper will discuss some of these issues, using for illustrative purposes the results of a current research project.

2. THEORETICAL FRAMEWORK

The research to be partially described in the following is directed at understanding the relationship between attitude and behaviour, and the factors influencing choice of mode for the Melbourne CBD worktrip. This trip purpose is of only limited significance in terms of total daily travel, and mode choice constitutes only one of the choice components of the overall travel decision making process. There are, however, very good reasons for its examination.

The study of mode choice provides a unique opportunity to isolate and analyse a variety of factors influencing individual behaviour in a discrete and recognizable choice situation Because many of the policy questions of public concern relate to existing and potential mode usage, information about

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travellers' perception of and sensitivity to factors influencing their choice is of vital interest. And finally, because of the structure of disaggregated demand models, mode choice can be modelled separately and later included in a much broader framework of travel demand models.

2.1 CHOICE THEORY

An appropriate theoretical basis for modelling choice behaviour comes from the combination of neo-classical utility theory (Lancaster (1966)), and mathematical psychology (Luce (1959), Marschak (1959)).

It may be postulated that the choice between goods is made so as to maximise the consumer's utility. This utility derives both from the individuals' preference orderings, and the attributes, or characteristics, of the good from the consumption of which the consumer derives utility. Using an assumption that the total utility of a good is the linear sum of the utility of its attributes, the utility function of a single consumer, i, for a single good, j, may be written

$$U^i(X^j) = \sum^k U_{ik}(X_{jk}) \qquad (1)$$

where X^j is a vector of the component attributes of the good j.

Most specifications of the utility function include a vector of socio-economic characteristics. This author disagrees with that formulation; it is felt that such characteristics do not by themselves determine utility. Rather, they act as intervening variables, influencing preferences only through the perceptual framework. The implication of this modification is, as will be mentioned later, that estimation of utility models should be undertaken using socio-economic stratification, rather than through the inclusion of dummy socio-economic variables.

As travel in a constrained choice situation, such as the work trip, does not generally afford positive utility of and by itself, it is easier to talk in terms of disutility, and postulate that travellers choose between travel modes so as to minimise the relative disutility of the trip. In a binary choice situation (where two modes are available for choice), the measure of relative disutility to be minimised is given by

$$G\left(\sum^k \{DU_{ik}(X_k^1) - DU_{ik}(X_k^2)\}\right) \qquad (2)$$

where $DU_{ik}(X_k^{1,2})$ are the attribute disutilities for models 1 and 2.

While it has been postulated that the probability of a particular choice is related in some way to the difference between the utilities afforded by the attributes of the relevant goods, no indication of the functional form of this relationship is immediately obvious. However, the field of mathematical psychology relating to individual choice behaviour does furnish such a form. Because only choice outcomes, and not choice probabilities themselves can be observed, it is not possible to directly infer from the outcomes the underlying discriminal process of choice, and its relationship to attribute disutilities. Physical measures of these latter can (generally) be obtained; their relationship to choice probabilities is more complex. What is needed, therefore, is some process by which this can be achieved; a measuring scale which maps choice probabilities onto measured attribute disutilities is required.

Assuming a binary situation, it can be shown (Luce and Suppes, P. 338), that the probability of choosing x over y from a (larger) set containing both is

$$\begin{aligned} Pr(x, y) &= Pr\,(V(x)+\varepsilon(x) \;>\; V(y) + \varepsilon(y)) \\ &= Pr(\varepsilon(y) - \varepsilon(x) \;<\; V(X) - V(y)) \end{aligned} \qquad \text{—— (3)}$$

where $V(x) + \varepsilon(x) = U(x)$, the attribute utility function for alternative x; $\varepsilon(x)$ is a random component, and $V(x)$ is the fixed, non-probabilistic measure of utility. The random variables $\varepsilon(x)$, $\varepsilon(y)$ arise both from specification and measurement errors, and from randomness on the part of the individual in his perception of the attribute utilities and in his choice behaviour in repeated choice situations. It is reasonable to assume that their distributions will be independent, and also identical; indeed, if these assumptions are not made, the problem of deriving a probability of choice model becomes intractable (Manski (1975)).

Using these assumptions, and denoting the distribution function of $\varepsilon(x) - \varepsilon(y)$ by ϕ, equation (3) becomes

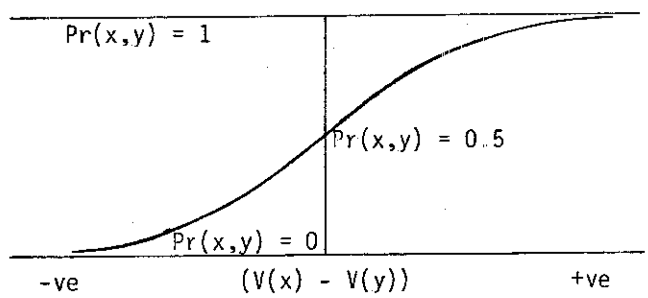
$$Pr(x,y) = \phi(V(x) - V(y)) \qquad \text{—— (4)}$$

The term $(V(x) - V(y))$ is an interval scale of utility differences which is a direct measure of the probability of choice (given ϕ), and together with ϕ, constitutes the scaling function required.

If it is assumed that ϕ is reciprocal exponential, (e.g., C.R.A.(1972))

$$\begin{aligned} Pr(x,y) &= \frac{1}{1 + e^{-(V(x) - V(y))}} \\ &= \frac{e^{(V(x) - V(y))}}{1 + e^{(V(x) - V(y))}} \end{aligned} \qquad \text{—— (5)}$$

which is the well known binary logit formulation. (Assuming that ϕ is joint normal gives the probit form; both are (now) capable of extension to the multinomial situation). The "logit" is defined as $\log\left(\frac{P(x,y)}{1 - P(x,y)}\right)$ and follows the S shaped logistic function, as below



If equation (5) is expressed as

$$Pr = \frac{e^{G(x;\beta)}}{1 + e^{G(x,\beta)}} \qquad \text{—— (6)}$$

it is obvious that the linear function $G(X,\beta)$ is similar to equation (2), and is the linear sum of the relative attribute disutilities. The vector β is a vector of coefficients to be estimated such that equation (2) is minimised. Estimation of this vector, and of the resultant individual choice probabilities is by the maximum likelihood method.

2.2 MODEL SPECIFICATION

It has been argued that formulation of a choice model must accurately reflect individual choice processes, and incorporate the factors which influence choice. The first task has already been accomplished, as the above form derives from theoretical concepts of choice behaviour, and has achieved considerable empirical validation in a diversity of choice settings. The second can be achieved if the variables used in the model are those perceived by the individual as affecting choice. However, as the model has so far been expressed in relative disutility terms, and because the planner has information about the transport system only, and not about the preference structures of the wider population, variables entering the model must be capable of physical quantification. Consequently it is necessary to be able to measure transport system characteristics in the way, and in the quantities, that they are perceived.

Quantitative Variables

Most frequently, mode choice models have included time and cost measures alone, with the (often implicit) assumption that it is the relative levels of these attributes between modes that governs choice. Various forms of the variables have been used, including differences, ratios, and composites of these two. A decision as to which is the most appropriate is generally made on the basis of statistical fit, and implicity it is assumed that the resulting form is that perceived by the choice unit. The quantity of the variable to be used has received considerable attention, and it is generally agreed that "perceived" times and costs are appropriate - if only they could be measured. Most typically, they can not, and actual measures are used, albeit reluctantly. This issue will be revisited in a later section.

Qualitative Variables

While modal attributes such as time and cost of travel are measurable, it is immediately apparent that many aspects of the transport system likely to influence choice lack any such obvious physical dimension, even though one may exist. Such factors include comfort, safety, convenience, as well as many others. For an accurate specification of the model, it is imperative that some way of including these factors be found. In the absence of physical measures, a second best approach is to attempt to measure preferences for these factors directly. If this can be achieved, these measures may be entered directly into the model. Further, the examination of attitudes, or preferential structures, will give considerable assistance to the problem of identifying the underlying physical dimension of concern. It is to these tasks that we now turn.

3. ATTITUDE MEASUREMENT AND USE

3.1 ATTITUDE DEFINITION

The nature and definition of attitudes has been the concern of psychologists for a very long time; only recently, however, has there been a recognition that techniques developed in this area can be fruitfully applied to understanding travel behaviour. There is now a large and expanding body of literature concerned with this problem in the transport context. It is generally, though not universally, accepted that "attitude" is a multi-dimensional construct, containing affective (liking), cognitive (belief), and conative (behavioural) components (Fishbein (1965)). While it has been recognised that behaviour, behavioural intention and attitude are decreasingly strongly related (Golob, Dobson (1974)), models incorporating behavioural intention are rare in the transport context. Instead, preference has been shown for a model containing variations of the affective and cognitive components, derived from the cognitive summation models of Rosenberg (1956), (Fishbein (1963) and Anderson and Fishbein (1965). In this model overall "attitude" is expressed as the sum over all relevant beliefs about the object, of the product of a measure of belief about the object and the evaluative aspect or importance of that belief. Expressed in the modified form in which it has appeared in the mode choice context, this becomes;

$$A_{ij} = \sum^{k} I_{ik} . S_{ijk} \qquad \text{—— (7)}$$

where A_{ij} = individual i's attitude toward mode j
I_{ik} = importance to individual i of modal attribute k
S_{ijk} = level of satisfaction of individual i with the kth attribute of mode j.

Reasons for the preference shown for this form of the model become apparent when its specification for a choice model is examined. As choice is postulated as being a function of relative preference for an object, judged over all attributes of that object, a choice model specified in attitudinal terms has a probability function

$$G(x) = G\left(\sum^{k} I_{ik} . (S^{1}_{ik} - S^{2}_{ik})\right) + \varepsilon \qquad \text{—— (8)}$$

This is exactly equivalent to the form of utility function proposed by Fishburn (1967), which expressed total utility as comprising measures of ranking, or importance of the attribute in the utility function, as well as measures of satisfaction with the attribute.

Considerable debate surrounds the above formulation, particularly as related to whether two measures of attitude are necessary. This issue will be discussed in a later section.

3.2 ATTITUDE MEASUREMENT

There are many possible ways in which attitude can be measured, once it has been appropriately defined. A review of techniques and their related problems is given by Golob (1972), Golob and Dobson (1974), and data requirements for their application by Dobson (1977). The technique used in this research was semantic differential scaling for measures of "satisfaction", and constrained point allocation for importance weight; their method of use is discussed later.

3.3 INCLUSION OF ATTITUDE INFORMATION IN A MODE CHOICE MODEL

It is apparent that individual attitudes towards modal characteristics, however well specified, can not readily be used in a modelling context, except for short-term, localised issues. (If they can be related to the underlying physical continuum from which they derive, and if the dynamic effect of changing environment can be isolated, this statement may no longer be correct) But only if a mode choice model is completely and accurately specified, can accurate estimates of susceptibilities to changes in the physical attributes of the system be gained. More specifically, if price and time elasticities of demand, and values of travel time are to be calculated, then all factors affecting choice should enter the model, so that these parameters can be estimated free from the disturbing influence of important but unspecified variables (Hensher (1972)).

Consequently it is argued that attitudinal measures of qualitative attributes should be included in any explanatory model. The problem then arises as to how best to include such measures, and it is this problem that is the focus of the present on-going research. This is based on surveys of CBD workers' evaluations of the attributes of their available journey-to-work modes, described in the following section.

4. THE SURVEYS

4 1 PRELIMINARY SURVEY

In order to furnish information for the main survey, a preliminary survey was carried out in December, 1974, yielding 157 responses from a sample of 400 office and professional CBD workers. The purpose of this survey was to isolate a relevant set of modal attributes judged by respondents as being important influences in their choice of mode. It is of course absolutely necessary to ensure that a complete range of characteristics be presented to the respondent, if model specification error is to be avoided.

In general, there are two main methods of accomplishing the definition of a complete and relevant set of attributes. The first is the open-ended-response type, in which the respondent lists the characteristics deemed important, and answers all subsequent questions using this self-defined list. The possible advantages of this method are that, as the respondent has defined the attribute set relevant to his perception of the "qualitites" of the competing modes, answers to subsequent questions related to these attributes should be logical and consistent. The disadvantages are that a wide range of attributes will emerge from all respondents, making their inclusion in any model difficult; inclusion of only the most frequently mentioned factors is likely to result in some degree of mis-specification due to the exclusion of some attributes. Perhaps more importantly, there is a high possibility that respondents will not be able to completely articulate the relevant attributes without prompting; again, this results in a possible under-specification problem.

The second method, and that used in this survey, is to collect a large list of attributes which will possibly be important, present these to a sample group, and by suitable scaling and statistical technqiues, determine the importance rankings and dimensionality of the attributes for the whole group.

This (reduced) set of attributes can then be used in a further survey. While this approach ensures that the attribute set relevant to the majority is identified, the possibility that attributes important to some individuals will be excluded remains. It is felt, however, that so long as a comprehensive set is maintained, this problem will be minimised.

From a comprehensive literature survey, a list of 37 modal characteristics likely to be important to individuals was selected. Respondents were asked to give importance ratings, on a pre-defined semantic differential scale of 1-5, to each attribute. An example is given below;

On your trip to work, HOW IMPORTANT IS IT TO:
Arrive at your intended time ☐
Be reasonably sure of getting a seat ☐
Travel in a clean vehicle ☐

Give a score from 1 to 5 from the importance scale, to each queation.

[1] *Not at all important*

[2] *Of little importance*

[3] *Of some importance*

[4] *Important*

[5] *Very important*

Using the means of the responses as rank-order importances, and by the use of factor analysis, which will not be described herein (but see Brunner, et. al. (1966)), a set of attributes was arrived at, and grouped according to the "dimension" to which they appeared to relate. This resulted in a set of three "factors" which were labelled for simplicity, and for purposes of comparison with other reported work, as "Comfort","Convenience". Reliability". However, it was obvious from the results of the factor analysis that more than 3 independent dimensions underlied the attribute set (see also Brunner (1966), Recker and Golob (1976)), but for ease of inclusion in the survey which was to follow, it was decided to combine all factors in the three previously mentioned. This resulted in 15 attributes; 5 in each factor as shown below.

COMFORT Items

CM1. *Travel in a clean, light, well-ventilated vehicle.*

CM2. *Have reasonable protection from weather and temperature in vehicle.*

CM3. *Be sure of getting a seat.*

CM4. *Stops & stations are clean, attractive, and give good protection from weather.*

CM5. *Public vehicles have easy to use exit & entry points, grips and handrails.*

CONVENIENCE Items

CN1. *Able to easily connect with other methods of transport.*

CN2. *Able to make trip whenever you want to.*

CN3. *Avoid having to change from one method to travel to another.*

CN4. *Have a frequent transport service available.*

CN5. *Parking easily available near work.*

RELIABILITY Items

RL1. Avoid waiting or delays during trip.

RL2. Arrive at intended time

RL3. Feel relatively free from chance of accidents.

RL4. Travel method has reliable

RL5. Not have to travel with other vehicles.

4.2 MAIN SURVEY

Having defined the set of modal characteristics for which attitudinal, rather than quantitative data was to be collected, the main survey was undertaken. For maximum cost-effectiveness, it was decided to survey at the workplace within the CBD. Accordingly, 35 firms were selected on a "representative" geographical and classification basis, and with their (considerable) co-operation, employee groups were issued questionnaires which were collected one day later. As a result of the co-operation by employers, and by careful questionnaire design and presentation, 3737 correctly completed responses from a total of 7400 issued questionnaires were received.

Information about all aspects of the usual and alternative modes of travel to work, as well as personal details of socio-economic characteristics, and attitudes towards usual and alternative modes on both "factors" and modal attributes, was gained in this way. Two distinct sets of attitude questions were asked. The first related only to the factors identified in the pilot survey, to which were added the factors, Time and Cost, in order to completely define attitudinal structure. (Only limited time and cost questions were posed in the pilot survey, as attention was being focused only on "qualitative" aspects). Respondents were asked to allocate importance points, totalling 100, to indicate how <u>important</u> each factor was to their choice of mode, and to rate from 1 to 7 their feeling of <u>satisfaction</u> with the level of that factor on both their usual and alternative modes. The second set related to the three qualitative factors previously identified, and to the attributes describing them. Scores for the importance that each attribute assumed in the individual's <u>definition</u> of the factor were obtained in the manner described above. Satisfaction scores for each attribute on both usual and alternative mode were collected as before.

Results from these surveys will be used to illustrate aspects of issues related to the use of attitudinal measures in mode choice models in the following section. The group used for analysis comprise those who faced a choice between car and train for their usual or alternative trip to work. There were 323 car drivers who gave their alternative mode as train, and 960 train travellers who gave their alternative mode as car (driven).

5. ISSUES IN ATTITUDINAL MODELLING

5.1 ABILITY OF RESPONDENTS TO CONSISTENTLY EXPRESS ATTITUDE

The question as to whether people can logically and consistently express their attitudes, and what reliance can be placed on their responses, appears to be one which concerns practitioners in the transport field. The short answer, based on a plethora of empirical evidence from both market research, and more relevantly, mode choice literature, is that they can and do. Tests of consistency are difficult to construct, and the most easily interpretable evidence comes from the ability of attitudinal measures to improve the performance of models in which they are included. This evidence is presented in a later section. However, a consistency test is possible using responses to the two separate sets of attitude questions collected in this research, as described previously.

Satisfaction scores were obtained for both factors and component attributes; obviously, if responses are consistent between these questions, factor satisfaction scores should be a function of the component attribute satisfaction scores. If such a relationship can be found, it is strong evidence that consistency exists. However, a further test for consistency is possible. As well as attribute satisfaction scores, respondents were asked to give an importance score to indicate how important, in their definition of the factors Comfort, Convenience, Reliability, were each of the 5 component attributes. Consequently, if it is assumed that factor satisfaction is a linear additive function of attribute satisfactions, then the coefficients of this linear function can be treated as "inferred" importance weights, and compared with the means of the reported importances. If there is a similar ordering of importance ranks, it can be concluded that a high degree of consistency is present, and that people's ability to express their attitudes consistently through questions of considerable dissimilarity is considerable These tests are presented below.

Inferred importances were obtained from the car/train mode pair by regressing reported satisfaction score with the three qualitative factors for the main mode trip, against their 5 component attribute satisfaction scores. The original 1-7 scores were recoded to have a zero origin, and the regression was constrained to pass through this origin. There are very good *a priori* reasons for this constraint. An unconstrained regression was also undertaken to ensure that the constrained model was not giving widely different results.

It is apparent from Table I that a significant linear relationship exists. Furthermore, the coefficients should theoretically sum to unity, and it is possible to constrain the model to do this (Gold berger (1964), P258). While this was not done, the results demonstrate that, even without this constraint, the sum of the coefficients is always very close to unity. These results demonstrate conclusively that response consistency between different questions exists; factor satisfaction can be regarded as a function of factor attribute satisfactions, and these alone.

The relative rankings of inferred and reported importances are also sensibly constant, with the two extremes, 1 and 5, corresponding between the two in 9 out of 12 cases. This is a very much more stringent test, as we are now examining consistency between 3 very different questions. Because many of the attribute satisfaction scores are highly correlated, and because of the way in which inferred importances were obtained, it is not surprising

TABLE I

INFERRED AND REPORTED IMPORTANCE SCORES FOR FACTOR ATTRIBUTES

Attribute	Ususal Mode Car		Usual Mode Train	
	Inferred	Reported	Inferred	Reported
CM1	0.23 (2)	30.7 (1=)	0.41* (1)	25.1 (2=)
CM2	0.89* (1)	27.8 (1=)	0.24* (2=)	24.4 (2=)
CM3	-0.11 (5=)	19.3 (3)	0.19* (2=)	26.7 (1)
CM4	-0.01 (5=)	10.7 (5=)	0.01 (5=)	11.7 (5=)
CM5	-0.01 (5=)	11.3 (5=)	0.03 (5=)	12.0 (5=)
	Σ = 0.99		Σ = 0.88	
CN1	0.29* (1=)	12.7 (5)	0.33* (1=)	15.6 (4)
CN2	0.44* (1=)	27.2 (1)	0.15* (5=)	19.5 (2=)
CN3	0.25* (1=)	16.3 (4)	0.10* (5=)	19.8 (2=)
CN4	-0.08 (5)	20.9 (2=)	0.33* (1=)	31.7 (1)
CN5	0.14* (4)	21.6 (2=)	0.09* (5=)	12.8 (5)
	Σ = 1.05		Σ = 1.00	
RL1	-0.02 (5=)	26.3 (1=)	0.20* (2=)	21.9 (2=)
RL2	0.33* (1=)	27.6 (1=)	0.15* (2=)	25.8 (1)
RL3	0.24* (3)	14.3 (4)	0.06* (4)	18.3 (4)
RL4	0.49* (1=)	21.0 (3)	0.45* (1)	21.8 (2=)
RL5	0.10 (5=)	8.7 (5)	-0.02 (5)	12.0 (5)
	Σ = 1.14		Σ = 0.84	

Note: * indicates that regression coefficients are significantly different from 0 at better than the 5% level.
() indicates rank order within group.

that the relative magnitudes of the scores differ. It is more surprising, however, that they do not vary more widely. In summary is quite apparent that very great consistency in response exists, and that people maintain their ability to express their attitudes in widely difering questions and circumstances.

5.2 FORM OF THE DEFINITION OF ATTITUDE

Considerable argument exists as to whether the two component model (equation (7)), including both importance and satisfaction measures, is appropriate as a model of "attitude". Louviere, Wilson and Piccolo (1977) question the combinatorial function, producing evidence that it is multiplicative rather than additive; indeed they question the composite formulation itself, arguing for the overall evaluative construct of attitude central to information integration theory (Anderson (1974)). This argument does not, however, dismiss the definition of attitude as a two-component construct, but infers that independent measurement of each component by direct questioning is of only limited value, a view also supported by Golob (1972).

On a more practical level, Hartgen (1974) argues from (rather limited) empirical evidence that the marginal improvement (in model performance) gained by including importance weights does not justify their use. Finally, it has been frequently argued that, if attitude variables are used in a regression or logit model, importance weights are obtained as the variable coefficients, and that direct measurement is not therefore necessary. This is not, of course, correct. Such coefficients, evaluated at the mean for all individuals in the sample, who may have widely differing preferential structures, cannot be considered as measures of individual importance weights (see also Hensher (1974)).

However, no concensus as to the appropriateness or otherwise of this formulation has emerged (see, for instance, (Wilkie and Pessemier (1973)). Opponents of the two-component model argue that importance weights are unnecessary and attitude is effectively measured by satisfaction measures alone; the inference is that independently measured satisfaction and importance scores are likely to be so negatively correlated that their combination is unnecessary.

Proponents of the two-component model (e.g , Hensher, McLeod, Stanley (1975)) argue that, from a theoretical point of view, importance weights are purely the scale transformation parameters required in the specification of a (Fishburn-type) utility model; satisfaction alone does not constitute a complete or meaningful measure of utility.

It is this latter view that is espoused here. If any concensus exists, it is at least in the direction of favouring the two-component definition, if not the model, of attitude. The issue appears to be largely a practical one, and rests on the appropriateness and accuracy of the data collection techniques. If a view is to be taken, however, some justification for it must be given; this is done below using results from the research as described.

To test for independence between the two components of attitude, importance and satisfaction, factor importance scores were correlated with both main mode factor satisfaction, and (usual - alternative) main mode satisfaction differences, for both car = usual, train = usual main mode separately. The results are given in Table II below.

TABLE II

CORRELATIONS OF FACTOR IMPORTANCES, FACTOR SATISFACTION

AND FACTOR SATISFACTION DIFFERENCE SCORES (CAR/TRAIN).

	Car Usual		Train Usual	
Factor	S^F	ΔS^F	S^F	ΔS^F
Time	.025	.107	-.015	-.077*
Cost	.061	.169*	.024	-.189*
Comfort	.109	.156*	-.045	-.044
Convenience	.143*	.038	.099*	-.083*
Reliability	.126*	.152*	-.13*	.058

Note: * indicates difference from zero at the 5% level of significance.

Several of these coefficients are significantly different from zero. There is no consistency of sign, however, and the magnitude of the coefficients themselves are not such as to invalidate the hypothesis that importance and satisfaction measures are independent. It can be concluded that each measures a different, and independent, aspect of attitude.

Evidence as to possible improvement in the performance of a model including attitudinal variables gained by including importance weights is not as strong, but still exists. Two logit models of car/train choice were estimated using attitudinal specifications alone. A binary dependent variable of 1 = choice of car, 0 = choice of train was used; hence the models estimate the probability of choosing car over train. Model I used differences in factor satisfactions alone as the independent variables, while Model II weighted these satisfaction differences by factor importance scores. Coefficients of the linear probability function, with their t - scores in parentheses, are given in Table III.

TABLE III

LOGIT MODEL RESULTS, VARIOUS ATTITUDINAL SPECIFICATIONS ALONE

	MODEL I	MODEL II
Factor	$G(X) = \Sigma\beta_F(S_F^C - S_F^T)$	$G(X) = \Sigma\beta_F I_F(S_F^C - S_F^T)$
	Coefficient (β_F)	Coefficient (β_F)
Time	-0.016 (0.4)	-0.003 (2.1)
Cost	0.335 (8.2)	0.016 (7.5)
Comfort	-0.091 (1.7)	0.008 (4.9)
Convenience	0.605 (11.9)	0.018 (10.9)
Reliability	-0.316 (6.8)	-0.005 (4.0)
Constant	-1.42 (8.6)	1.74 (12.1)
Pseudo R^2	0.426	0.454
$-2 \log \lambda$	435	470
Classification	Car: 160/323	164/323
	Train: 885/960	905/960

In most aspects, Model II - using importance weights - performs better. The negative signs of both Time and Reliability are incorrect; the probability of choosing car should increase as relative satisfaction with car increases. The increase in the constant is also cause for misgivings. Despite these inadequacies in the model, there is still improvement afforded by the inclusion of importance weights in the model.

The evidence presented justifies the view that, if attitudes are to be described by the two-component model and measured by direct questioning, then importance weights are necessary to complete the description. No conclusion can be drawn, however, as to the relative merits of this specification of attitude over other forms already discussed. This is an area that requires further research.

5.3 USE OF ATTITUDINAL VARIABLES IN A CHOICE MODEL

The possible advantages of including attitudinal variables in a choice model have already been discussed. These relate to the more accurate specification of the model by the inclusion of previously unspecified but influential factors, and the concomitant increase in accuracy of the model parameters. It is not suggested that attitudinal measures as discussed herein can be used in a predictive model, because of their lack of physical dimensionality. As stated by Levin (1977). "without proper operational definitions linking... (attitudes).. to manipulable system attributes, these.... have no reliable explanatory basis. That is, one cannot "explain" behaviour with concepts that themselves need to be explained."

While this is true, it is part of the task of attitude research to uncover the physical dimensions influencing attitude, and significant advances in this direction have already been made. Nevertheless, it is not true in an explanatory (as opposed to a predictive) context. If the relevant factors influencing choice are completely described, and if some are measured attitudinally, then their inclusion in a model can be justified, as demonstrated below.

Two further models of the probability of choosing car over train were estimated, one using physical variables alone, the other with the addition of attitudinally measured qualitative factors. The results are given in Table IV.

TABLE IV

MODEL RESULTS; TIME COST AND ATTITUDINAL VARIABLES

	MODEL III	MODEL IV
COSTD	-0.031 (12.2)	-0.031 (10.6)
STNOD	0.236 (2.6)	0.224 (2.1)
INOTD	-0.045 (7.8)	-0.033 (5.0)
WTTD	-0.108 (7.4)	-0.085 (5.2)
ISDCM		0.008 (4.6)
ISDCN		0.017 (10.0)
ISDRL		-0.002 (1.5)
CONST	0.142 (0.8)	-0.802 (3.5)
Pseudo R^2	0.398	0.563
$-2 \log \lambda$	403, 4D.O.F	614, 7D.O.F
Classification: Car	154/323	202/323
Train	903/960	903/960

Note: Variables in sequence, expressed as differences (car-train) are: cost, journey stage number, in-vehicle travel time, total waiting time, importance x∆ satisfaction (comfort), Ix∆S(convenience), Ix∆S (reliability).

The improvement in model performance as a result of including attitudinal measures of comfort, convenience and reliability is considerable. The models are not perfect, however. The variable measuring journey stage number difference has an incorrect positive sign, but decreases its significance in Model IV. Reliability is unexpectedly insignificant in Model IV, which also has an increased constant, indicating the presence of unincluded influences.

As no account has been taken of situational or socio-economic factors, this is not surprising. Despite these shortcomings, Model IV provides a much improved classification of travellers, with 63% of car travellers correctly classified, as opposed to 48% in Model III.

On examination of the relative magnitudes of the model coefficients, it is apparent that the increased specification of Model IV has reduced the apparent influence of travel time. This is in complete agreement with the explicit assumptions made previously. The implications of this effect need emphasis, as they are of major significance.

Using the usual measures to establish value of travel time, the following results emerge:

Model III: Value of time = 85 c/hr ≑ 17% wage rate*
Model IV : Value of time = 64 c/hr ≑ 13% wage rate*

Despite the fact that these "values" have been calculated under conditions unsuitable for the establishment of "correct" measures (see, for example Hensher (1972), Beesley (1974)), it is obvious that the effect of "pure time" is not being measured in Model III. Instead, the obscuring effects of the conditions under which time is being spent are being measured. Model IV, which removes these effects, gives values which are much more accurate.

The conclusion is an important one; values of time calculated from models including time and cost variables alone will give grossly inaccurate results, a result also found by Hensher (1977). In this case, the error is of the order of 30%.

5.4 THE EXISTENCE OF BIAS IN PERCEIVED VARIABLES

In the market-research literature, the existence of "halo effects" - or bias of reported attitudes in the direction of favouring preferred objects - is widely recognised (Wilkie and Pessemeir (1973)). As will be shown, this effect has been found in this research, and has also been reported in other work (Golob, Horowitz, Wachs (1977)).

Satisfaction scores reported for each factor and for each factor-attribute, for both usual and alternative main modes, are plotted in Fig 1. Car users' evaluation of car and of train, and train users evaluation of train and of car, are plotted separately. The pattern is strikingly clear. Car is rated by both groups as being more satisfactory than train for all but 2 of the 15 attributes. But car users consistently rate car higher, and train lower, than do train users. Clearly, bias is present, though which way it operates is not clear.

Significance of Bias in Attitudes

The significance of this finding is considerable. If reported attitude (as distinctfrom behavioural intention) is a function of choice, and biased to suit that choice, predictions or estimations based on these measures will be inaccurate. If, on the other hand, perception and behavioural intention as well as reported attitude are biased, and the choice process as assumed by, say, the logit model is accurate (i.e., it is a compensatory process), there will be no affecton estimates of choice behaviour. Expressed another way, if only reported attitudes are biased, and not perceptions, the analyst will be using incorrect data, and model results will be accordingly in error. As soon as perceptions change in the direction of reported attitudes, this problem is reduced. Whether this occurs or not is a question that remains to be answered.

Bias in Perceptions of Physical Variables

Because most models use measured system variables and not attitudinal measures of these, the above problem may not seem to be of major relevance. However, it is. There is no reason to suppose that bias present in reported attitude

*The average annual income for the group = $9630. The "wage rate" was calculated, assuming a 37½ hour week, 52 week year, as = $4.94.

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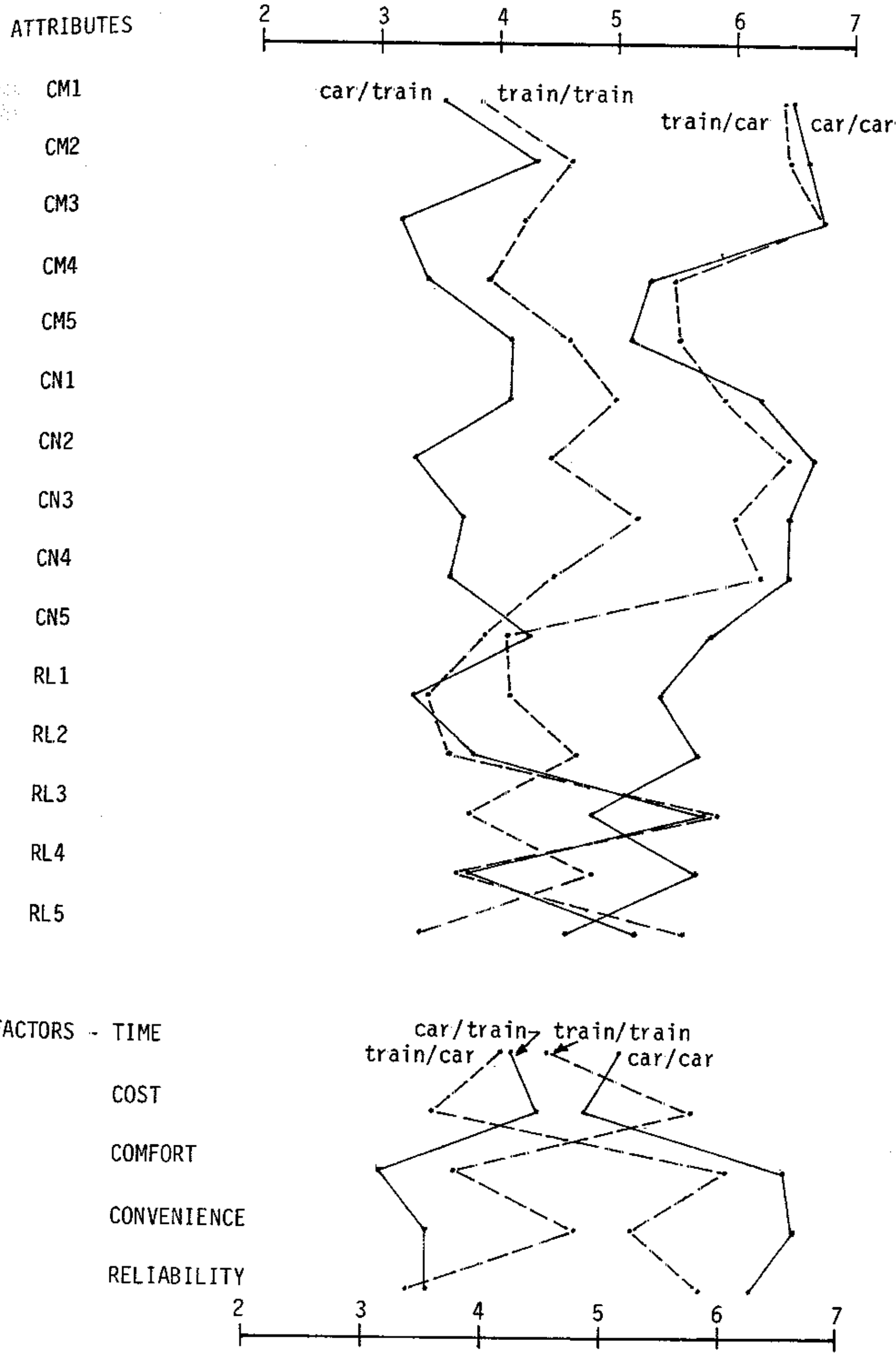
Fig 1 - Mean satisfaction scores for factor attributes;

car driver's evaluation of car, train; train evaluation of train, car.



is not present, at least to some degree, with reported physical variables. In fact, the problem is even more pervasive, as it must be perceived rather than measured variables which are used in a choice model.

There is some evidence from this research that reported measures of car running costs are significantly greater than perceived measures. A mean running cost of 14 cents/mile was reported, yet a range of models tested with values of this variable ranging from 0-14 cents indicated that a value of 2 cents/mile gave the "best" model performance. This may be due in part to the (as yet unexplored) possibility of choice constraints on car drivers, but it is highly unlikely that this would account for all of the difference between reported and the statistically derived "perceived" measures.

If this situation exists in reality, then the analyst has no alternative but to use actual, or "engineering" measures of system variables. Unfortunately, the same problem may arise, as it is likely that the perceived measures will still diverge from actual measures, with the resultant model error. There is a greater likelihood that these divergences will be random rather than exhibit a consistent bias, however, and it appears that, if this could be shown to be the case, actual measures of system characteristics would be less subject to consistent error. While perceived measures must continue to be the most appropriate, if the only way to collect them is through reported measures having a high probability of bias, a second-best solution is called for.

This area remains long overdue for research.

6. CONCLUSIONS

It has been argued that a complete specification of a choice model must include all factors that are relevant to that choice process. Some of the relevant factors are qualitative aspects of the transport system characteristics. It has been suggested that until the physical dimensions underlying perceptions of these aspects have been isolated, an appropriate method of inclusion is via the use of attitudinal measures of the characteristics. In fact, inclusion of attitudinal variables in a mode choice model has been shown to considerably improve both the performance of the model, and the estimates of value of time that can be obtained from it.

Problems relating to the ability of individuals to respond consistently to attitude questions have been addressed, and it has been shown that remarkable consistency of attitude expression via extremely dissimilar questions is possible. This should lend support to beliefs in the usefulness of attitude measures in a planning context.

While continued research towards the development of attitude measuring techniques may render the two-component model of attitude obsolete, evidence has been presented which indicates that it still has considerable strength. Nevertheless, the problem of bias in reported attitude remains, with its implications for the measurement of perceived levels of system variables.

The application of attitude measures to choice models is only one area, and a limited one at that, in which these techniques can be of use. There is evidence to suggest that only in special and rather rare circumstances are choice processes compensatory (i.e., involve a trade-off). This has obvious implications for the structure of choice models, but only through research into the psychological processes of choice will more accurate models emerge, or the existing ones be validated.

Attitudinal research has already achieved considerable success in isolating the likely effects and impacts of policy changes, and has great potential for further advances. It is to be hoped that it will continue to be actively supported.

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