DETERMINANTS OF TRAVEL MODE CHOICE
IN URBAN AREAS

by

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ABSTRACT

This study has two major concerns: the identification of mode choice determinants, and the formulation of a mode choice model which accounts for the determinants defined. First, the concepts underlying users' behaviour are expounded. These concepts relate users' mode choice to several influences, the perceived attributes of the transportation system, his socio-economic characteristics, and sensitivity toward modal attributes. In this study, the latter is hypothesized to be a function of the user's time budget and other indications of his lifestyle.

Thus, an individual may attach a great significance to savings in travel time as a result of his engagement in activities which put considerable demand upon his time, although most members of his income group may be sensitive primarily to the travel cost attribute. User's lifestyle may therefore create divergent sensitivities within the same socio-economic group. Previous research findings support the hypothesis that variations in these sensitivities are independent from the socio-economic characteristics.

The study's model makes use of this concept. The model is composed of two parts: the first is concerned with the grouping of all users according to their sensitivities toward attributes of the mode choice situation, and subsequently

the calibration of a stochastic function to explain users' choices in each group. The second part of the model relates the user's time, age and occupation (as indications of some aspects of his lifestyle) to these sensitivity, which is an additional step to substantiate the rationale of the model and its predictive quality.

The information to be fed into the calibration procedure is to be collected in a questionnaire survey on users' behaviour under choice conditions. The model is therefore a behavioural one; its basic function is to explain the predict users' choices. This approach is different, for example, from the propensity model approach, where users' preferences, rather than behaviour, are the basis for calibration.

The model proposed in this study can be applied as a planning tool to demonstrate the impact of various transportation policies on users' choices. The model is capable of providing estimates of the number of users that would be attracted to public transit as a result of, for example, introducing a new transit system, improving the existing level of service, increasing parking charges or gasoline prices. Other applications include the assessment of the impact of introducing novel transportation modes on ridership under the assumption that their attributes are comparable to the existing ones. Also, since the model accounts for certain aspects of the individual's lifestyle, it is possible to link changes in the latter to his mode choice.

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CHAPTER I

INTRODUCTION

1.1. Introductory Statement

Planning is concerned with the future. Hence, predicting the characteristics of a future situation is an essential phase in the planning process. A major task for those engaged in transportation planning is estimating future demand for various transportation facilities; and based upon these estimates, and possibly cost or social priorities, recommendations are put forward for the construction of the facilities needed. Gross errors in making these estimates lead to mispresentation of future needs, and thereby fostering decisions which may distort priorities held in check by the community.

In the evolution of the planning process over the last two decades, emphasis has been placed first on the accommodative function of the transportation system, that is, to satisfy the projected travel demand by various modes, subject to the economic criterion of benefit maximization.[1] The more recent trend is to place emphasis on the normative aspect of planning, according to which the transportation policy should be formulated so as to encourage the use of certain modes, while discouraging the use of others. By taking into account the environmental, social and economic implications of such a policy, the supply of different transportation facilities can be manipulated so as to affect the demand for different modes, and thereby bring about the desired change.[2]

Whether the main concern is the accommodation of demand or the manipulation of supply, concrete knowledge of mode choice determinants is essential to effective transportation planning. In the first case, the identification of mode choice determinants is necessary to explain and predict users' choices. In the latter, information is needed on the policy variables affecting users' choices so that incentives for mode shift can be employed effectively.

1.2. Statement of the Problem

Over the last two decades, mode choice analysis has taken different orientations. In earlier transportation studies, conducted in the fifties and through the mid-sixties, mode choice was explained in terms of the socio-economic characteristics of the population.[3] The urban area was divided into geographic zones, each containing a population reflecting a degree of homogeneity in terms of social, economic and demographic characteristics. In explaining mode choice, these characteristics were taken into account, and in many instances, other variables were considered: trip characteristics, such as trip length and purposes; frequency of departure times of transit as a measure for quality of service; and possibly an index of location, usually the relative accessibility of various parts of the city by transit and highway measured in time units. These variables were entered into a regression model which produced an estimate of transit users for each geographic zone. Other studies utilized these inputs to arrive at the mode split ratio, i.e., the ratio of transit to car users for the given zone.

In a later phase of development, researchers have placed emphasis on the personal characteristics of the user and the characteristics of his mode choice situation, i.e., his socio-economic characteristics, and the difference between the attributes of alternative modes available to him.[4] The argument was advanced that by accounting for the characteristics of the individual user rather than the zonal population, i.e., the disaggregate versus the aggregate data entry, a more accurate description could be made for the individual observation.[5]

This seemed to be an improvement in the operational characteristics of the model. But there were certain improvements in the conceptual framework of the analysis as well. The decision role of mode choice was to take place at the individual user's level, not by a geographic zone, and thus accounting for the individual's behaviour would reflect greater similarity to the real world, which is an important feature of reliable behavioural models.[6]

Another conceptual advantage associated with the use of disaggregated models was their concern with the probability of a person making one mode choice or the other, rather than the mere production of an estimate of model users by employing deterministic models. Some researchers held the view that predicting a person's choice should be expressed as a probability (there is 60 per cent chance he would select this mode). The probability function relating choice determinants to a specific choice is usually non-linear, yet deterministic models, it was argued, simplified this relationship by using regression functions.[7]

A completely different approach was pursued by researchers whose interest was the marketing of transit services among car users who had access to transit. In a questionnaire survey, car users were asked to state how important each of the attributes of car and transit, and the extent to which they were satisfied with each mode with respect to each individual attribute.[8] The user's attitudes, or rather his sensitivity toward modal attributes, expressed quantitatively along a graduated 5-point Linkert scale, were fed into a set of mathematical functions to predict users' choices. The socio-economic characteristics, at least in some instances, were not accounted for.

The question which may arise as a result of the literature review is whether any of these models employed a complete set of the choice determinants relevant to the problem. In other words, since both types of models have provided some explanation for users' behaviour, would the addition of one set of determinants to the other contribute to the expansion of the explanatory power of the model? If so, what are the ramifications of this to the conceptual analysis of mode choice, and how would the model structure be affected as a result?

These questions are the main concern of this study.

1.3. Objectives of the Study

Three major objectives are to be pursued in this study:

(a) To identify mode choice determinants in urban areas in as far as there is evidence in the literature to support their significance in explaining users' behaviour.

(b) To develop a conceptual framework which provides a rationale for the relationship between users' behaviour and its determinants.

(c) To formulate a mode choice model which makes use of this conceptual framework and employs the choice determinants identified in the study as the input variables.

It is clear from the statement of objectives that this study is a continuation for previous research on mode choice analysis, and that the ultimate purpose of this and previous work is to expand the explanatory power of the mode choice models and their ability to predict users' behaviour. Thus, the study attempts to improve upon the present state-of-the-art, at least conceptually, the state-of-the-art being the use of socio-economic characteristics and characteristics of the mode choice situation as model inputs. The possible improvement to be explored here is the addition of the user's sensitivity toward modal attributes to other mode choice determinants. In any case, the use of the mode choice determinants already identified in previous works, together with those to be advanced in this study, should be incorporated in a conceptual framework whose rationale can be defended either on *a priori* ground, or on the basis of previous research findings.

1.4. Conceptual Framework

Previous studies have already established that socio-economic characteristics are significant in explaining users' mode choices.[9] But there are indications that they are not the only personal characteristics which could be significant and that others should be taken into consideration. Research has already identified the individual's perception and attitudes as relevant to the analysis. It can also be easily demonstrated that the individual circumstances may affect his mode choice behaviour. As Williamson and Moses' analysis has demonstrated, the probability of choosing between two modes, one of which is more costly but takes less time, might depend on whether the individual could convert the time difference into working time.[10] Or, if the individual had the opportunity to spend the time saving in an agreeable activity worthy of the extra cost, he may then, even occasionally, shift to the faster mode. Thus, in general, the individual's sensitivity toward modal attributes may reflect his circumstances, (and possibly his lifestyle), but not necessarily his socio-economic characteristics.[11]

The primary hypothesis of this study can be stated as follows: the user's mode choice behaviour is affected by four sets of determinants: his socio-economic characteristics, the perceived attributes of the transportation system, the significance he attaches to the individual attributes (i.e., his sensitivity toward these attributes), and the circumstances of the trip, e.g., the trip purpose. It is hypothesized here that the user's sensitivity toward modal attributes is not strongly correlated with his socio-economic characteristics, except to the extent that the latter contributes to the explanation of the individual's lifestyle.

In pursuing this concept further to what might lead to the causal underpinnings of users' behaviour, attention must be given to the possible relationship between the user's sensitivity toward modal attributes and his individual circumstances. We may also hypothesize that the latter can be attributed to the user's lifestyle--lifestyle being the pattern by which the individual user allocates his time and monetary resources among various activities in which he is engaged. This set of relationships is advanced here as a rationalization for the study's conceptual analysis and possibly for the model formulation, but since empirical data is lacking in this respect, no attempt is made in the study to support these relationships except on a priori ground.

1.5. Outline of Research

In establishing a conceptual framework for the study's model, it is worthwhile to make use of the existing concepts and theories on mode choice behaviour: (a) the abstract mode choice theory which places emphasis on the modal attributes rather than its institutional form, e.g., bus, train, etc., (b) the utilitarian theory of mode choice, which relates the probability of making a certain choice to the disutility savings made by such a choice, (c) the theory of time value formulated to explain the trade-offs between time and travel costs as evidenced in the users' mode choice behaviour, and (d) concepts and theories related to the individual's perception and attitude, and their effect on behaviour.

In addition, the stated objectives of the study call for the formulation of a conceptual framework of a model which promises a greater explanatory power than those already in use. The refinement thought to achieve this improved capacity is hinted at previously, that is, by accounting for the user's sensitivity toward modal attributes. Yet, for this refinement to be a worthy undertaking, sufficient evidence must be brought forward to indicate that no strong correlation exists between the user's sensitivity toward modal attributes and his socio-economic characteristics. Such evidence will be sought in previous research findings.

For the purposes of model formulation, other mode choice determinants should also be assessed individually: the user's socio-economic characteristics and the characteristics of his mode choice situation, i.e., differences between the attributes of the alternative modes available to him. The manipulation of these as model inputs requires a careful consideration to ensure its compatibility with the concepts developed in the study. Again, the information required for this step can be derived from previous research conclusions.

For reasons discussed in Section 1.2., the model to be formulated here is a disaggregated one. Initially, all users are to be classified into "sensitivity groups", according to the modal attribute to which they are most sensitive. Discriminant analysis can then be used in conjunction with a probability model to explain and predict users' mode choice within each group. The user's socio-economic characteristics, and attributes of the mode choice situation are to be employed in deriving the discriminant function.

1.6. Scope and Limitation of the Study

Although the conceptual analysis of this study is relevant to any mode choice situation, the model to be formulated here is specifically designed for application to urban areas which can be considered as medium or large size cities. This particular range is dictated by the model calibration requirements. To derive a behavioural model of the kind being considered here, there should be sufficient observations to cover a wide range of mode choice situations. This can be achieved in a user's sample which is spatially dispersed over a relatively large geographic area. It is suggested that a sample collected in a small city may not satisfy this criterion, and moreover, the transit service in such cities is minimal, if at all existent, and hence does not offer a real alternative to the car. The threshold separating small from medium cities is set arbitrarily by this author at the population of three hundred thousand.

This research is set to formulate a mode choice model, but does not attempt an actual data analysis or calibration of the model in question. Therefore evidence brought forward to substantiate the selection of any of the model inputs, as well as the justification for various procedures to be adopted, are to be drawn totally from previous research findings.

1.7. Significance of Research

The escalating prices of oil products as a result of an ever increasing demand upon a depleting resource, the bleak prospect of continued price escalation, together with various environmental considerations, have renewed the interest in public transportation to meet the community needs for mobility. Previously, planners who advocated greater reliance on public transportation had difficulty, at least in some instances, in recruiting support for such a policy. The more recent trends in gasoline pricing strengthened the planners' argument that a real alternative to the car must be offered.

For such a transportation policy to be effective, information is required on the impact of altering the mode choice situation (by improving the transit service, for example) on various social or economic groups of the population. This study, along with others on the subject of mode choice, attempts to explain and predict users' behaviour in response to changes in the mode choice situation, whether it is a planned change, such as increasing the frequency of transit service, or "unplanned" change, such as the increase in gasoline prices. The refinement proposed here, by accounting for the user's sensitivity toward model attributes, is thought to expand the explanatory power of the model.

If this objective can be achieved, the planner can benefit from this improved capacity in several ways. First, the initiation or the improvement to transit service can be guided accordingly so as to meet different user's criteria in various parts of the city. Likewise, the planner may be better equipped to predict the user's response to gasoline prices, for example. Secondly, by linking the user's lifestyle, or some measure of it, to his mode choice behaviour, it would be possible to anticipate change in demand for various modes as a result of some social or economic changes, e.g., reduction of the weekly working hours and increase in leisure time.

Finally, improved knowledge of users' evaluations of modal attributes is progress toward predicting demand for novel transportation modes. Obviously, conventional methods based on linear or curve extrapolation would not be helpful in estimating demand for such modes. The precedence upon which extrapolation can be based is non-existent. For this purpose, the utilitarian theory of mode choice could be more useful because of its applicability to "abstract modes," modes which are described by their travel disutilities, and not by its institutional form.

FOOTNOTES

1. A brief analysis of this approach is presented in <u>Modal Split: Documentation of Nine Methods for Estimating Transit Usage</u>, by Martin J. Fertal et al., U. S. Department of Commerce, 1966.

2. This trend is strongly expressed by Gerald R. Brown's study, <u>Mode Choice Determinants of Selected Socio-economic Groups: An Investigation of a Planning and Control Mechanism to Direct Automobile Drivers to Public Transportation</u>, Ph.D. in the Department of Community and Regional Planning, The University of British Columbia, 1971, published by the Department of Civil Engineering, 1972.

3. A detailed analysis of the recent evolution of mode use prediction techniques is provided in "Disaggregate Stochastic Models of Travel Mode Choice," by Peter R. Stopher and Schalom Reichman, <u>Highway Research Record</u>, Rep. No. 369, 1971, pp. 91-103.

4. The subjects of this study, i.e., the travelers with whom we are concerned in the analysis, are referred to in two different ways. The term "users" is mentioned in connection with any group of persons using a certain mode, e.g., car users, or persons whose behaviour is relevant to mode choice analysis, e.g., user's modal bias. In the ensuing discussions on lifestyle, or sensitivity toward modal attributes, this term may also be used if the purpose of the discussion is directly related to mode choice. Otherwise, the study subjects are referred to as individuals or persons. This distinction is in harmony with the current usage in the literature.

5. Stopher and Reichman, <u>op</u>. <u>cit</u>., p. 94.

6. <u>Ibid</u>.

7. <u>Ibid</u>., pp. 91-113.

8. See, for example, "Investigation of the Effect of Traveler Attitudes in a Model of Mode Choice Behaviour," <u>Highway Research Record</u>, Rep. No. 369, 1971, pp. 1-14.

9. Fertal, <u>Modal Split: Documentation of Nine Methods.</u>

10. Leon Moses and H. Williamson, "Value of Time, Choice of Mode and the Subsidy Issue in Urban Transportation, <u>Journal of Political Economy</u>, Vol. 71, 1963, pp. 247 - 264.

11. This concept was hinted to by F. X. De Donnea, <u>The Determinants of Transport Mode Choice in Dutch Cities: Some Disaggregate Stochastic Models</u>, Rotterdam University Press, Rotterdam, 1971, p. 157.

12. Attributes of the transportation system refer to the activities involved in using the alternative transport modes available to the user, e.g., walking, waiting, in-vehicle travel time, etc.

CHAPTER II

THEORY OF MODE CHOICE

2.1. Introduction

The formulation of a plausible theory explaining users' mode choices is a major task to be undertaken in the course of this study. The "new approach" to the consumer theory as advanced by Lancaster and others, and its parallel in the transportation planning field, the abstract mode choice theory, are introduced in this chapter. Within the framework established by these theories, a transport mode is "reduced" to a "bundle" of attributes, or a combination of characteristics, and users' choices are explained as a function of the relative utility or disutility associated with each possible selection.

Attention is also given to the utilitarian theory of mode choice, since it places emphasis on how these attributes are weighted by different individuals, and the bearing this may have on their behaviour. The range and complexity of the hypothesized relationships between mode attributes and users' choices are investigated and evidence supporting their validity in previous research is presented below. Finally, we may address the problem of perception and attitudes, and the effect of these psychological processes on users' behaviour.

ABSTRACT MODE THEORY

2.2. The Concept

Major transportation studies conducted in the fifties and the sixties have reflected the influence of the classical consumer theory in providing a rationale for mode choice analysis.[1] According to this theory, the user selects a combination of goods which gives him the maximum utility under the given budget constraint. Hence, the limitation is on the monetary resources and the choice is among goods. Viewed in this context, mode choice is equivalent to the selection of the good which, together with other goods, gives the user the maximum utility possible under the given constraint.

A departure from this conventional approach was made in the new approach to consumer theory.[2] This approach placed emphasis on the characteristics of the goods rather than the goods themselves. Goods *per se* do not give rise to utility nor provide satisfaction; rather, the qualities they possess. Further, these qualities are not possessed exclusively by one good, but are generally shared among several goods. The choice is therefore not among goods, as suggested in the classical consumer theory, but among combinations of characteristics. The rational user would then select a collection of goods whose combined characteristics give him a greater satisfaction than any other possible combination.

This simple modification of the consumer theory provides us with an enlightened view of the transportation mode choice problem. A transport mode in this conceptual analysis is viewed as a "bundle" of attributes: speed, cost, level of comfort, appearance, etc., but the popular image of the mode, whatever this may be, is isolated from the mode choice problem. The emphasis is therefore placed on the utilitarian aspect of the transport vehicle, rather than its institutional form: bus, train, car, etc. Hence, the choice problem is reduced to selection of combination of attributes.[3]

This new approach is a break with the traditional approach to mode choice analysis, where the researcher was concerned with the direct relationship between the users' socio-economic characteristics and their choices among two modes, car and transit. Some studies recognized one or few mode attributes, such as travel time, as variables accounting for users' mode choices.[4] But, in general, the system attributes were not given adequate consideration and the entire analysis was mode-oriented, i.e., car or transit, not attribute-oriented.

2.3. Evaluation

Having introduced the abstract mode theory, and identified the differences between this and the conventional mode split analysis, we can proceed to discuss the possible advantages of the new approach:

(a) The most significant outcome of any transportation planning model is the identification of the relationship of policy variables to users' behaviour. Obviously this would be useful information for planning purposes, particularly if the main objective is to affect users' behaviour.[5] This information is afforded only by a model in which the system attributes are accounted for. To the extent that these attributes are alterable, and that they affect users' choices, such a model is a proper tool which can be used in the formulation of transportation policy. The more advanced is our knowledge on the relationship expressed in the model, the more effective the transportation policy is likely to be.

In contrast, a model which explains mode choice in terms of the socio-economic variables exclusively gives us no guidance as to what measures can be applied to affect users' choices--since users' socio-economic characteristics are not policy variables. Due to this shortcoming, such a model would afford limited information about, for example, an estimate of transit users if service is extended to a given part of the city. The assumption under which this estimate can be made is that the level of service is the same as other parts of the city for which the model was originally calibrated.

On the other hand, a model which accounts for the system attributes would produce an estimate of users who would be attracted to any given mode as a result of improving its service, or undermining the characteristics of competing modes. That is, we would be able to estimate the increase in transit ridership as a result of increasing its frequency, lowering the fare, or raising the parking charges.[6]

(b) The system attributes express the influence of many exogeneous variables which can not be accounted for in the mode choice model, but which may have a definite impact on users' behaviour. For example, the increase in gasoline prices, as a result of increased demand on a depleting resource, would have a strong impact on users' behaviour which can not be accounted for without including the cost attribute.

But there are other uses for modal attributes which are more subtle. Suppose, for example, that government and business institutions opted for staggering working hours to save their employees the problem of travelling in the peak hours congestion. Would this have an effect on users' mode choices? In some instances there would be a substantial impact. We may be reminded that transit operating on a separate right-of-way has a strong advantage over the car in the peak hours, when traffic movement is slow. To spread the peak hour travel demand over many hours may alleviate the peak congestion, and thereby reducing the relative advantage of transit use. Again, without accounting for travel time by alternative modes, the impact of such a change can not be identified in the model's output.

It is obvious from the foregoing discussion that by taking modal attributes into account, we would be better equipped to anticipate the impact of some social or economic changes on users' behaviour.

(c) In studying users' behaviour in any choice situation, the identification of cause-effect relationships is a highly desirable objective. This is particularly true in the planning field where a great significance is attached to the identification of means by which users' behaviour can be affected. But, unfortunately, this can not be accomplished by any of the statistical techniques yet known. In a mathematical model, we have no evidence to suggest that the relationship expressed, no matter how strong, encounters those variables directly causing these relationships to come into effect.

In evaluating behavioural models, equal attention should be given to their statistical significance as well as the plausibility and logic that is reflected in the relationship expressed. A valid model should be supported on both accounts. For planning purposes, as we have argued previously, the utility of the model increases as its content approximates more closely the implied cause-effect relationship. Using this as a criterion for evaluating mode choice models, the advantages for accounting for mode choice attributes become more obvious. The association between users' mode choices and their socio-economic characteristics does <u>not</u> exhibit a strong causal relationship. Does income or age, for example, cause the users to select a certain mode and avoid the use of others? Traditionally, we have accepted this relationship without questioning if sufficient explanation is provided <u>within</u> the model. Regardless of the statistical significance of such a model, it is the opinion of this author that the logic of such a relationship is not adequate.

It is argued here that the inclusion of the system attributes would increase the explanatory content of the model, not only statistically, but logically as well. This is not difficult to demonstrate. In the first case, the model would state that higher income groups would select mode A, and lower income groups mode B. The inclusion of the mode attributes would produce a model stating, for example, that higher income groups are likely to choose mode A given that it is faster than mode B, while lower income groups are likely to use mode B given that its use is less costly than mode A.[7] It is obvious that the latter account is more satisfying, and is closer to express a causal relationship.

(d) A model which accounts for the system attributes can possibly be employed to estimate demand for new transportation modes. These new modes are now sought by the transportation industry to alleviate the pressing problems of street congestion, pollution, and to meet the challenge of the energy crisis. The vehicle or the system which may be designed for this purpose could be radically different from those known to the users. This would cause difficulty to the planner who attempts to predict users' responses to the new mode. The conventional calibrating procedure based upon data collated from an existing mode choice situation is no longer applicable, simply because such a situation does not yet exist.

This difficulty can be partially overcome by studying the users' responses to the differences between attributes of alternative modes. Such information can be derived from an existing or a previous mode choice situation, and can be related to the differences created by the introduction of the new mode.

Turning our attention now to the limitation of the abstract mode choice approach, two problems become immediately apparent. The first is the extent to which a travel mode can be reduced to a "bundle" of attributes without eliminating any of the characteristics relevant to the problem. Although many researchers have investigated users' perception of modal attributes, no systematic methodology has been developed to identify the perceived relevant modal attributes.

The second problem associated with the abstract mode approach is the extent to which the relevant attributes are comparable from one mode to the other. For example, how does the flexibility of routing, or the freedom of choosing the departure time, inherent to car use compare with the fixed route and schedules associated with the transit use? These two problems can be considered as the basic limitation of the approach, which limitation is accentuated further as the study progresses toward the model design.

UTILITARIAN THEORY OF MODE CHOICE

2.4. The Concept

In formulating a conceptual framework for users' behaviour in mode choice situations, the utilitarian theory of mode choice complements the abstract mode theory. Together, they form a useful set of hypotheses. In the latter, emphasis is placed on the attributes of the transport mode, while the former relates users' choices to their perception of such attributes.

The hypothesis entertained in this theory states that the travel activity has various dimensions which corresponds to the attributes of the travel mode.[8] These dimensions give rise to users' disutility or dissatisfaction, which comprises, in total, the "generalized price" of the travel activity. In choosing a travel mode for a given trip, the user attempts to minimize his dissatisfaction by choosing the mode associated with the least generalized price.

The theory states further that each individual user perceives the disutility of travel by any given mode differently from other users. Hence, for any group of users, the generalized price of travel by any given mode varies. This variation, however, occurs in a certain pattern which can be approximated by a normal probability distribution function. Hence, if the generalized price of the travel mode and its alternative are known, it is possible to assign a certain probability to the user's making one choice and the other.

The graph below (Fig. 1) demonstrates this concept clearly. The horizontal axis refers to difference in the generalized price between modes A and B, and the vertical axis gives the probability of making one or the other selection. In a mode choice situation where the difference in the generalized price is zero, i.e., both modes are equally dissatisfying, the probability of using either mode is 0.5. In another situation where the generalized price of using B is higher, the probability of using A increases, and that of B

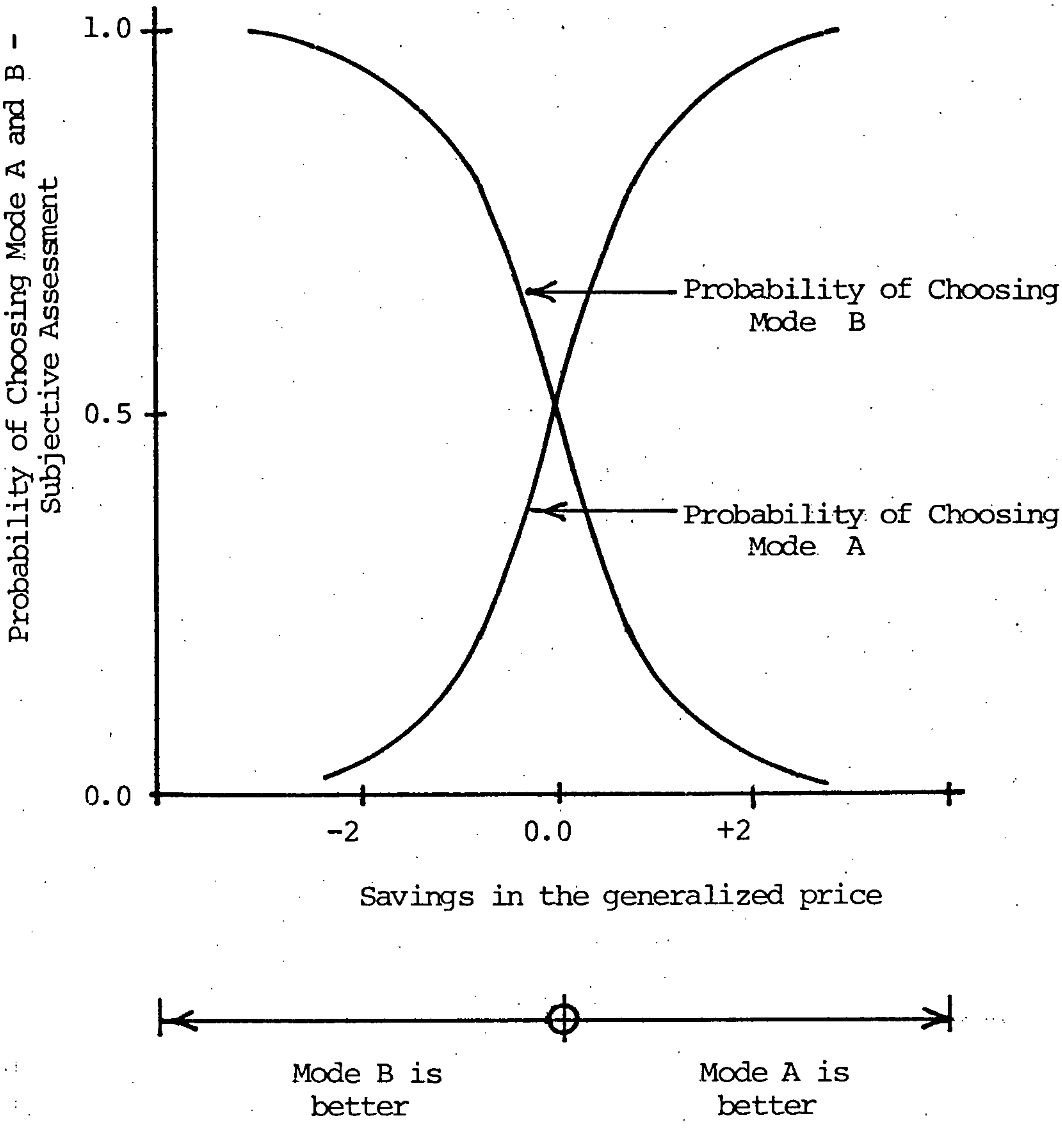

Fig. 1. Probability of Mode Choice as a Function of Savings in the Generalized Price

declines as shown in the graph. We may note that in this mode choice situation, there is still the possibility, however low, that the second-best mode would be selected. But, as the disutility of this mode increases over its alternative, the probability of making the "wrong" selection declines consistently. This "deviation" can be attributed mainly to the concept of individual perceptual variation of travel disutility. That is, if all users perceived travel disutilities in exactly the same manner, every user will be choosing mode A over mode B as long as a saving in the generalized price can be achieved by making such a choice. But, since users' individual perceptions vary, for reasons to be discussed in Section 2.8., this is not the case in both theory and observation.

2.5. Evaluation

The utilitarian theory of mode choice puts forward two basic concepts which are useful for the purposes of this study. The first of these is the concept of generalized price, which refers to the perceived disutilities associated with the travel activity (for a given trip and by a given mode). The second concept is concerned with the pattern by which user perceptions of the disutility savings of using one mode vis-a-vis its alternative vary among any group of users.

The notion of generalized price is extremely useful in explaining users' behaviour. Without resorting to this concept, it is impossible to scientifically explain how users compare one mode against the other, since each is perceived as a bundle of attributes. It is argued here that the only way to do so is by expressing all the travel dimensions in terms of some common units of measurements, be it time, money, or simply "utiles." The disutility of these various dimensions comprises the generalized price of the travel activity, and, hence, a comparison can be drawn between the use of a mode vis-a-vis others.

The important question that may arise from this discussion is whether the user himself perceives the disutility of travel dimensions in this manner, and whether his behaviour supports the notion of the generalized price. A detailed discussion on this relating time and money is provided in Section 2.6. Here, suffice to mention that there is evidence to suggest that users do make trade-offs between one travel disutility and the other, thus supporting the hypothesis that different disutilities can be compared in quantitative terms.

The second concept to be evaluated here is related to the notion that savings in the generalized price to be made in using the best mode over its alternative is not constant for any group of users, but varies from one user to the other. This was attributed to variations in value systems, socio-economic characteristics, and sampling errors common to all statistical analyses. These, and other possible explanations, are discussed in Section 2.9. Here, our interest is confined to the implications of this on model formulation.

The hypothesis that savings in the generalized price are weighted differently by individual users is by itself a plausible one. Indeed, it would be unreasonable to hypothesize the opposite, since users' perception of the "advantages" of one mode over the other can hardly be expected to be identical. This perceptual variation, as we may call it here, has an obvious impact on users' behaviour, and we would be wise to account for it in the model formulation.

Without information on the pattern of individual perceptual variations, users' behaviour can not be predicted. But the theory states that perceptual variation of the difference in the generalized price can be approximated by a normal probability distribution function. This is assumed in all statistical analyses where no evidence is encountered to suggest that the shape of the curve is otherwise. This assumption --here it is part of the theory--simply implies that in any unbiased sample, users' perception of the generalized price savings is homogeneous. That is, there are few who are extreme in evaluating such saving, but the majority tend to "agree" on some common value.

Further, the hypothesis on the shape of the curve, a quality usually referred to as the homoscedasticity, is an important part of the mode choice theory as it enables the researchers to predict the choices to be made by any group of users. By using the central limit theorem, it is possible to predict the user choice given his perceived generalized price saving and the average perceived saving in the sample.

2.6. Empirical Evidence: Value of Time

In searching for evidence on the validity of the utilitarian theory of mode choice, our attention should be directed to the "time value" theory, the main concern of which is the identification of the trade-off values between time and cost as a mode choice determinant. Our interest in this theory is justified by the suggestion that time and cost are two of the most significant travel disutilities, and furthermore, because the voluminous amount of research on this relationship provides us with empirical data on the trade-offs between these disutilities.

This theory has developed as a result of the interest of transportation economists in evaluating the benefits of proposed highway improvements. In 1961, the American Association of State Highway Officials expressed the view that ". . . the dollar value of time savings may vary considerably and no precise method of evaluation has yet been determined. A value of time for passenger cars of $1.55 per hour is used herein as representative of current opinion for a logical and practical value."[9] In response to this statement, Moses and Williamson noted that "no explanation is given for why $1.55 is more logical and practical than any other figure."[10]

Likewise, the use of the average hourly wage, as an equivalent to the value of time saved in travel, was criticized on the ground that "time saving contributes to a tangible reduction in the cost of transportation only to the extent users are able to make productive, i.e., gainful, use of time saved."[11] Limited research was conducted in 1963 to derive two separate values for working and non-working times. But these were also estimates based on what seemed practical and logical, with no evidence to support them.[12]

In this study, we are not interested in the monetary value of time per se, and therefore the dispute on the correct value is irrelevant in this context. Rather, our interest is focused on the following questions: (1) do users perceive travel time and cost as two disutilities to be traded one against the other? and (2) is the trade-off value constant or variable? and if the latter is correct, is this value correlated with, or dependent upon, other variables? and what are these?

One way of investigating this problem is by examining users' behaviour in mode choice situations, their personal characteristics, and the characteristics of the choice situation itself. This approach was followed in many studies, whose findings are discussed below.

To start our discussion on the empirical research findings, we make reference to Beesley who made the first attempt to derive time value from data collated on users' choices between two transit modes in London, England.[13] These data included travel time by each mode, the fare, income category and occupational status. Beesley assumed that the level of comfort is the same in the two choices, and, hence, explained mode choice as a trade-off between cost of travel and total travel time savings. By the trial and error technique, he attempted to reach the time value which explains users' choices with a minimum of misclassifications. The value which yielded the best results was 31% of the average wage of clerical office workers, and 37% for executive office workers. A third time value was derived for the high income groups, which varied from 42% to 50% of the hourly wage of this group.[14] The model formulated on the basis of these values classified 75% of the observations correctly, which was considered satisfactory.

Although Beesley's work was only exploratory, he established a case for deriving the perceived time value from users' behaviour. He also identified the relationship between perceived time value on the one hand, income and occupational status on the other. A reference was also made, without an in-depth analysis, to the possible relationship between time value and the circumstances of the trip: value of time saved was made dependent, among other things, upon the mode of travel.[15]

Quarmby pursued this approach in a more detailed study on mode choices in the work trip in Leeds, England.[16] Three choices were available to the user, car, bus and the train. This study was more advanced in that "excess time," i.e., out-of-vehicle travel time, walking, waiting, was treated as a different disutility separate from the in-vehicle travel time. The hypothesis implied in this treatment was that the disutility of excess time was perceived differently from the in-vehicle time. A further advance made by Quarmby was the use of discriminant analysis to calculate the disutility function of each mode, a method which was at least more scientific than the trial and error technique.

The outcome of Quarmby's work supported the notion that users trade time savings against cost, and that the value of the trade-off was dependent upon the user's income. Quarmby found this value to be between 20% to 25% of the user's wage, a percentage which held true for a wide range of income groups.[17] The hypothesis that the disutility of excess time was different from the in-vehicle time was also supported. The former was valued at 2.3 times the latter.[18] This finding is extremely significant for planning purposes. A further finding of this study was the relationship between time value and the mode being used: time saved on the car trip was valued less by the user than time saved on the bus trip, the former being 40% to 50% of the latter.[19] This could possibly be attributed to the comfort level which added to the disutility of time spent in the bus in comparison to the time spent in the car. Later in Section 2.7., the problem of accounting for the comfort level as a separate disutility is examined.

The results of Stopher's study in County Hall, London, England, were in basic agreement with the definition of time value in previous work: it ranged from 23% to 32% of the hourly wage rate, slightly higher than the range defined by Quarmby.[20] A much higher percentage, about 50% of the wage rate, was derived by Lisco in a Chicago study. Value of excess time was found to be three times the in-vehicle time in this study.[21] Unfortunately, the details of Lisco's study was not published, and therefore no explanation can be given here as to the reason for this unusually high value.

The above quoted authors, Beesley, Quarmby, Stopher and Lisco, investigated the concept of trade-off between time saved and cost of travel in a variety of mode choice situations. However, in all these studies, except that by Lisco and possibly Quarmby, the variation in the level of comfort from one mode to the other was not accounted for. Hence, it may be argued that the trade-off was not merely of money against time (assuming car use yields time savings), but probably against time plus increased level of comfort. The value of time derived in this manner would then be inflated.

The solution to this problem could be found in a different phase of mode choice analysis. Research on the benefits of highway improvements attempted to define how the users perceive the time saved (through such improvements) and the monetary value they attach to this saving. Such information was provided in the users' choices between two highway routes, one of which is a toll road, but a shorter route. In such situations, users' choices involved a trade-off between time and cost, yet the level of comfort in both cases was nearly the same. No other situation could provide us with more accurate information on the validity of the time value concept.

Thompson and Thomas made use of a theoretical framework previously advanced by Haney to conduct an extensive analysis of time value.[22] In this framework, it was hypothesized that the marginal value of time was not a constant, rather a function of the time saved. Haney hypothesized that the time value was very small for small amounts of total time savings, but it increased, as shown in Fig. 2.a., with the increase in total time savings. The increase did not continue ad infinitum, however, and beyond certain value, more time savings brought lesser increase in time value, obviously in conformance with the law of diminishing marginal returns. This conceptual framework was brought forth by Haney demonstrating what he thought to be a plausible hypothesis on users' evaluation of time savings, but he did not investigate the possible effect of the total trip length on time value.

However, according to Haney's scheme, it would be improper to assign a single value to time. Thomas also reached this conclusion as he tried and failed to derive a constant time value.[23] The data he collated for this purpose was on highway tolls and the time savings offered in return. The sample encountered different mode situations with various tolls and time savings. Thomas and Thompson made various attempts at defining the time value, and finally they produced a model relating this value to income and total time savings.[24] In a subsequent work such a model was calibrated for each trip purpose: work, personal business, social recreational and vacation. Using a set of these models, the authors produced several tables, each giving the time value for eight income groups (the columns) and total time savings by increment of one minute (the rows) up to 20 or 30 minutes.[25] The aim of these tables was to facilitate the task of the highway economist in evaluating the benefits of highway improvements.

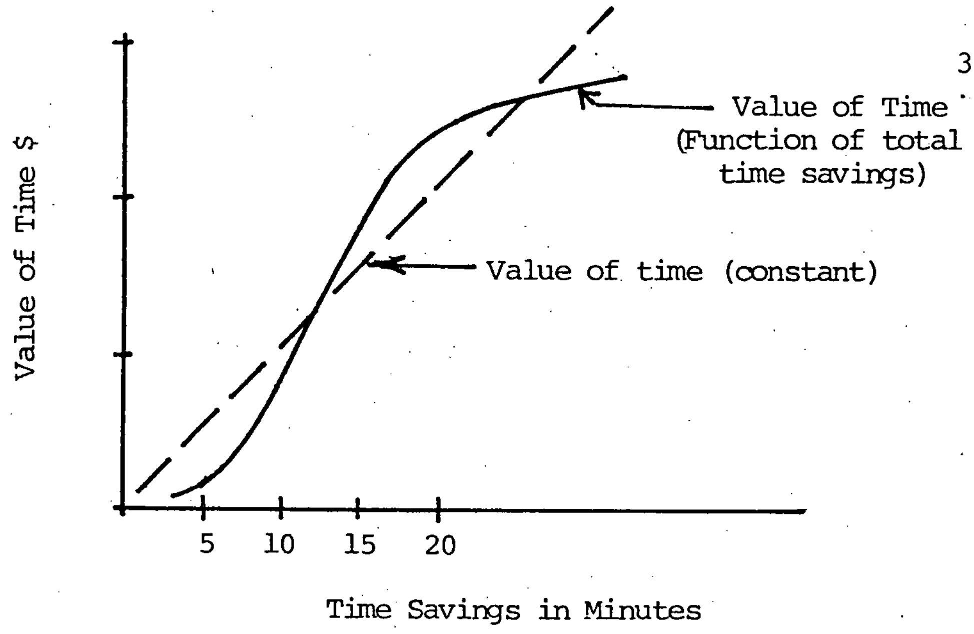

Fig. 2.a. Value of Time as a Function of Total Time Savings (Haney's Scheme)

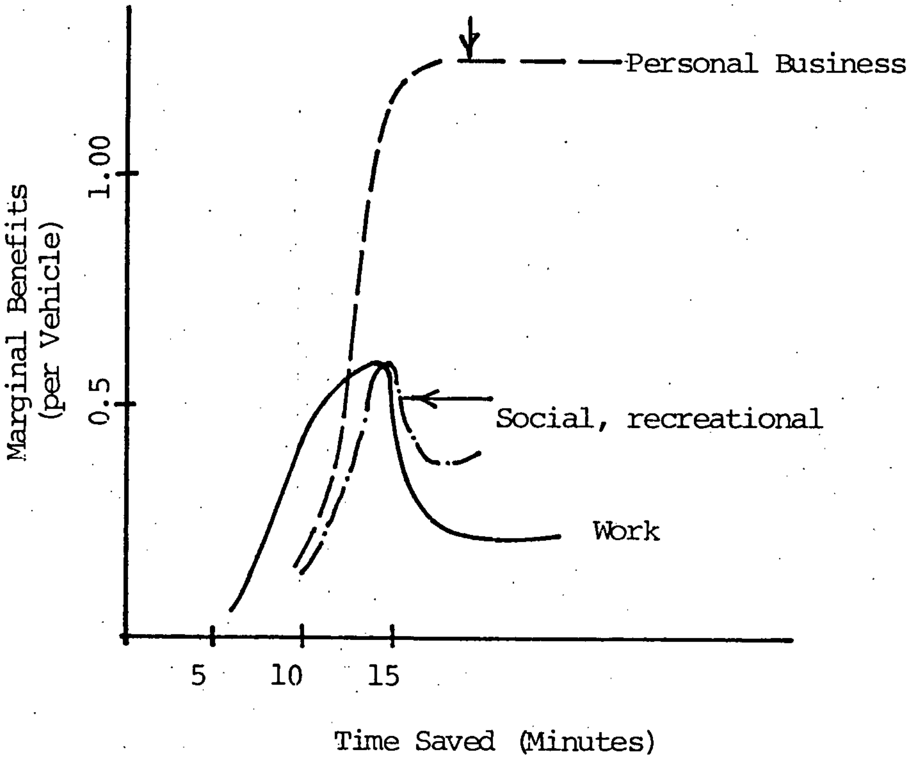

Fig. 2.b. Marginal Benefits of Time Saved by Trip Purpose (Income Group: $8000 - $9999)

To make use of these tables, information is needed on the expected number of users, their income category, trip purpose, and the time saving offered by the improvement. The expected monetary returns can then be calculated from the tables.

The models calibrated by Thomas and Thompson affords us the opportunity to test the validity of the theoretical scheme of time value advanced by Haney. The graph constructed by Reichman, shown in Fig. 2.b., is helpful for this purpose.[26] Reichman used Thomas and Thompson's tables to demonstrate the relationship of marginal value of time to the total time savings for four kinds of trips. Except for vacation trips, changes in the marginal value of time reflects a clear pattern which is characterized by the following zones:

(a) from one to five minutes savings, the marginal value of time shows little or no increase.

(b) from five to fifteen minutes savings, increase in time savings is paralleled by the greatest increase in marginal value of time.

(c) beyond fifteen minutes savings, which is the zone of diminishing marginal returns, the marginal value of time is either maintained at the same value, or declining.

These changes in the characteristics of the curve, as it proceeds from one zone to the other, are almost identical with those of the curve constructed in Haney's scheme after accounting for the fact that the latter depicts the marginal value of time savings, while the former depicts the average value of time. This analysis gives us empirical evidence to support Daney's theory of time value, which is indeed far more sophisticated and possibly more plausible than the average, single time value approach which was pursued by Quarmby and others.

To sum up this section, evidence brought forward in the literature suggest that at least two travel disutilities, cost and time, were perceived in quantitatively comparable terms by the users, and that their behaviour clearly indicated that certain trade-offs were made in their mode choice. The trade-off value identified was not constant, since the relationship between time and cost was found to be non-linear. However, early researchers identified the consistency in users' behaviour in making these trade-offs, and found that the value of time was dependent mainly upon users' income, and to a lesser extent upon the circumstances of the trip. It was recognized that the value of time was not uniform since a higher disutility was assigned to excess time than the in-vehicle time. Hence, in formulating a mode choice model, these two should be entered separately.

This aspect of users' behaviour, the trade-off between time and cost, was expressed more clearly in those studies concerned with the choice of toll routes. In such situations, time savings were achieved at cost, while all other variables remained unchanged. Further support for the theory of time value was brought forth, and more importantly, two other dependencies of time value were identified: total time saving and trip purpose. These findings were derived from an empirical data analysis, and considering the plausibility of the conceptual framework, it is the view of this author that the literature bears support for at least this aspect of the utilitarian theory of mode choice.

2.7. The Disutility of Comfort Level

Together with travel time and cost attributes, the disutility of the comfort level are considered to be the most significant mode choice determinants.[27] However, research failed to define the contribution of the latter to the generalized price of the travel activity, and hence its relationship to time and cost has not been expressed in quantitative terms.

The difficulty researchers have encountered in accounting for the comfort level can be attributed to two factors: first, the ambiguity of the term and hence the variety of interpretation it may entail, and secondly, the problem of providing an objective, accurate measurement for comfort.

The ambiguity of the comfort term can be demonstrated as one attempts to define the difference in the comfort level between, for example, the private car and the bus. The level of comfort of each is determined by a great number of mechanical characteristics, the interior and possibly the exterior of the vehicle. Few of these lend themselves to measurement, e.g., level of noise and vehicle vibrations. But the latter are relatively insignificant relative to the psychological, more influential factors: e.g., the discomfort associated with the vehicle crowding.

Furthermore, we should also be concerned with the user's comfort during the entire trip, from origin to destination. This would include, in addition to those items mentioned above, the discomfort in walking, waiting for the vehicle, and exposure to inclement weather conditions. The discomfort associated with these activities, which is likely to vary seasonally, is difficult to quantify in any meaningful manner, which compounded the researcher's problem.

This difficulty has lead to a considerable confusion in accounting for the comfort variable in previous works. Many researchers have accounted for each quantifiable variable separately, e.g., time, cost, but accounted collectively for all other quantifiable attributes under the comfort level "umbrella." Hence, Lisco's calculation, for example, for the value of the working trip comfort at $2.00 is likely to be invalid. It is the contention of this author that such a monetary value is equivalent not only to the comfort of car use, but other advantages in addition, such as the flexibility of routing and departure time.[28]

Other researchers made a partial account for the disutility of the comfort level through its association with excess travel time (walking, waiting and transfer time.)[29] The rationale of this approach was that the comfort level of the trip declined with the increase of this time, since it involved physical effort and possibly exposure to inclement weather.

Obviously, this approach provided an incomplete account for the trip comfort level in that the in-vehicle comfort was not included.

Researchers' failure to account for the comfort attributes has been detrimental to progress in mode choice analysis. A working definition for the comfort level and a reliable method of measurement have not been found, and hence, this attribute can not be isolated from other unquantifiable system attributes. Up to this stage of research, the contribution of this attribute to the generalized price of travel is largely undefined. This problem is investigated further in Sections 3.11., and 3.16.

PERCEPTION, ATTITUDES AND BEHAVIOUR

This study identifies the user's individual perception and attitudes as mode choice determinants. Previous discussions demonstrate the effect of perceptual variations on users' behaviour, yet without explaining why individuals' perception vary in the first instance. Also, definitions of perception and attitudes were not attempted. These questions are to be addressed in the following sections, which would help us clarify many aspects of users' behaviour unexplained so far.

2.8. Perception and Attitudes

In investigating the psychological underpinnings of users' behaviour, an explanation of some basic concepts becomes inevitable. Psychologists, concerned with the formulation of a theory of human behaviour, defined perception as the way by which the individual experienced and interpreted the world.[30] Thus, real world is unknown to the individual--except through perception. Yet, it is not merely a process of recognition, it involves filtering, modification and distortion of reality:

> No one experiences the world exactly as it is, and no two persons experience it in precisely the same way, because knowledge of the world --or our experiences with it--is filtered and modified by physical and psychological factors within us.[31]

This conclusion, that individuals vary in their perception of events and objects, is useful in understanding some aspects of the utilitarian theory of mode choice. We have more to say about this in the following section.

Another behavioural concept to be advanced by psychologists was the identification of the individual's perception through his behaviour. Since perception was not directly observable, how, then, could this phenomenon be searched objectively? The answer suggested was to consider as objective data:

> . . . inferred events that stand in a logically consistent relationship with the publicly observable. This means that the objectivity of a concept is determined by the efficiency with which it yields reliable replications of observations.[32]

This approach was widely employed by transportation researchers in studying the user's perception of the disutilities of time and cost of travel.

To this extent, psychologists' efforts have been paralleled by similar advances in research on mode choice behaviour. Transportation researchers, however, did not pursue this or any other approach to define the modal attributes perceived as relevant by the user. Although researchers seemed to agree on the relevance of time, cost and comfort, intuition suggests that there are other attributes whose significance are still undetermined.

We may now turn our attention to the individual's attitude, which was also identified as a significant factor affecting behaviour. It was described as predetermined position or bias for or against certain objects, which was motivated by an enduring set of perceptual processes.[33] Thus, perception and the formation of attitudes are two mutually effective phenomena, which leads us to the inference that modal bias, if it exists, is expressed in the user's perception of modal attributes. This inference also suggests that if the model accounts for the user's perception, this can be considered as an indirect account for his personal biases.

2.9. Effect on Users' Behaviour

Basically, there are three ways by which users' choices are affected by the psychological processes mentioned above. The first of these is the users' perception of the various attributes of the travel modes, which is expressed by the parameters to be derived in the calibration of the disutility function in mode choice models employing the discriminant analysis technique. It is in this manner that Beesley, Quarmby, Stopher, Lisco, Thomas and Thompson derived the perceived value of time, and it is in this manner that some of these authors identified the disutility of excess travel time relative to the in-vehicle time. As reported previously in Section 2.6., users' perception was found to be consistent, when various samples are compared, in regarding the disutility of these attributes.

Another aspect of users' behaviour which is of a psychological nature is modal bias. Attitudes can create a bias for or against any of the modes available to the user. As a result, the user sees the attributes of the preferred mode better than what they actually are, but does the opposite with the alternative mode (sees its attributes worse than they are). This tendency is understandable since the individual is usually anxious to justify his choice even through distortion of facts. Thomas reported such a bias in a similar situation.[34] In this study of choice of toll routes discussed in Section 2.6., he noticed that users reported shorter travel time by the chosen route than the actual travel time as measured by the researcher. The users also reported longer travel time for the alternative mode than the actual time. In other words, those who preferred the toll routes exaggerated the time savings, while other users who preferred the free route under-estimated the possible time savings. Obviously, then, users' bias affect their perception of travel times in such a way that justified the choices made.

Apart from Thomas' observation, the hypothesized relationship between the users' attitude and perception can be useful in explaining the notion of individual perceptual variations discussed in Section 2.4. Attitudes of any group of users toward a given transportation mode can hardly be expected to be uniform, and as they vary, the perception of travel disutilities vary accordingly. Theoretically, this variation is distributed as a normal probability function. That is to say, in much simplified words, for each user who exaggerates the disutility saving, there is another who equally under-estimates its value. Further, there are few whose perception of disutility saving is very different from the correct value, while the majority of users are more or less correct in their perception.

This concept was validated in the work of a considerable number of researchers. The cumulative frequency diagram of the probability function produced by Warner, Stopher, Pratt, Shunk, and De Donnea, clearly indicated a strong similarity between the theoretical probability distribution function and the observed choices of the users.[35]

Finally, some researchers pointed out that, in addition to the perceptual variation caused by the user's personal bias, there was the possibility that modal bias was uniform among the users. That is, the user's personal modal bias was furthered by a bias common to all users. If this were true, the effect of this uniform bias would be to shift the probability function downward or upward, thus increasing the probability of selecting the preferred mode as shown in the graph below. Accordingly, even when the generalized prices of travel by the two alternatives were equal, the probability of choosing the preferred

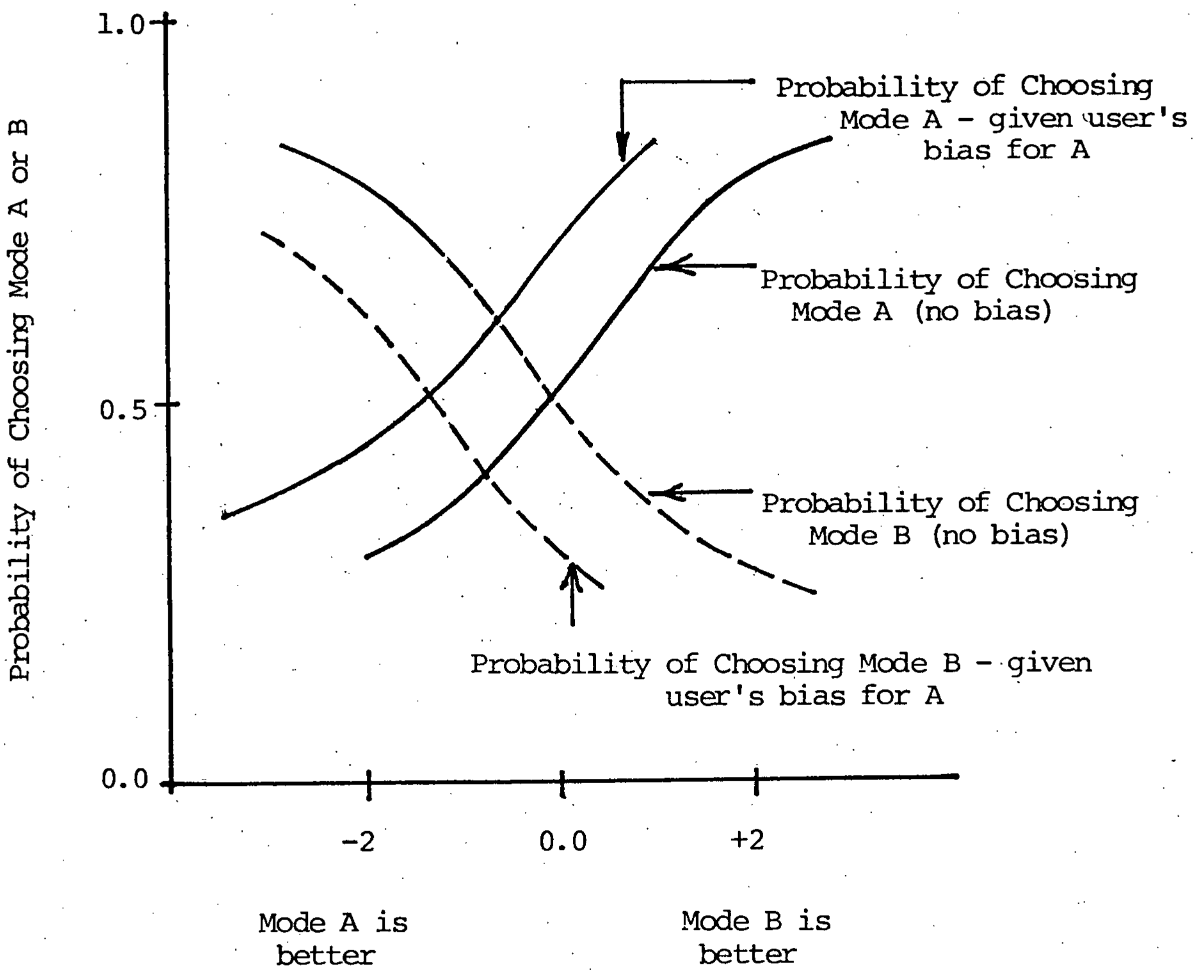

Fig. 3. Effect of "Uniform" Bias Among Users for Mode A

mode would be higher than 0.5. De Donnea and Stopher have found evidence to suggest the presence of car bias in the users' behaviour examined in their sample. However, we should view their findings with precaution since both authors did not account for the unquantifiable attributes of the system. Hence, what they considered a bias for car could merely refer to the influence of the comfort, or flexibility associated with the car use.

2.10. Summary and Conclusions

This chapter is devoted to the formulation of a theoretical framework for users' mode choice, and discussion of evidence brought forward by researchers on the validity of this framework. The broad concepts outlined here are derived from two theories: (a) the abstract mode choice theory, and (b) the utilitarian theory of mode choice. A brief account for two psychological processes, perception and attitudes, and their impact on users' behaviour are also attempted.

In the abstract mode choice theory, emphasis is placed upon the attributes of the travel mode rather than its institutional form. Users' behaviour could be better explained when each mode is taken as a "bundle" of attributes, or a combination of characteristics. The analysis conducted in this chapter clearly indicates that a comprehensive account for mode attributes would increase the explanatory and predictive power of the model. More significantly, it is only in this way it would be possible to identify the transportation policy variables and the influence of each on users' behaviour.

The concept of the "generalized price" to be incurred in any travel activity is introduced as a tool to explain users' behaviour. It refers to the perceived disutilities of travel by alternative modes for any given trip. Its value is thus affected by both the mode attributes and users' perception. Furthermore, the user's personal bias for or against any travel mode is expressed in his perception of the disutility difference between the two best modes. It is hypothesized that in any unbiased sample of users, the perceived disutility savings varies from one user to another, and that this variation can be approximated by a normal probability distribution function.

The evidence brought forth in the literature on the validity of these concepts were mainly concerned with the following aspects of users' behaviour:

- users' perception of travel time and cost attributes,
- the variables affecting users' perception of these attributes, and
- users' perception of the disutility savings offered by the best mode.

A detailed discussion of the time value theory and the empirical findings of other researchers on its validity produced sufficient evidence to suggest that users perceive the disutility of time and cost in quantitatively comparable terms. The parameters derived in several statistical analyses indicated that users' perception of these disutilities were consistently expressed in their mode choice behaviour. The analysis further indicated that the perception of the disutility of time and cost was dependent upon the user's income, trip purpose, level of comfort, and total time savings.

The influence of the disutility of the comfort level on users' behaviour was identified by several authors. Yet, due to the difficulty of measuring the level of comfort associated with each mode, and its confusion with other non-quantifiable variables, the exact contribution of this attribute to the disutility function remained largely undefined. Only a partial account was made for discomfort through its association with excess travel time.

Several writers found support to the hypothesis that the disutility savings gained by using the best mode over its alternative was perceived differently by various users. The pattern of this perceptual variation reflected a similarity with the normal probability distribution function as maintained in the utilitarian theory of mode choice.

The conceptual analysis and empirical evidence introduced in this chapter render the utilitarian theory a workable hypothesis, and validate many of the concepts introduced on users' behaviour. To increase the usefulness of this theory to mode choice analysis and prediction, a further advance is needed on the method of measurement and accounting for the non-quantifiable variables such as comfort, flexibility of travel time, etc. These attributes present the researcher with some "thorny" problems (some of which will be tackled in the following chapter). In addition, further research is also required to define the user's perception of modal attributes, thus permitting a full description of the mode choice situation.

FOOTNOTES

1. A summary analysis of various modal split analytical techniques for this time period is provided in Modal Split: Documentation of Nine Methods by Martin J. Fertal, et al.

2. This approach is documented by several sources, Kelvin J. Lancaster, "A New Approach to Consumer Theory," Journal of Political Sciences, Vol. 74, 1966, pp. 133-157, Richard W. Quandt and William Baumol, "The Demand for Abstract Transport Modes: Theory and Measurement," Journal of Regional Science, Vol. 6, No. 2, 1966, pp. 13-25, Richard E. Quandt, "Estimation of Modal Splits," Transportation Research, Vol. 2, March 1968, Kan Han Young, "An Abstract Mode Approach to the Demand for Travel," Transportation Research, Vol. 3, No. 4, 1969, Thomas F. Golob, "The Survey of User Choice of Alternate Trasnportation Modes," High Speed Ground Transportation Journal, Vol. 4., No., pp. 103-116, and Alexis N. Sommer, "Toward a Theory of Traveler Mode Choice," High Speed Transportation Journal, Vol. 4, Jan. 1970, pp. 1-8.

3. A corollary to this hypothesis is that, by accounting for all the relevant modal attributes, the user is "mode-neutral", having no bias for or against any particular mode. Thomas Lisco, who accounted for the cost, time and comfort attributes reported, "there was no evidence of an irrational commuter 'love affair' with the automobile," in "The Value of Commuter's Travel Time - A study in Urban Transportation," unpublished Ph.D. dissertation, University of Chicago, 1967, abridged in Highway Research Record, Rep. No. 245, 1968, p. 36.

4. See, for example, the section on trip-end modal split, Erie, Pennsylvania, in Modal Split: Documentation of Nine Methods Fertal et al., p. 27.

5. A study which placed emphasis on the policy variables was prepared by Brown, Mode Choice Determinants of Selected Socio-economic Groups.

6. Studies which investigated the manipulation of modal attributes as a planning tool to affect users' choices are that of Leon Moses and H. Williamson, "The Subsidy Issue", Journal of Political Economy, "Choice of Travel Mode for the Journey to Work," Journal of Transport Economics and Policy, Sept., 1967, pp. 273-314, Charles A. Lave, "A Behavioural Approach to Modal Split Forecasting," Transportation Research, Vol. 3, No. 4, 1969, pp. 463-480, Robert G. McGillivray, "Demand and Choice Models of Modal Split," Journal of Transport Economics and Policy, May 1970, pp. 192-206, G. Brown, Mode Choice Determinants, 1971, David T. Hartgen, George H. Tanner, "Investigations of the Effect of Traveler Attitudes in a Model of Mode Choice Behaviour," Highway Research Record, Rep. No. 369, 1971, pp. 1-14, and Frederick J. Beier, "Marketing Programs For Mass Transit," Traffic Quarterly, Oct. 1972, pp. 533-545.

7. Such conclusions have been reached in the studies conducted by De Donnea, The Determinants of Transport Mode Choice, p. 206, and A. J. Sobey and J. W. Cone, "The Case for Personal Rapid Transit," Highway Research Record, Rep. No. 367, 1971, pp. 70-89.

8. The utilitarian theory of mode choice is presented in a number of publications: Peter R. Stopher, "A Probability Model of Travel Mode Choice for the Work Journey," Highway Research Record, Rep. No. 283, 1969, pp. 57-65, Richard A. Pratt, "A Utilitarian Theory of Travel Mode Choice," Highway Research Record, Rep. No. 322, 1970, pp. 40-53, Sommer, "Mode Choice,"High Speed Transportation Journal, Vol. 4, No. 1, 1970, pp. 1-8, Gordon A. Shunk and Richard J. Bouchard, "An Application of Marginal Utility to Travel Mode Choice," Highway Research Record, Rep. No. 322, 1970, pp. 30-41, and Peter R. Stopher and Shalom Reichman, "Disaggregate Stochastic Models," Highway Research Record, Rep. No. 369, 1971, pp. 91-103.

9. Moses and Williamson, "The Subsidy Issue," Journal of Political Economy, p. 248.

10. Ibid.

11. United States Secretary of Commerce, Final Report of the Highway Allocation Study, 1961, p. 205, in ibid.

12. M. E. Beesley, "The Value of Time Spent in Travelling: Some New Evidence," Economica, Vol. 32, 1965, p. 174.

13. *Ibid.*, pp. 174-185.

14. *Ibid.*, p. 182.

15. *Ibid.*, pp. 182-183.

16. Quarmby, "Choice of Travel Mode," *Journal of Transport Economics and Policy*, pp. 273-314.

17. *Ibid.*, pp. 295-297.

18. *Ibid.*, p. 292.

19. *Ibid.*, p. 289.

20. Stopher, "Probability Model," *Highway Research Record*, p. 61.

21. Lisco, "Value of Travel Time," *Highway Research Record*, p. 36.

22. Dan G. Haney, The Value of Time for Passenger Cars: A Theoretical Analysis and Description of Preliminary Experiment, Stanford Research Institute, May 1967, in Thomas C. Thomas, "Value of Time for Community Motorists," *Highway Research Record*, Rep. No. 245, 1968, p. 27.

23. *Ibid.*, pp. 17-34.

24. Thomas C. Thomas and Gordon I. Thompson, "The Value of Time for Commuting Motorists as a Function of Their Income Level and Amount of Time Saved," *Highway Research Record*, Rep. No. 314, 1970, pp. 1-19.

25. Thomas C. Thomas and Gordon I. Thompson, "Value of Time Saved by Trip Purposes," *Highway Research Record*, Rep. No. 369, 1971, pp. 104-117.

26. The discussion section by Shalom Reichman in *ibid*, p. 115.

27. Lisco, "Value of Time," *Highway Research Record*, p. 36.

28. In his study of Chicago commuters behaviour, Lisco isolated all the observations where the users' travel time by transit was equal that by car. From the analysis of this set of observations, he concluded that the "average" commuter in his sample was paying an additional amount of $2.00 (in car operating costs, parking charges, etc.) per day to use his car instead of transit. Lave, "A Behavioural Approach," Transportation Research, p. 464.

29. Quarmby, "Choice of Travel Mode," Journal of Transport Economics and Policy, p. 281, Lisco, "The Value of Time," Highway Research Record, p. 36, Pratt, "Utilitarian Theory," Highway Research Record, p. 48, and Shunk and Bouchard, "Application of Marginal Utility," Highway Research Record, p. 32.

30. S. H. Bartley, Principles of Perception, Harper, New York, 1958, p. 4.

31. Ibid., p. 22.

32. William Bevan, "Perception: Evolution of a Concept," Psychological Review, Vol. 65, No. 1, 1958, p. 34.

33. D. Krech and R. S. Crutchfield, Theory and Problems in Experimental Psychology, McGraw-Hill, New York, 1948, p. 152.

34. Thomas, "Value of Time," Highway Research Record, 1968, pp. 22-23.

35. S. L. Warner, Stochastic Choice of Mode in Urban Travel; A Study in Binary Choice, Northwestern University Press, 1962, pp. 40-41, Stopher, "Probability Model," Highway Research Record, p. 62, Pratt, "Utilitarian Theory," Highway Research Record, pp. 44-51, Shunk, "Application of Marginal Utility," Highway Research Record, p. 36, and De Donnea, Determinants of Transport Mode Choice, p. 147.

CHAPTER III

MODEL STRUCTURE AND APPLICATION

3.1. Introduction

While the main concern in the previous chapter is with the literature review, and derivation of a conceptual framework upon which the study's model may be based, the present chapter is concerned with the model structure and definition of its operational characteristics. This entails four sequential steps:

(a) Development of criteria for identification of mode choice determinants.

(b) Selection of appropriate variables which represent these determinants in the model.

(c) Manipulation of these variables as model inputs.

(d) Defining the model structure, and selection of the statistical techniques to be used.

Another problem to be addressed in this chapter is the assessment of the explanatory and predictive value of the model. A justification will be given as to why the study's approach would advance our knowledge of users' behaviour and improve the researcher's ability to predict the users' response to changes in the transportation system, and to trends in the social, economic or demographic characteristics of the urban population.

In dealing with these subjects, the chapter is divided into four basic parts. The first three parts are devoted to identification and analysis of the model inputs, (a) the users' lifestyle, Section 3.3., (b) the users' socio-economic characteristics, Sections 3.4. to 3.7., and (c) the transportation system attributes, Sections 3.8. to 3.12. The model formulation, and its operational characteristics are discussed in the final part, Sections 3.13. to 3.16.

3.2. Research Orientation

It might be appropriate at this stage to define the study's basic approach to the problems to be encountered in this chapter. Briefly, these are as follows:

(a) the conceptual framework of the model,

(b) the statistical technique to be employed, and

(c) the methods to be used in collecting the data required for the model calibration.

In the conceptual analysis, this study differs from others in that emphasis is placed upon the user's sensitivity toward modal attributes as an influential mode choice determinant. Such sensitivity refers to the significance the user attaches to various travel dimensions, cost, time, etc. It is hypothesized here that this sensitivity is a function of two sets of variables, the user's time budget, and some related socio-economic characteristics, namely age and occupation. These two sets are employed in this study to provide an indication of some aspects of the user's lifestyle which may affect his sensitivity to mode attributes, which in turn affects his choice behaviour.[1]

In addition to the individual's sensitivity, this study identifies the socio-economic characteristics as mode choice determinants. It is the primary hypothesis of this study that the user's socio-economic characteristics are <u>not</u> strongly correlated with his sensitivity toward modal attributes.

In addressing the second item mentioned above (the statistical technique to be used in data analysis), the model to be employed in this study is basically a disaggregated stochastic model which explains and predicts users' mode choices on the basis of their personal characteristics, and characteristics of their individual mode choice situation (i.e., differences in the attributes of the transportation modes available to the user). Each individual user is to be accounted for separately in the model, and by means of discriminant and probabilistic function, the model produces the probability that a given user belongs to one or another group of mode users, on the basis of the characteristics mentioned above.

All the necessary information on the users' characteristics and attributes of the mode choice situation are to be collected in a questionnaire survey. This is a basic constraint in designing this research, which is recognized in selecting many of the model's procedures.

3.3. Lifestyle: Conceptual Considerations and Application

In an attempt to expand the explanatory function of mode choice analysis, this study provides an exploratory treatment of the concept of lifestyle. It should be made clear, however, that our interest in this concept is confined to the possible relationship it might have to the users' mode choice behaviour, and hence, the study's approach may be different from another approach which scholars in the fields of sociology or psychology may wish to pursue.

The study's definition of lifestyle as the individual's time and money budgets refers specifically to the number of hours and amount of dollars allocated to each of the activities in which he is engaged. Assuming that we can identify and describe this pattern, the question we want to investigate at the outset of this inquiry is whether such a pattern can be related to the individual's mode choice, and furthermore, how such a relationship can be rationalized, if it all exists, and what evidence can be brought to support its validity.

For the purpose of outlining a conceptual framework for this inquiry, we may wish to consider the individual's time and money as limited "resources". Various time- and money-consuming activities "compete" for these resources, and depending upon the individual's personal values, needs and circumstances, certain amounts of time and money are allocated to these activities--including travel. But since the choice of the travel mode entails a "commitment" to certain expenditures of time and money, which usually vary from one mode to the other, it is therefore affected by other choices to be made concerning other time- and money-consuming activities.

Thus, the relationship outlined above can be described as follows:

$$L = f(m_1, m_2, \ldots , m_k, \ldots , m_n,$$
$$t_1, t_2, \ldots , t_k, \ldots , t_m)$$

where L is the individual's lifestyle,

t_i is the time allocated to activity i,

m_i is the money allocated to activity i,

t_k is the time allocated to the travel activity,

m_k is the money allocated to the travel activity, and

n is the number of activities in which the individual may be involved

One of the constraints of the allocation problem is that both time and money, for any given person, are limited:

$$T = t_1 + t_2 + \ldots\ldots\ldots t_n$$

$$M = m_1 + m_2 + \ldots\ldots\ldots m_n$$

where T and M are constants.

There are other constraints to the problem of time and money allocation. Such allocation should reflect the individual's value system, his needs and circumstances. Thus, we may expect a person who values cultural opportunities or social activities which put demand upon his time to opt, in his mode choice behaviour, for time savings. Another person who puts extra working hours may behave similarly. In contrast, a person whose circumstances puts a great demand upon his financial resources (he is supporting a big family) may opt for the less expensive mode.[2] Thus, in broad terms, time and money budgets may reflect certain aspects of the user's lifestyle, which would, as <u>a priori</u> consequence, influence his mode choice behaviour.

But the problem of time and money allocation is far more complex than what is exhibited in the conceptual framework outlined above in that the effect of the individual's value system, his needs and circumstances on his allocation of time and money budgets is not sufficiently clarified. What is provided here is a cursory treatment to what might be a complex phenomenon. Also, taking into consideration the methodological problem of collecting such information in a questionnaire survey (would a person express his value system adequately on a questionnaire?), we may recognize then that the task of accounting for the individual's lifestyle in a meaningful manner is unmanageable for the study purposes.

Furthermore, the literature provides neither a conceptual nor empirical analysis of the hypothesized relationship between the user's time and money budgets to his mode choice behaviour, except for few attempts and references made by some authors which, while by no means provide the necessary support for the concept, are worth mentioning:

(a) Moses and Williamson's hypothesis on the relationship between the value of time and the user's ability to convert time savings into working hours. In this analysis, reference has been made to the effect of other leisure activities in increasing the value of time saved in transportation.[3]

(b) Brown and De Donnea's reference to the sensitivity toward time savings expressed by members of the managerial and professional occupations in their mode choice (See Section 3.5.). Such sensitivity might be attributed to lifestyle, since members of these groups, by the virtue of their level of education, were likely to be engaged in a variety of social and cultural activities.

Because of the absence of a vigorous analytical framework, and support of empirical data, the concept of lifestyle must be modified to be useful for the study's purposes. This modification should be aimed at simplifying the concept, or narrowing it down where it becomes feasible for this study to outline a practical method for collecting the data required to support its validity. Furthermore, the attempt should be made to bring the modified concept under the "umbrella" of previous research findings. That is, the model structure which is to be formulated accordingly should be made to stand the scrutiny of empirical verification when compared with the findings of other researchers.

The proposed modification is as follows: in as far as mode choice is concerned, the user's lifestyle is likely to be expressed as a sensitivity, or a set of sensitivities, toward the relevant modal attributes. Sensitivity is defined here as the significance the user attaches to any given attribute, be it travel time, cost, etc. Thus, persons who are pressed for time because of their cultural and social engagements, or other time-demanding duties, would be sensitive to the time attribute in their choice behaviour. In comparison, those whose financial resources are burdened by certain obligations would be sensitive to the cost attribute, all other factors being equal.

Thus, for the specific purpose of formulating the study's model, the user's sensitivity toward modal attributes can be used as a surrogate for his lifestyle in that it expresses those aspects of his lifestyle which affect his mode choice behaviour. More significantly, the literature provides sufficient evidence to indicate that these sensitivities may vary independently from his socio-economic characteristics (See Section 3.13.), and hence, for the purpose of model formulation, there is a strong justification to incorporate both kinds of variables as model inputs. (A possible interpretation for this independence is that variation in lifestyle may create divergent sensitivities within the same socio-economic group. We have more to say about similar findings and their interpretations in Section 3.13.).

The question remains as to what are the attributes to which the user may be sensitive, and how can this sensitivity be expressed in a manner which allows for their incorporation in the model. On the basis of the work conducted by Hartgen and Tanner, who attempted to identify the significance of some thirty transportation system attributes, the following can be identified as the most relevant, and are to be used for the study purposes:

- total travel cost,
- total travel time,
- excess travel time,
- flexibility of departure time, and
- comfort level of the trip.

Turning our attention to the problem of expressing these sensitivities, two methods can be identified: (a) to ask the user to rank these attributes by their order of significance to his mode choice, and (b) to ask the user to express their significance along a Linkert scale. Both methods could prove operational, but for the purposes of this study, an arbitrary choice is made for the latter.

Having placed emphasis on the user's sensitivity toward modal attributes, this study goes a step further by attempting to explain this sensitivity, or rather, set of sensitivities by relating these to a simplified account for the user's time budget and some of his related socio-economic characteristics, namely age and occupation.[4] A simple account for the user's time budget is proposed here as the number of hours allocated by the user to work, family (or at home, with relatives), social and cultural activities and outdoor recreation. It is unfortunate that the literature does not provide any useful analysis of the relationship of time budget and mode choice behaviour, and thus we have to accept the above mentioned classification which is developed on the basis of the author's subjective evaluation.

The addition of the user's time budget, age and occupation (as an explanatory variable to the user's sensitivity toward modal attributes) to the model structure is an experimental step which is hoped to provide some badly needed evidence on a plausible hypothesis, should this proposed model be implemented. This relationship is expected to improve the rationale of the model and possibly give the researcher some hints as to the causal relationships underlying users' mode choice behaviour. However, since this is an experimental undertaking, the model should be formulated so as to be capable of explaining users' choices on the basis of these sets of characteristics alone (if necessary): (a) sensitivity toward modal attributes, (b) the users' socio-economic characteristics, and (c) attributes of the mode choice situation. In other words, the relationship hypothesized here to explain the user's sensitivity should be "attached" to the model structure as an "off-line" procedure whose success or failure should not affect the explanatory power of the model, at least not in the statistical sense.

To sum up this section, the user's sensitivity toward modal attributes is selected as a surrogate for his lifestyle for the purpose of model formulation. It is argued here that such sensitivity is not strongly correlated with his socio-economic characteristics (except for, perhaps, age and occupation). An additional step is developed in the model to explain this sensitivity on the basis of some indications of the user's lifestyle: time budget allocation, age and occupation. In the following sections, each of the socio-economic characteristics and attributes of the model choice situation is analysed separately. In the final part of this chapter, the attempt is made to use the information and concepts developed on mode choice determinants in structuring the study's model, and that is where much of the study's concepts are to become considerably clearer to the reader.

THE USERS' SOCIO-ECONOMIC CHARACTERISTICS

The following four sections are devoted to analysis of the user's socio-economic characteristics, income, occupation, age and sex, in relationship to his mode choice behaviour. These variables have been dealt with in detail by most studies in this field, and only a brief reference is made here to demonstrate the extent to which the study's approach is similar to or different from others.

3.4. The Household Income

The influence of the income variable on the user's behaviour can be felt in several ways:

(a) Availability of financial resources is likely to induce the user to attach less significance to the cost attribute, yet a greater significance to other attributes:

travel time, level of comfort, etc.

(b) Income, in general, determines the social class of the user, and hence the biases to which he may be subjected in his social environment.

(c) The income level also determines the availability of alternative activities in which the user and his family can be engaged. The availability of such alternatives is likely to increase the user's satisfaction to be derived from his out-of-work time, since he has the resources to satisfy his personal taste. Accordingly, the demand upon his time is greater, and his time value is likely to be higher, which, in turn, affects his disutility of the time spent in the travel activity.

The use of the household income as an input variable raises a difficulty which should be recognized here. Since those members of the household who contribute to its total earnings are likely to have more liberty in utilizing these financial resources to satisfy their personal taste, their travel disutility is likely to be different from other members of the household. The use of the household income variable ignores this difference. To solve this problem, De Donnea entered a dummy variable in the mathematical function to indicate whether or not the user is the head of the household, i.e., the main earner in the family.[5] Although this variable was found to be significant, it should be remembered that this is only a partial solution since no account is made yet for the possibility that a second income earner (the wife, the son,

. . .) could be in similar position to utilize these financial resources to satisfy his taste in his mode choice behaviour.

This study pursues a different approach to the above mentioned problems. While it accounts for the household income, it also accounts for other related characteristics:

(a) Whether the user has an access to an alternative mode, and if so

(b) His sensitivity toward modal attributes.

Thus, information is obtained on whether the user is in the position to satisfy his taste (does he have a choice?), and if so, whether he is sensitive to the cost attribute (can he utilize the financial resources of the family to satisfy his taste?). Such information provides sufficient description of the influences which varies for different members of the household with respect to their mode choice.

3.5. Occupation

Since occupation is not a continuous variable, its influence on the user's mode choice can only be identified in cross-classification statistical analysis, where it is possible to compare the percentage of any given group of mode users from one occupational group to the other. Because of this constraint, most of the studies employing a mathematical function did not account for this variable. Among the few who explored this variable was De Donnea who found that the percentage of car use was significantly higher in two occupational groups, executive professions and blue collar workers.[6]

He considered this to be a bias for car use and accounted for its influence by entering a dichotomous variable in the model to indicate whether or not the user belonged to any of the two occupations.

Brown's study revealed some unexpected results on the effect of the occupation variable on users' behaviour. In his sample, he found a higher percentage of bus users in managerial and professional employees and secretaries than expected.[7] Clearly, this behaviour was not expected from the former two groups. In a further analysis based upon what was considered users' stated preferences, Brown found that managerial and professional employees, more than any other groups, were sensitive toward travel cost, and that this sensitivity was not shared by the secretarial professions.[8] Again, these were unexpected findings. Yet, the more interesting observation encountered in this study was that professional employees were more time-sensitive than other users in the <u>same</u> income category.[9] This sensitivity might be attributed to the possibility that professional employees were engaged in more cultural or social activities, or that they have to put more hours into work to meet the responsibilities of the job. Thus, allocation of time budget could have possibly provided an explanation to these particular observations.

The observations made by Brown and De Donnea are significant empirical findings. Yet, on <u>a priori</u> ground, there appears to be no plausible relationship between the user's occupation and his mode choice, except, perhaps, through the association of the former with the user's income and his lifestyle. Since both these characteristics are accounted for in the study's model, the use of the occupation variable as a direct input to the model would probably be redundant.

Information on the occupational status of the user, however, could be useful if it can be related to the user's lifestyle, or his sensitivity toward modal attributes. Since future demand for various occupations for any given region can roughly be predicted, it would be useful for the researcher to identify the influence of occupation on the user's mode choice behaviour. This approach is adopted in the present study, and as mentioned in Section 3.3., the attempt is to be made to incorporate such a relationship into the model structure. (See Sections 3.14, and 3.16.).

3.6. Age

The relationship between the user's age and his mode choice has been identified in the studies conducted by Brown, De Donnea, Warner, Lisco and Lave.[10] Although these authors agreed on the significance of the age characteristic, they employed different methods to account for this variable. These differences reflect a discrepancy among these authors in understanding how age affected the users' behaviour. Briefly, three methods were in use:

(a) Age was accounted for as a continuous variable to be entered in the model without any transformation. Roughly speaking, age and car use were found to be positively correlated.[11]

(b) Warner used a different technique: users were grouped into nine categories and were given a code number, with code number 1 given to the younger group (16 to 19 years) and 9 for the older group (65 years and older). He entered the natural logarithm of the code number of the user's age group into the model to account for this characteristic.[12]

(c) By cross-classification analysis of mode users, Brown found that the bias for car use was evident in the age group 40 to 60,[13] while De Donnea contended that such a bias was common among the 25 to 55 age group.[14] De Donnea accounted for the effect of age as a dichotomous variable in the same manner he accounted for the occupational bias.

For the purposes of this study, however, the use of the age characteristic as an input to the model raises a difficulty similar to that of using the user's occupational status in that there is no identifiable cause-effect relationship between this variable and mode choice, except through the effect of the user's time budget, sensitivity to modal attributes or lifestyle. Indeed, one expects the user to change his lifestyle as he grows in age. Lave suggested that, "it is possible that there is a systematic relationship between the shape of a commuter preference function (disutility function?) and his age or sex."[15] Hence, if lifestyle, or some measure of it, is accounted for, the use of the age variable would be redundant.

But, again, this is not completely true. Along with the occupational status, the age characteristic of the user can be employed to explain and eventually predict the user's sensitivity to the modal attributes. The age characteristics of a given regional population can be roughly predicted for future years by demographic analysis, and hence it may be possible to foresee its effect upon the sensitivity of the user and his mode choice behaviour.

3.7. Sex

At this early stage of research on the relationship between the user's lifestyle and his mode choice, it is not conceptually clear how the sex variable would affect the user's behaviour, although such a relationship is already documented in the literature. The notion that males are "car oriented" was supported by Brown, Warner, Lisco and Lave.[16]

This relationship can be explained in two ways:

(a) Female members of the household have "less access" to the car. For example, if the husband needs the car to commute to work, he is likely to have a priority in using the car. To take this possiblity into consideration, Lisco accounted for two characteristics of the mode choice situation, (i) whether the husband was the only person in the household having access to the car use, and (ii) whether the wife needed to drive to work independently. An affirmative answer to each of these questions was entered separately as a dichotomous variable.

In this study, we need not be concerned with this problem, since the data analysis is confined initially to those users having access to the car, in addition, of course, to transit. The model does not make a distinction between "degrees" of accessibility to car, and simply assumes that if the user has access to the car, it is an undeterred access.

(b) Females have generally an aversion to car driving. This is obviously an anti-modal bias, and indeed could be the only argument encountered in the literature to support the notion that such a bias exists. It is for this reason that the sex variable should be accounted for as a dichotomous variable in the study's model.

THE TRANSPORTATION SYSTEM ATTRIBUTES

3.8. Problems of Identification

In accounting for the transportation system attributes, several significant research problems arise for inquiry and solution:

(a) what attributes should the model ideally account for?

(b) what attributes is it possible and practical to account for?

(c) should modal attributes be accounted for as they are, or as they are perceived by the user?

In addressing the first two problems, the argument previously advanced in Section 2.2. that a transportation mode is to be considered, at least conceptually, as a bundle of attributes, should be brought into discussion. Now, with emphasis being placed on the model formulation rather than the conceptual analysis, we may question what such a "bundle" contains. Is the colour of the vehicle, for example, an attribute?

Obviously, certain criteria must be developed to assist in identifying these attributes for the purposes of the study:

(1) There should be sufficient evidence to suggest that such attributes are significant in affecting users' behaviour. Since this study is not concerned with collecting such information directly from the users, evidence should be sought in previous research findings.

(2) For any given mode choice situation, attributes which are influential in affecting the users' behaviour are those which differ significantly from one mode to the other. As an example, Hartgen found that users in his sample ranked "arriving without an accident" as a highly significant attribute of the transportation mode they would use.[17] But, in the mean time, the users' satisfaction with the two modes available, car and transit, did not differ substantially with respect to this particular attribute. Thus, the attribute, albeit significant, evidently would have no effect on the users' behaviour in this or a similar mode choice situation.

With the choice between car and transit being the main concern of this study, attention should be given to those system attributes which have been identified by the users as significant, and clearly differ between these two modes. To identify these variables, researchers have taken two directions: the first, by analysing the users' actual mode choices, using discriminant analysis or similar statistical techniques; the second, by asking the users to identify the relevant attributes in a questionnaire survey. By pursuing the first approach, the following attributes were identified:

(a) total travel time.

(b) excess travel time.

(c) travel cost.

These findings clearly conform to research expectations and no substantial argument is required at this stage to justify their inclusion. Researchers who pursued the second approach arrived at results which confirmed these findings, and identified, in addition, two further attributes:

(d) arrival at intended time.

(e) comfort level of the vehicle.

These two attributes require some elaboration. The former is particularly important in circumstances where, for example, the traffic congestion is such that the arrival time becomes uncertain, or that the scheduling of the transit service does not match the user's intended departure time. Hartgen found that users in his sample were satisfied with the car in this respect, but less so with the available transit service.[18] In essence, the user's satisfaction or dissatisfaction with the scheduling of transit service is obviously dependent upon the frequency of transit service for the intended trip time. Frequent service, say at three minute intervals, can provide the user with the same degree of flexibility as that provided in car use. The longer the interval, the greater the inflexibility and dissatisfaction. Thus, in mode choice situations involving transit, frequency of transit service can be used as a proxy for flexibility of departure time.

Accounting for the comfort level attributes raises several difficulties which have been discussed in Section 2.7. Hartgen and Tanner, for example, did not identify the comfort level as a single variable, rather, as a "composite" of many attributes of the travel activity:[19]

(a) avoid walking less than a block,

(b) vehicle unaffected by weather,

(c) ride in a clean vehicle, and

(d) ride in a modern vehicle.

The first of these is obviously correlated with the excess travel time, which is accounted for separately. The other attributes are essentially a description of the comfort level of the vehicle itself. To account for this variable, a simpler, more economic method is proposed in Section 3.11., to allow for one-dimensional measure of this complex attribute.

The studies consulted by this author provide strong evidence to indicate that the attributes discussed so far are significant determinants of users' mode choice behaviour. Hartgen's study clarified this question further by identifying several attributes which are <u>not</u> significant: availability of package space, and the provision of bus shelter.[20] But in either case, we have no assurance that the list is conclusive, since many other attributes have not been explored as to their effect on users' behaviour, e.g., privacy. Indeed, this element of uncertainty is inherent in the conceptual framework of this type of model, and to the abstract mode choice approach, where the universe of the relevant system attributes is initially defined by the researcher. Thus, the exercise of a certain degree of subjectivity is inevitable.

The other problem to be addressed in this section is whether an account should be made for these attributes as they actually exist (and, hence, the measurements are to be taken by the researcher to ensure the objectivity of reporting), or, alternatively, attributes should be accounted for as they are perceived by the user (and thus users' reported data are to be employed instead). This problem was addressed by few researchers, Thomas and Thompson, and Watson, and the discrepancy between the users' reported attributes and actual attributes was identified and attributed to several reasons:[21]

(a) personal bias: in route choice situations, users tended to exaggerate the benefits they receive from the chosen route, and under-value the potential benefits of using the alternative route. This was obviously an effort to justify a choice already made. In mode choice situations, users are very likely to behave in similar manner.

(b) rounding errors: most users tended to define travel time in "lumps" of five minutes, thus expressing their personal bias by rounding travel times upward or downward to multiples of five minutes, so that their mode choice appears justifiable.

(c) perceptual errors: the users' perception of time and cost of travel could be far from correct, particularly when onerous activities, like walking or waiting in inclement weather conditions, are involved.

Despite the validity of these observations, it is obvious that the user's mode choice is affected by what he perceives as modal attributes, and definitely not by any of the objective measurements made by the researcher. Therefore, all researchers who investigated this problem unanimously employed the users' reported data, rather than objectively measured attributes.

The purpose of this section was to discuss the problems associated with the identification of the modal attributes which are relevant to users' behaviour. In the following sections, attention is given to methods of manipulating these attributes as model inputs. It should be remembered in examining these attributes that our interest is not with the system attributes *per se*, rather, with the comparison between attributes of alternative modes. The method of making such a comparison may vary from one modal attribute to the other, and, hence, each of these is discussed separately in the following sections.

3.9. Travel Time

Basically, there are two methods to account for travel time in any mode choice situation:

(a) As absolute savings in the travel time by using the fastest mode, that is, $T_1 - T_2$.[22]

(b) As the ratio of travel time by one mode to the other, T_2 / T_1.[23]

The difference between the two approaches is not trivial. In the first case, a time savings of, say, five minutes in a trip of ten minutes would have the same entry to the model as five minutes savings in a fifty minute trip. In the second case, the total length of the trip by each mode is accounted for in the ratio.

Quarmby tested the two approaches and found that, in his sample, the former approach yielded a greater explanatory power for users' behaviour.[24] His findings may not be applicable to other samples: it is possible, one can argue, that the latter approach is more appropriate in samples where there is considerable variations in the travel times. But since no evidence was encountered to support this argument, it is suggested that the former approach is to be adopted for the study's purposes--subject to further testing to confirm Quarmby's findings.[25]

The other problem to be addressed in this section is whether excess travel time should be accounted for differently from the in-vehicle time. As demonstrated in Section 2.6., there is evidence to suggest that the disutility of excess time is considerably higher than the in-vehicle time, presumably 2.5 to 3 times the latter. To account for this difference, two methods can be employed:

(a) to enter savings in excess time and in-vehicle time separately as two variables.

(b) to convert excess time for each mode to in-vehicle time (by multiplying the former by a factor of 2.5 or 3) and enter savings in the total travel time, as computed after the conversion, as a single variable.

Intuitive judgement may indicate that the disutility of excess travel time could be considerably higher than 2.5 or 3 times the in-vehicle time in travel conditions where the user is exposed to inclement weather, for example. Thus, it would be inappropriate to accept a standard conversion factor in principle. This suggests the first approach is more useful for the study.

3.10. Travel Cost

Accounting for the cost attribute difference among transit alternatives is a simple procedure by which the transit fares are compared from one mode to the other. The difficulty appears in mode choice situations involving the car alternative, since travel cost by car is not clearly defined. Conceptually, travel cost in this case can be accounted for in two different ways:

(a) The average cost approach, that is, the travel cost for the trip including parking charges; operating cost, gasoline, oil, lubrication, maintenance, and repair, annual depreciation in car value, insurance cost, and the cost of the committed investment (interest to be paid). By summing these expense items for say, a year, and dividing these costs by the annual mileage travelled, it is then possible to derive the average travel cost per mile.

(b) The marginal cost approach, which entails the additional or out-of-pocket cost of any given trip: gasoline, oil, parking charges, and road tolls if any.

A substantial argument can be developed to support each of these approaches. In the first case, the real costs of travel by car are fully expressed, in the latter, only costs which are paid specifically for making this trip. Lave argued that if the user purchased the car for the purpose of commuting to work, then the average cost of travel to work should be accounted for. But, if the car was purchased to serve mainly for recreational purposes, the cost of commuting to work should be accounted for as the marginal cost (the car is already in the user's possession, what is the cost of making a work trip?). The argument for the use of the first approach in one case, and the second approach in another case was obviously tenuous since it was difficult to define the user's motivation in purchasing the car, a fact which Lave recognized in his article.[26]

This problem was addressed in Quarmby's work, who stressed that the user's perception of travel cost should be recognized as the appropriate entry to account for the cost attribute. In the discriminant analysis he conducted on the users' choices, he entered the average and marginal cost of travel, each at a time, and concluded that the latter yielded the model a higher explanatory power.[27] It can be inferred from this conclusion that the users' behaviour was affected by the marginal, rather than the average cost of travel. Since this inference is drawn from the users' behaviour, it can also be stated that it defines the users' perception of travel cost by car.

Accounting for the travel cost difference, rather than the cost ratio, seemed to be the approach most researchers agreed upon, except for Warner.[28] The cost difference approach, in the opinion of this author, is more plausible, since the user's perception of monetary units is uniform, and is likely to be independent from the total cost of travel.

3.11. The Comfort Level

The discussion introduced in Section 2.7. identifies some of the research difficulties to be faced in accounting for this attribute. In addition to these conceptual difficulties, empirical research findings have been inconsistent in defining the role of the comfort attribute in affecting users' behaviour. Brown and Hartgen seemed to indicate that the comfort level of the vehicle was not a very significant factor, while Lisco's study concluded the opposite.[29]

Since no definitive evidences were encountered in the literature to suggest that the comfort level can be safely ignored, the model to be formulated in this study should initially account for it. The method suggested here is to enter this attribute as a continuous variable. The information required on the user's evaluation of the comfort level of alternative modes can be obtained in a questionnaire survey, where the user is asked to rank the comfort of each vehicle along a Linkert scale. The difference, expressed as abstract units of measurement, can be entered as a continuous variable.[30]

For the part of the trip spent outside the vehicle in walking, waiting or during the transfer time, since it is considered by most users as sheer discomfort, the account is made through its association with the length of excess travel time. It is particularly difficult, and possibly redundant, to provide a separate account for the user's comfort level during this time.

3.12. Frequency of Transit Service

This attribute expresses the user's flexibility in selecting his departure time, and subsequently, his arrival time at destination. In comparing various modes with respect to this attribute, the difference in the frequency of service would be a valid measure, with the increase in frequency of one mode relative to the other indicating a greater degree of flexibility. For example, if the frequency of service of mode A is ten minutes, and that of mode B is five minutes, the difference indicates the advantage of B over A.

The same method is also applicable to mode choice situations involving car and transit. But, since the car is usually immediately available, the difference between departure times can, in this case, be set equal to zero, while such a difference for the transit service, whether small or large, would give an indication of its relative disadvantage relative to the car. Thus, instead of calculating the difference in the frequency of the two modes, we need only to enter the time period between departures of the transit service, as a continuous variable.

THE MODEL FORMULATION

3.13. The Problem of Colinearity

Having defined the universe of mode choice determinants, we may now address the problem of colinearity, which has a considerable bearing on the model performance. By scanning the choice determinants identified so far, one may suspect that the user's lifestyle, or its surrogate, the sensitivity toward modal attribute, may be correlated with the user's socio-economic characteristics. This problem should be investigated to ensure that the inclusion of some measure of the user's lifestyle would not be redundant.

The study's hypothesis postulates, however, that the socio-economic variables do not provide an adequate description for the user's personal characteristics, and that by accounting for some indications for his lifestyle, the explanatory power of the model would be expanded. The purpose of this section is to discuss previous research findings to this effect.

From previous research conclusions, some inferences can be drawn to suggest that the inclusion of lifestyle as mode choice determinant could have possibly been useful in explaining some aspects of users' behaviour. Further, a firm assertion can be made from these findings that the user's sensitivity toward modal attributes is not, in general, strongly correlated with his socio-economic characteristics:

(a) De Donnea reported that bias for car use in his sample was identified among the executive professions and blue collar workers.[31] Since these two groups have apparently no social or economic characteristics in common, an adequate explanation for such a bias cannot be derived from the socio-economic characteristics alone. Likewise, Brown finding that the share of managerial and secretarial professions in transit usage was unexpectedly high is difficult to interpret.[32]

(b) Further significant findings were reported in Brown's study as an outcome of the applications of the propensity model. The purpose of this model was to identify the changes in the system attributes so that a given proportion of the users would shift to transit use. By relating the users' socio-economic characteristics to their sensitivities to changes in the modal attributes, Brown reported some unexpected findings in that the income influence was inconsistent, at least in some instances, with what one would expect on intuitive grounds. In examining their propensity to shift to transit use, higher and middle income groups demanded lower overall out-of-pocket cost (marginal cost?) while the lower income group seemed to be satisfied with the level of cost.[33] Further to this, it is the medium and high income groups who would tolerate longer walking distance at the residential end, while the lower income group would not.[34]

The occupation variable seemed to show similar influences (which are also difficult to explain) in that managerial and professional groups demanded lower fares, and tolerated longer walking distance at the residential end of the trip (insensitivity to travel time?), while labourers and craftsmen were unwilling to tolerate longer walking distances.[35] Furthermore, labourers, sales people and managers were above the average in their sensitivity to travel cost.[36] The test conducted to identify the influence of age indicated that those under forty expressed higher propensity to shift to transit.[37]

All of these observations are apparently inconsistent with what one would intuitively expect on the relationship between the user's socio-economic characteristics and his sensitivity toward changes in various travel attributes. They are also in direct contrast with empirical research findings on the relationship between the user's income and his evaluation of travel time savings (See Section 2.6.). Thus, there is sufficient ground to suspect that the socio-economic characteristics do not provide an adequate description for the user's characteristics. This finding supports the argument introduced in Section 3.2., thus, placing the concept of lifestyle as an explanatory tool in more favourable light. It is conceivable that lifestyle might have provided an explanation for the observations mentioned above, for example, that Brown's sample included a substantial number of lower income users whose lifestyle put a great demand upon their time. Hence, the sensitivity of these users to time savings.

(c) Beier's work provided by far the strongest evidence to indicate that there is no correlation between the user's income or age, and his sensitiveness toward modal attributes. The data collated by Beier provided information on the user's income, age, his ranking of the modal attributes, and the improvements in transit service which would motivate a shift to transit use.[38] By grouping users according to their age and income categories, Beier found that the user's ranking of the relative significance of modal attributes, as well as their individual propensity to shift to transit use, did not significantly differ among the defined groups.

(d) Hartgen's work gave further indications that the correlation between the user's socio-economic characteristics and his attitudinal bias is not a strong one. He devised an attitudinal bias index which expressed the user's satisfaction with car relative to transit with respect to the modal attributes considered significant by the user himself. By using this index as a measure for the user's attitudes, Hartgen found that it exhibited no relationship to the user's income or occupation.[39]

Although these findings did not produce definitive evidence on the significance of the user's lifestyle as a mode choice determinant, they provide us with the assurance that user's sensitivity (or attitudinal bias, using Hartgen's terminology), is not, in general, correlated with his socio-economic characteristics, and hence, the problem of colinearity is not expected in the study's model.

3.14. An Overview of the Mode Choice Model

In the previous sections, we have already identified some mode choice determinants and grouped these into three sets of variables: (a) the user's socio-economic characteristics, (b) perceived attributes of the transportation system, and (c) the user's sensitivity toward modal attributes. Another determinant to be added to the above is the trip purpose. This addition is justified on the account that the value of time saved for any given trip is dependent, among other things, upon the trip purpose, as established in Section 2.6. A further justification is that the trip purpose usually gives an indication, although indirect, of some of the circumstances of the travel activity which may affect the user's behaviour. For example, work trips are usually associated with street congestion, crowded transit vehicles, and so on.

On the other hand, no attempt has been made in this study to demonstrate how these determinants are to be manipulated as model inputs. This is discussed in detail in Sections 3.15. and 3.16. But, before this task is attempted, a brief review of the model structure (which is demonstrated graphically in Fig. 4), would be appropriate at this stage of the study.

The initial step in the model operation entails the "filtering" of raw data to omit all captive users from the data

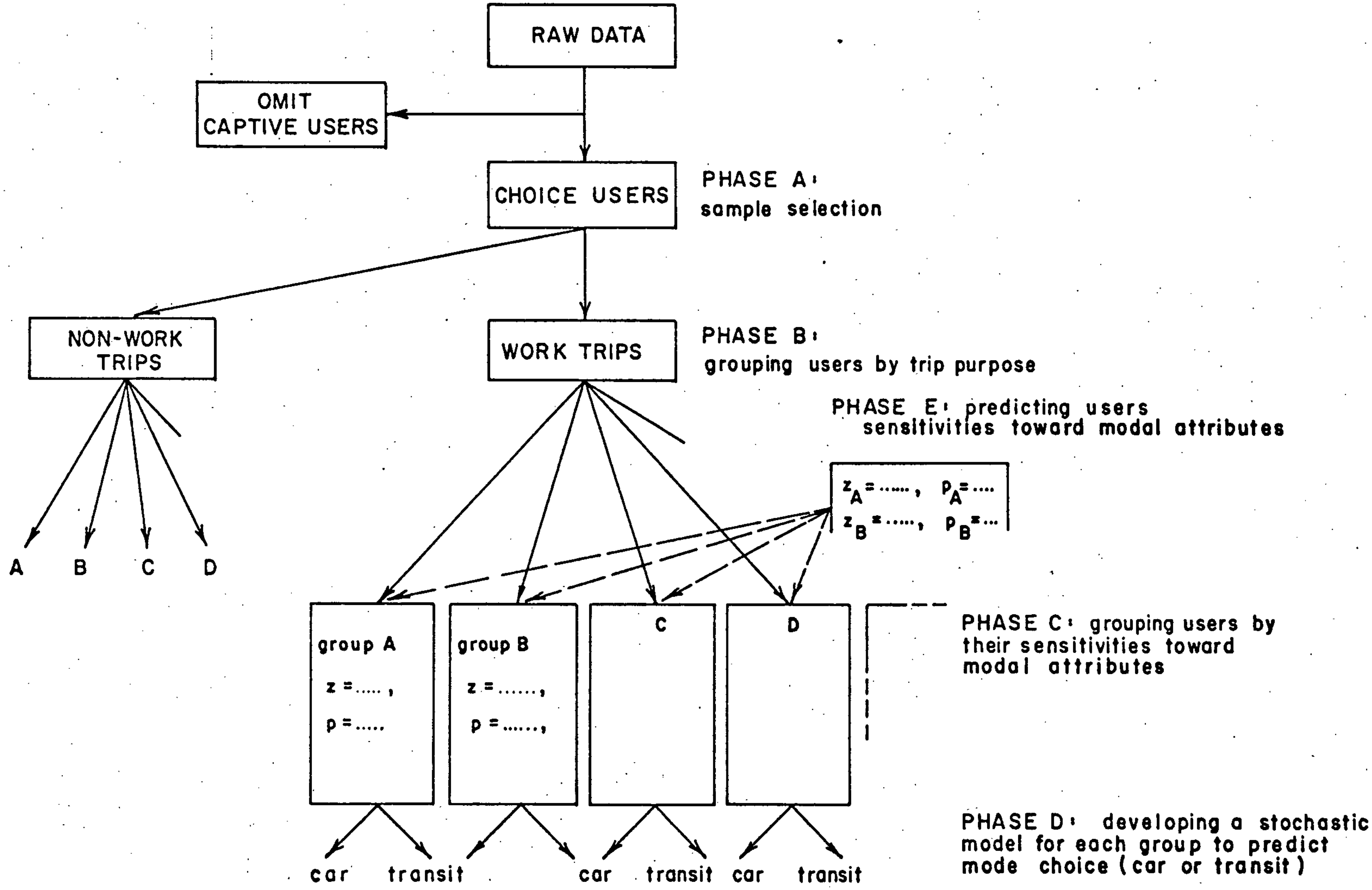

FIG.4 THE MODEL STRUCTURAL RELATIONSHIPS

set. Thus, subsequent analysis is to be conducted on users in mode choice situations only. All users are then grouped according to the trip purpose, that is, work and non-work trips. (If the sample size allows, the latter may be divided into personal business, shopping, social and recreational trips). For each of these groups, users are classified further into sub-groups according to their sensitivity toward modal attributes. For example, one of these sub-groups would include users who expressed (in a questionnaire survey) travel cost as the most significant attribute affecting their choice. Another group would include comfort-sensitive users, and so on. Having created these sub-groups, which are presumably homogeneous with respect to the sensitivity variable, the following step would be the calibration of a set of stochastic functions (for each sub-group) to explain and predict users' mode choices on the basis of some of the socio-economic characteristics (income and sex), and attributes of their individual mode choice situation.

Another step is added to the model structure (Phase E in Fig. 4), to explain and eventually predict the user's sensitivity toward modal attributes. In this step, the user's age, occupation and time budget are employed as independent variables in a set of discriminant functions to predict such sensitivity. This step is meant to enhance the predictive quality of the model by providing an account for some aspects of the user's lifestyle which are thought to influence his mode choice behaviour. In as far as the operational characteristics of the model are concerned, this step can also be considered as an alternative to phase C, since it relates the user's sensitivities toward modal attributes to some of their personal characteristics.

The latter step may not contribute to the expansion of the explanatory power of the mode choice model in the statistical sense, but it may improve the rationale of the model in that it defines the relationship between the user's characteristics and his behaviour in a clearer, more understandable manner. Furthermore, this set of functions may prove useful for planning purposes, as mentioned previously in Section 3.2., in that they demonstrate the impact of social or economic change, or new trends in the lifestyle of the population on their sensitivity toward modal attributes, and in turn, upon their mode choice behaviour.

On the other hand, should this set of discriminant functions fail, for any reason, to explain the users' sensitivities in the actual data analysis, this step can be omitted from the model structure without affecting its explanatory power in the statistical sense, although the rationale of the model and its predictive quality might be affected.

The purpose of the foregoing discussion is to briefly outline the various phases of the mode choice model. More detailed analysis of these steps is provided in the remainder of this chapter, which includes, in addition, a description of the stochastic models and an assessment of their usefulness for planning purposes.

3.15. The Use of Stochastic Models in Transportation Planning

In mode choice analysis, stochastic models are commonly used in conjunction with discriminant, logit, or probit analysis. In these models, the main concern is to define the probability that a user would make a certain mode choice given his characteristics and the characteristics and choices of all users in the sample. Usually, these characteristics provide a description for his mode choice situation, that is, attributes of modes available to him, his socio-economic status, or in some instances a combination of these two groups of variables.

Mathematically, the stochastic model is formulated as a conditional probability problem.[40] Given the characteristics of two users' groups, and the total number of users in each group, the problem here is to define the probability that a certain user, whose characteristics are known, belongs to any given group. The Bayesian Theorem provides an answer to this problem in the following mathematical function, which is a commonly used formula for the stochastic models:

$$p\ (x) = \frac{e^z}{1 + e^z} \qquad (1)$$

where p (x) is the probability of membership in a given users group,

z is the discriminant score of the observation

In discriminant analysis, the discriminant score can be derived from the following mathematical function:

$$z = a_0 + \sum_{i=1}^{n} a_i X_i \qquad (2)$$

where a_0 and a_i are parameters to be derived in the calibration process, and

X_i is the input variable describing the users' characteristics.

In the first run of the model, users' characteristics and their mode choices are employed in the calibration process, so that the values of the coefficients a_0, a_i can be derived. One mathematical criterion for deriving the above mentioned function is to maximize the "variance between" the populations relative to the variance within the populations. The model can be refined by omitting the variables which do not contribute significantly to the identification of users' groups, or variables which are highly correlated with others. Once the model is calibrated and refined, the researcher can assess its explanatory power by examining the appropriate statistical parameters, which also enables him to recognize the relative significance of each of the explanatory variables.

For any new observation--the choice of which is not known, but its characteristics X_i are given--the model produces the probability p(x) that this observation belongs to a certain users group. Each observation is to be assigned to the group which the model associates with the highest probability. One measure of the model performance is the percentage of correct classification in the iteration procedure.

In transportation planning research, the disutility function was construed as a special case of the discriminant function. In this case the input variables (X_i) are confined to the modal attributes, e.g., time, cost, comfort, etc. The discriminant score z can then be interpreted as a measure of the disutility of travel by the given mode, with higher score indicating increasing modal disutility, and vice versa. In other models, where the input variables are measures for the attributes differences between alternative modes, the disutility score can be interpreted as the disutility savings in the generalized price of travel mode using one mode as opposed to its alternative. The disutility savings concept, referred to in Section 2.4., was employed by Stopher, Thomas and Thompson, Pratt, Shunk and De Donnea,[41] but this study does not make use of this concept, and employs discriminant analysis in the conventional manner to identify users' groups on the basis of modal attributes and the users' socio-economic characteristics. Hence, the discriminant score z cannot be interpreted here as a disutility index.

3.16. The Model Structure

The statistical technique to be employed in this model is the discriminant analysis as described in the previous section, except for few modifications to take into account multiple users' groups instead of the binary case.[42] The discriminant score can be derived as follows:

$$z = - c_k + v_{ik} X_{ik} \tag{3}$$

where z is the discriminant score

c_k is a parameter to be derived in the calibration procedure.

v_{ik} is a vector of parameters to be derived in the calibration process for variable i and group k.

X_{ik} is a vector of variables selected by the researcher to differentiate between users' groups.

Having derived the discriminant score for the user (for each group), the probability that such a user belongs to group k is given by:

$$P_k\ (z_\ell) = \frac{(n_\ell / \sigma_\ell \sqrt{2})\ \exp\ (- \frac{1}{2} \chi^2_{z_\ell})}{\sum_{k=1}^{g} (n_k / \sigma_k \sqrt{2})\ \exp\ (- \frac{1}{2} \chi^2_{z_\ell k})} \tag{4}$$

where P_k is the probability that a user with discriminant score z_ℓ belongs to group k,

$_\ell$ and $_k$ are the standard deviations in users' groups ℓ and k respectively,

n_ℓ and n_k are the number of users in groups ℓ and k respectively,

$$\chi^2 = (z_p - \bar{z}_k)^2 / \sigma_k^2$$

The above formula is the general case to be used for a priori classification of users, which takes into account the size of each group.

The preliminary steps of the data analysis in this study are as follows:

(a) grouping users according to their trip purpose; work and non-work trips,

(b) within each group, five sub-groups are to be created to accommodate users whose sensitivity toward modal attributes are similar; that is, users who specify travel cost, total travel time, excess travel time, frequency of transit service, or comfort level of the trip as the most significant attribute should be grouped accordingly.[43]

In these two steps, ten sub-groups of users are created for further analysis. For each of these sub-groups, a discriminant function is to be derived to explain and predict users' choices (car or transit) on the basis of the following characteristics of the mode choice situation:

X_1, the household income,

X_2, the user's sex (a dichotomous variable),

X_3, total travel time difference ($T_{car} - T_{transit}$),

X_4, excess travel time difference, that is, out of vehicle time, walking, waiting, etc.,

X_5, travel cost difference,

X_6, comfort level difference, and

X_7, frequency of transit service.

The use of the cost difference variable and the comfort difference variables, X_5 and X_6, require some elaboration. Travel cost by car, as argued in Section 3.10., should include only the marginal cost of making the trip, i.e., parking, gasoline and oil, and road tolls if applicable. For the purposes of this study, a figure of $0.04 per mile can be used as an estimate for the marginal cost of operating a car.[44] This figure, together with the estimated length of the trip and parking charges are to be used to produce an estimate of the car trip. Comparing this estimate with the transit fare will give us the travel cost difference.

The comfort attribute is also to be entered as a continuous variable. It is suggested here that the user be requested in the questionnaire to assess, along a Linkert scale, the comfort level of both his car and the transit vehicle. The difference in his rating of the two vehicles, expressed as abstract units of measurement, can then be entered as X_6.

The above mentioned variables, together with the user's sensitivity toward model attributes are thought to provide an adequate explanation for user's choices. It is argued here that the user's sensitivity toward modal attributes provides some account for his lifestyle, at least insofar as mode choice behaviour is concerned. However, such an account would yield limited benefits unless a user's sensitivity toward modal attribute can be rationally and statistically explained within the model structure.

To explain and predict the user's sensitivity toward modal attributes, it is suggested here that other variables, which may also be related to his lifestyle, should be considered. One set of variables is the user's time budget. Other indications which may be associated with lifestyle are the user's age and occupation (See Sections 3.5., and 3.6.). By including a dichotomous variable indicating whether the user is over or under 40, the influence of age on lifestyle, (and hence on the user's sensitivity), might be accounted for. It might also be desirable to include another dichotomous variable to account for the occupational status of users in management, professional or executive groups.

Thus, an additional set of discriminant functions is required to explain and predict the user's sensitivity toward the five system attributes, X_3 to X_7, (for each of the two trip purpose categories) on the basis of the following variables:

Y_1, the user's age, a dichotomous variable,

Y_2, the user's occupation, a dichotomous variable,

Y_3, the number of weekly hours the user puts into work,

Y_4, the number of weekly hours spent in social and cultural activities,

Y_5, the number of weekly hours spent in outdoor recreation, and

X_6, the number of hours spent at home, with the family, etc.

The purpose of this additional set is to improve the rationale of the model and enhance its predictive quality, but should these variables fail to explain the user's sensitivity toward modal attributes, this step can be omitted without affecting the statistical parameter of the model which reflects its explanatory power. This precautionary measure fulfills a requirement set in Section 3.3., as a result of the lack of empirical data to support the validity of this relationship.

The model structure outlined above fulfills the study's basic objectives. However, if the researcher is interested in creating more homogeneous groups, (for which the discriminant functions to be derived), so that the model yields a greater explanatory power, several possibilities exist for his consideration. One method of achieving this is by dividing non-work trips into shopping, social, recreational, personal business and other trips. Furthermore, an improved description of the user's sensitivities may be achieved by accounting for the second most important attribute, the third most important attribute, and so on till all attributes are accounted for. This method of classification increases the number of possible users' groups up to 120 categories (the factorial of the total groups number, that is 5 X 4 X 3 X 2 X 1 = 120) for each trip purpose. Obviously, such a detailed classification would make the research task unmanageable, and the researcher is required to exercise his judgement as to the most appropriate classification to serve the research purposes, taking into consideration the total sample size as well as the minimum size of the sub-groups to be created.

3.17. Summary

The design of the study's model is aimed, through data analysis and "filtering," at isolating choice users, and dividing them into sub-groups each of which reflects a certain degree of homogeneity with respect to some of the influential factors affecting their choice behaviour. The criteria employed for classification are: (a) trip purpose, and (b) the users' sensitivities toward modal attributes. This procedure allows for the model to account for certain aspects of the users' lifestyle which may affect their choice behaviour. In addition, it ensures that further analysis is conducted on samples of users which are homogeneous in certain respects.

For each of the user's sub-groups defined, a stochastic probabilistic function is to be derived to explain and predict the users' choices: car or transit. The discrimination is to be based upon two sets of variables:

(a) characteristics of the mode choice situation, that is, differences between the car and transit with respect to travel cost, total travel time, excess travel time, the comfort level, and the frequency of transit service, and

(b) some of the user's socio-economic characteristics, age and sex.

These inputs are believed to be adequate to explain the users' mode choices. Yet, for the model to be of predictive value, the relationship between these variables and future changes in the social, economic, or demographic characteristics of the population should be identified. Thus, for any given region, changes which may affect the users' behaviour can be identified as follows:

(a) changes in the characteristics of the mode choice situation: cost of travel (increasing cost of gasoline, parking), travel time (street congestion, new transit technology), comfort level, etc.

(b) changes in the socio-economic characteristics of the population, age structure, income distribution, demand for various occupations, etc.

(c) changes in the population lifestyle, higher living standards, availability of leisure time, new work or leisure ethics, etc.

These changes may or may not be predictable. However, in as far as the trends can be identified, and the researcher is willing to attach a degree of credibility to these predictions, their impact on the users' expected behaviour would also be identifiable. The study's model is formulated so that the users' socio-economic characteristics and his time budget are related to his sensitivity toward modal attributes. This relationship is expressed in another set of discriminant functions to explain and predict the user's sensitivity toward modal attributes on the basis of his age, occupation and time budget. This additional set obviously does not add to the explanatory power of the model in a strictly statistical sense, but it enhances its rationale as well as its predictive and practical value.

The model inputs so far seem to cover many of the changes in the population socio-economic characteristics, and some indication of their lifestyles. The researcher may be willing to predict that such changes will take place, and the result of his analysis would be to define their impact on the users' mode choices. Alternatively, he may be merely seeking information on what the impact of these changes would be on the users' behaviour, regardless of whether the changes in question are expected with any degree of certainty.

FOOTNOTES

1. Such a sensitivity can be identified in the person's statement in a questionnaire survey for example, or alternatively, in his mode choice behaviour. The sensitivity of users toward excess travel time was identified by the relatively high disutility derived from users' behaviour (see Sec. 2.6).

2. The notion that some users are "pressed" for time, and that this may have an affect on their mode choice is referred to by De Donnea, Determinants of Transport Mode Choice, p. 157, and Brown, Mode Choice Determinants of Selected Socio-economic Groups, p. 103.

3. Moses and Williamson, "The Subsidy Issue," Journal of Political Economy," pp. 247-264.

4. We should note that, although the users' socio-economic characteristics and their sensitivity toward modal attributes are not, in general, strongly correlated, it is might possible, however, that some users groups, enjoying, say, a high occupational status (e.g. managers, professionals) would express similar sensitivities toward modal attributes. But this is only because such groups may have similiar lifestyles. Likewise, age may not be related to the user's sensitivity toward modal attributes, except to the extent that it indicates a trend in lifestyle.

5. De Donnea, Determinants of Transport Mode Choice, p. 130.

6. Ibid., p. 193.

7. Brown, Mode Choice Determinants of Selected Socio-economic Groups, p. 101.

8. Ibid., p. 223.

9. Ibid., p. 103.

10. Ibid., p. 222, De Donnea, Determinants of Transport Mode Choice, p. 137, Warner, Stochastic Choice of Mode, p. 35, Lave, "Behavioural Approach," Transportation Research, p. 472.

11. Brown, in ibid., pp. 123-127.

12. Warner, Stochastic Choice of Mode, p. 85.

13. Brown, *Mode Choice Determinants of Selected Socio-economic Groups*, p. 101.

14. De Donnea, *Determinants of Transport Mode Choice*, p. 137.

15. Lave, "Behavioural Approach," *Transportation Research*, p. 471.

16. Brown, *Mode Choice Determinants of Selected Socio-economic Groups*, p. 101. Warner, *Stochastic Choice of Mode*, p. 35, Lave in *Ibid*., p. 472.

17. Hartgen and Tanner, "Effect of Traveler Attitudes," *Highway Research Record*, p. 5.

18. *Ibid*.

19. *Ibid*.

20. *Ibid*.

21. Thomas, "Value of Time," *Highway Research Record*, p. 24, and Peter L. Watson, "Problems Associated with Time and Cost Data Used in Travel Choice Modeling and Valuation of Time," *Highway Research Record*, Rep. No. 369, 1971, pp. 148-158.

22. This approach was pursued by De Donnea, *Determinants of Mode Choice*, pp. 77-88, and Quarmby, "Choice of Travel Mode," *Journal of Transport Economics and Policy*, pp. 280-281.

23. Warner, *Stochastic Choice of Mode*, p. 35.

24. Quarmby, "Choice of Travel Mode," *Journal of Transport Economics and Policy*, p. 297.

25. If the researcher concluded from testing approaches a & b in this section that the ratio yields the model a greater explanatory power, he may wish to use this approach. This procedure is also valid for all attributes, yet a certain degree of consistency in treating these attitudes (either by accounting for the difference or the ratio) may also be desirable.

26. Lave, "A Behavioural Approach," *Transportation Research*, pp. 467-468.

27. Quarmby, "Choice of Travel Mode," *Journal of Transport Economics and Policy*, p. 290.

28. Warner, Stochastic Choice of Modes, p. 35.

29. Brown, Mode Choice Determinants of Selected Socio-economic Groups, p. 105, Hartgen and Tanner, "Effect of Traveler Attitudes," Highway Research Record, p. 5, and Lisco, "Value of Travel Time," Highway Research Record, p. 36.

30. The Linkert scale, as used in this study, is a graduated five points scale, which allows the user to express his subjective evaluation of any given attributes. For example, the user may be asked to state how he evaluates the comfort level of the trip (a) very comfortable . . . ., (b) comfrotable, ..., (c) somewhat comfortable . . . ., (d) uncomfortable . . . ., or (e) very uncomfortable . . . .

31. De Donnea, Determinants of Transport Mode Choice, p. 131, and Brown in ibid., p. 101.

32. Brown, Mode Choice Determinants of Selected Socio-economic Groups, p. 101.

33. Ibid., p. 207 and 213.

34. Ibid., p. 207.

35. Ibid., p. 213.

36. Ibid., p. 216.

37. Ibid., p. 200.

38. Beier, Marketing Transit, Traffic Quarterly, pp. 538-539.

39. David T. Hartgen, The Influence of Attitudinal and Situational Variables on Urban Mode Choice, Department of Transportation, New York State, Rep. No. PRR. 41, March, 1973, p. 40.

40. For detailed discussion of the mathematical formulation of this model, see Multivariate Data Analysis, by William W. Cooley and Paul R. Lohnes, John Wiley, New York, 1971, pp. 243-286, and Stochastic Choice of Mode, by Warner, pp. 5-16.

41. Stopher, "Probability Model," Highway Research Record, Thomas and Thompson, "The Value of Time," Highway Research Record, Rep. No. 314, 1970, Pratt, "Utilitarian Theory," Highway Research Record, Shunk and Bouchard, "Application of Marginal Utility," Highway Research Record, and De Donnea, Determinants of Transport Mode.

42. Gerald R. Brown, "Policy Model for Multimodal Transportation System Planning," Transportation Research Series, Rep. No. 2, The University of British Columbia, April, 1973, pp. 2-6.

43. This idea should be attributed to Russel L. Ackoff, "Individual Preferences for Various Means of Transportation," Interim Report of Management Science Centre, University of Pennsylvannia, May 1965, p. 13.

44. This figure was estimated on the basis of gasoline consumption at the rate of 13 miles per gallon, fifty cents per gallon. Perhaps a more appropriate approach is to experiment with similar values of car operating cost and adopt the value which yields the model a greater explanatory. This is, in essence, Quarmby's approach.

CHAPTER IV

SURVEY AND QUESTIONNAIRE DESIGN

4.1. Introduction

This chapter is devoted to problems associated with sample selection and questionnaire design. This is to be the final part of the study's course of investigation, since no attempt is made to collect and analyse raw data on users' behaviour. Evaluation of the study's progress and its pertinence to planning is expounded in the following chapter.

4.2. Survey Design

The discussion put forward in Section 3.16., concerning the data requirements for the model calibration procedure clearly indicates that such information can be drawn from only a sample of users whose behaviour is monitored in choice situations. Information on captive users is not useful for the model calibration and should be excluded from the data analysis prior to this stage.

To satisfy this condition, it is suggested here that the questionnaire survey be conducted in transportation corridors where car use is practical and transit service is available. In the meantime, it is also desirable to extend the sample space so as to include modes choice situations which shows a wide range of variation in the disutility savings between car and transit. Thus, the survey would not include a random sample of users; rather, the attempt is made to collect sufficient information specifically for the purpose of model calibration.[1] It follows that the data should include the average as well as the "extreme" mode choice situations, i.e., varying degrees of "competition" between car and transit.

Thus, the sample space to be defined for the study purposes should satisfy certain criteria:

(a) Total time difference. The sample should include choice situations with time savings between car and transit use varying from small to large, and should ideally reflect the advantage of car in some cases and the advantage of transit in others. It is very likely that if car use has an advantage over transit use with respect to time savings, such an advantage would increase with the distance travelled. Thus, by accounting for choice situations at different locations along the transportation corridor, the sample would include choices made under varying degrees of competition between car and transit with respect to this particular attribute.

On the other hand, choice situations where transit is more advantageous with respect to total travel time are likely to be somewhat limited. Such situations may be encountered in cities where transit operates on its own right-of-way, while other vehicles operate on congested streets. Otherwise, the use of transit vehicles, such as buses, may only be advantageous (with respect to the time attribute) in "internal" downtown trips, i.e., trips whose origin and destination are in the downtown area, since walking to and from the parking space at both the trip ends are likely to be inproportionate relative to the in-vehicle time.

(b) <u>Travel cost difference</u>. The sample should also include mode choices with a wide range of cost differences. But since travel cost by transit does not vary significantly (regular bus fare, monthly pass fare), the required range can only be created by variation in the travel cost by car: operating cost, parking charges, and toll roads if applicable. Operating cost, it should be noted, may not always be significant ($0.04 per mile), and toll roads are not common in this country. Thus, to include choices with substantial cost differences, the sample should ideally include a number of car users who are carrying commercial parking charges, and others who are provided with free or subsidized parking (employee parking).

(c) <u>Differences in levels of transit service</u>. Choices involving transit use should also account for different levels of service. Generally speaking, the level of transit service is a function of two attributes: frequency of departure times at various hours of the day, and the "density" of transit lines in the city sector, i.e., the length of routes divided by the area serviced. The former accounts for the flexibility the user may have in adjusting his departure time with other daily activities, while the latter expresses the convenience of transit use. To account for this variation, the sample should include users in areas which are provided with levels of transit service varying from poor to good with respect to these two attributes.

4.3. Definition of the Sample Space

The question to be addressed in this section is how to define the sample space so as to meet the criteria established above. It is suggested here that a deliberate effort be made so that the study sample would account for a variety of mode choice situations. This objective can be achieved by several alternative procedures, one of which is expounded below.

As a first step, the researcher may select several residential areas at different locations in the city which reflect a substantial variation in the quality of transit service provided (e.g., frequency of departure times, route mile per serviced area) at different distances from the downtown area. In selecting these areas, it may be desirable to assess their suitability for the analysis intended with respect to the socio-economic characteristics, and possibly other characteristics which may seem relevant, e.g., residential density.

Having identified the residential areas to be included in the analysis, the researcher may want to consider partitioning the sample into three sub-spaces which correspond initially to the number of questionnaires to be distributed in various parts of the city. These sub-samples, to be named here A, B, and C, can be described as follows:

(a) sample space A, which is to include car and transit users travelling from these areas to downtown,

(b) sample space B, to be devoted to observations concerning users starting their trip from downtown to the selected residential areas,

(c) sample space C, to include downtown "internal" trips, i.e., trips originated and ended in the downtown area. The method of achieving this partitioning in the survey and the purpose served in each case is discussed below.

The survey proposed here is designed as a mail questionnaire survey. Thus, to "fill-in" sample space A, the questionnaire forms are to be distributed to users starting their trips in the selected residential areas and are destined to downtown. The transit users' questionnaire forms are to be handed to users as they step into the transit vehicle, if they answer affirmatively to the question whether they are headed to the downtown area. (It may be advisable to avoid the distribution of these forms at major transfer points, so that the sample be confined to residents of the areas selected for the study). Likewise, the car users' questionnaires are to be distributed to car drivers in the area who satisfy the same condition (again, avoiding major arterials so that through traffic is excluded).

To formulate sample space B, a number of bus users' questionnaires are to be distributed in the downtown area to users destined to the selected residential areas in the same manner as above. However, the distribution of car users' questionnaires in this sample space is different in that a number of these are to be distributed in commercial and employee parking lots, so that the sample space would include users carrying parking charges, as well as others who are provided with free or subsidized parking.

Sample space C, as mentioned previously, is created for internal trips in the downtown areas by car and transit. The questionnaire is to be handed to users starting and terminating their trips in the downtown area. The purpose of creating this space is to ensure the sample also accounts for time savings which may be achieved by transit use.

The rationale for partitioning the sample space into three divisions is now becoming clear: for sample space A, it is to ensure that a sufficient variation in travel time and level of transit service have been included in the data base; for example space B, it is to ensure that a wide range of cost variation is accounted for. Sample space C is devised to include a wide range of time variation by accounting for "negative" time savings to be made by car use in some mode choice situations.

Although there are sufficient grounds to suggest the survey design as discussed above, it should be remembered that there is a possibility that the selection of a biased sample may not prove useful as anticipated in this study. Taking these extreme mode choice situations into account may possibly weaken the explanatory power of the model, if the extreme cases actually reflect different kinds of trade-offs from the bulk of the sample. Should this be the case, the researcher may wish to exclude such extreme cases, so that the data analysis would be confined to users whose behaviour is more homogeneous.

The researcher may also wish to consider other modifications in the research design. For example, a random sample (rather than a biased sample), could be more useful if the researcher is interested in analysing the behaviour of users in a geographic area. Another modification is possible if the research is conducted in a city where transit vehicles operate on a separate right-of-way, and thus, transit use would yield time-savings even in longer trips, e.g., home-to-work trips. In this case, sample space C would not be required.

In other situations, it may be desirable to consider sample spaces A and B as mutually exclusive. That is, the selected residential areas will be divided into two groups, a number of questionnaire forms will be distributed to users in the first group to form sample space A, and another number of questionnaires will be distributed to users in the downtown area destined to the second group of residential areas to form sample space B. The purpose of this distinction is to avoid the possibility that the same user may be given the questionnaire form twice, once in his residential area, and a second time in the downtown on his way home.

The researcher should exercise his judgement as to the number of questionnaire forms to be distributed in each of the sub-samples mentioned above, the specific location and time of the distribution. It should be remembered that according to the model designed for the study purposes, ten stochastic functions are to be formulated (See Sections 3.14., and 3.16.). Since each of these would require a minimum of eighty observations for the calibration procedure, it may be necessary to distribute some 4000 questionnaire forms so that the researcher may have a reasonable chance to receive at least the minimum number of observations required for the calibration of each function.

4.4. The Questionnaire Design

Two questionnaire forms are designed for the study's survey, one for car and the other for transit users. The questionnaire text is put forward in Appendices A and B. The questionnaire should, if answered fully, provide the researcher with all the information required for the model formulation phase as outlined in Sections 3.14., and 3.16.

The transit users questionnaire is phrased specifically for bus use. It provides the following information:

(a) origin, destination, and starting time of the trip.

(b) trip purpose.

(c) travel time by the chosen mode, as perceived by the user, broken down to walking, waiting and in-vehicle time.

(d) frequency of transit service at the trip time.

(e) trip cost.

(f) the user's assessment of the relative significance of the following attributes:

- travel cost,
- total travel time,
- excess travel time,
- frequency of bus service, and
- comfort level of the bus trip.

(g) whether the user could have travelled by the car instead, and if so, the following data are requested:

- walking and in-vehicle time,
- parking charges if any.

(h) the user's socio-economic characteristics: age, sex, income level, occupation, and number of persons in his household.

(i) the user's approximate time budget, i.e., allocation of his time among five basic categories: work, at home or with family, cultural or social engagements, and outdoor recreation.

(j) whether the user can, at his will, work overtime.

The use of these data as inputs into the study's model is discussed in detail in the previous chapter, except for the inclusion of some additional information which the researcher may wish to explore its value for the analysis:

(a) non-work trips are classified further into five categories,

(b) assessment of the system attributes is extended to five important attributes (instead of being concerned with the most important attribute only), and

(c) the user's ability to work overtime at will,

(d) the number of persons in the household.

The researcher may wish to alter his research design to account for any of these variables, should his investigations indicate its significance.

The car user's questionnaire provides similar data to those itemized above, and, in addition, information on whether the user is motivated to use the car because:

(a) he needed the car at the end of the trip to make other trips,

(b) he has to take along another passenger,

(c) he is sharing a car pool with others,

(d) he needs the package space in the car for shopping bags, working tools, etc.,

(e) using the bus is affecting his social status.

This information, together with other data requested in item 5 in the questionnaire (Appendix B), allow for "filtering" the sample prior to the calibration procedure. Those having no access to an alternative mode, need the car at the end of the trip, or use the car for the benefits of someone else are practically captive users and should be omitted from the analysis. Likewise, users who opted for the car because they are sharing a car pool (door-to-door service?), need the package space in the car, or using the car as a status symbol should also be excluded from the data base. Such users are influenced by attributes which are not characteristic to transit, and they are also, in a sense, captive users. As a result of this filtering process, only users who have a real choice and are affected by attributes common to the two modes available may be accounted for.

A similar problem is raised by users who qualify as choice users (according to the criteria mentioned above), but are not aware of the attributes of the alternative mode. For example, a user who has a full access to transit use and has no compelling reason to use the car, may still choose it for travel without acquiring any information on the attributes of the transit system. The problem raised here is two-fold. First, such a user made his choice on the basis of incomplete information on his mode choice situation, and hence, the constraints affecting his behaviour would be different from other "informed" users. Secondly, for the purposes of model formulation, attributes of the transportation modes available to the user are necessary information without which the discriminant functions cannot be derived.

The latter difficulty can be resolved, if the researcher chooses, by estimating the attributes of the travel activities by the alternative mode for such users, and feeding these into the calibration procedure. The information on the user's origin, destination, trip time, and attributes of the existing transportation system can be utilized to provide these estimates.

However, one may suspect that the behaviour of "uninformed" users could be different in some respects from

other users. For example, modal bias may be more pronounced in the behaviour of the former group. In handling this difficulty, the researcher has two alternatives to follow:
(a) to drop such observations altogether from the data base, thus confining his analysis to informed, choice users,[2] or
(b) to include such observations (complemented by the estimated attributes) subject to further analysis to ensure that their inclusion will not reduce the explanatory power of the model. The researcher may want to arrange for two runs for the model, with and without observations on the "uninformed" users. It can then be determined whether their inclusion would be to the deteriment of the model performance. In any case, the researcher would be well advised to conduct a further analysis on this group of users to identify any differences which may be of relevance to the inquiry on users' behaviour.

FOOTNOTES

1. The problem of incomplete coverage of data to a sufficient range of mode choice situation can be identified in the following works: Beesley, "The Value of Time, Economica, Shunk, "Application of Marginal Utility, "Highway Research Record, and De Donnea, Determinants of Transport Mode Choice. Only Thomas and Thompson seemed to have had a sufficient data base, "Value of Time," Highway Research Record, 1971.

2. If the researcher finds that a substantial proportion of choice users are not aware of the attributes of the transit system, he may infer from this observation that either the transit system is providing a poor level of service, and thus very few consider it a choice, or the information on the transit system is not readily accessible to the public, in which case he may wish to initiate an advertising campaign to remedy the situation.

CHAPTER V

SUMMARY AND CONCLUSIONS

5.1. Introduction

This chapter, being the last, is a summary and a critical analysis of the study's course of investigations. The study approach and conclusions are appraised, and its pertinence to planning is discussed. Finally, the study's limitations are expounded, and as a result of acknowledging these, the attempt is made to outline further research possibilities.

5.2. Summary and Evaluation of the Study

The dual concern of this study is with the identification of mode choice determinants, and the formulation of a model which promises greater explanatory capabilities than what is afforded by the current state-of-the-art in this field. This required an evaluation of the existing theories and concepts pertinent to mode choice behaviour, namely: the abstract mode choice theory, the utilitarian theory of mode choice, theory of time value, and concepts developed on perception, attitudes, and behaviour.

In summary, the theoretical framework which can be established from the literature review and empirical research findings defines the probability of making a certain mode choice as a function of two sets of variables: differences between modal attributes of alternative choices, and the users' socio-economic characteristics. The concept of the generalized price of the travel activity identifies the user's perception also as a mode choice determinant. The generalized price, as employed in this study, is a combined measure for modal attributes and the user's perception of these. It is implied in this concept that the disutility of various travel attributes are comparable in quantitative terms. Supportive evidence to substantiate this concept was encountered in the literature.

The conceptual framework established for the study's purposes makes use of the concept of the individual's lifestyle, the latter being initially defined as the pattern by which the individual allocates his time and monetary resources. Further analysis leads to certain modifications in this concept: in as far as mode choice behaviour is concerned, the individual's lifestyle is likely to be expressed in his sensitivity to modal attributes, which in turn, can be traced to availability and the demand upon his time and monetary resources. This concept can be useful in formulating the operational procedures of the model as follows:

- users can initially be classified into sub-groups on the basis of the emphasis they place on various system attributes,

- for each of these sub-groups, a stochastic model is to be formulated to explain users' choices on the basis of their socio-economic characteristics and characteristics of the mode choice situation.

- another set of probabilistic functions is to be formulated as an "off-line" procedure in the operation of the model. That is, the model can be operational without this set although its potential uses and value would be restricted.

The purpose of this additional set is to explain the user's sensitivity toward modal attributes on the basis of his time budget and some related socio-economic characteristics. This step is introduced merely to improve the rationale of the model and enhance its predictive quality rather than its explanatory function in a strictly statistical sense.

The model is to be calibrated from information on users' behaviour in actual mode choice situations. Users are asked to provide information on the mode selected, characteristics of the choice situation available to them, their sensitivity to modal attributes, their socio-economic characteristics, and an approximate account for their time budget. The model is, therefore, a behavioural one, its basic function being to explain and predict users' choices.

This approach is different from the approach pursued in the propensity models where the user is asked to specify the conditions under which he would shift modes.[1] In the latter case, it can be readily argued that the prediction made is valid only to the extent that users act in the manner they previously specified as their preference, or "would-be" behaviour. Yet, the relationship between the users' preferences and their actual behaviour has never been established in the previous research in this field, and the issue is still considered, at best, a thorny one.[2] This problem is avoided here in its entirety by pursuing the behavioural approach.

In evaluating the model structural relationships, it may be noted that some of the concepts employed seem to be supported on a priori grounds, while others were empirically verified in previous research. The primary hypothesis of the study, that users' sensitivities toward modal attributes are not strongly correlated with their socio-economic characteristics, is supported by evidence in the literature which are considered by this author to be adequate, and hence, a strong case can be made to account for both sets of determinants in model choice analysis. On the other hand, no substantial evidence was encountered to suggest that such sensitivities are caused by or related to the user's time budget. This plausible relationship remains unproven hypothesis. (Indeed, this subject in its entirety is still unexplored).

Other elements of uncertainty in the application of the time budget concept is whether the description provided for various activities (works, family, social, recreational), will prove useful and reveal similar relationships to those discussed in Section 3.4. However, in addressing the latter two criticisms, it should be pointed out that the use of the time budget concept in the model is confined to the "off-line" procedure which is added to the basic structure of the model (phase E in Section 3.14., and Fig. 5) to explain and predict user's sensitivities toward modal attributes. Should the time budget scheme prove unsuccessful in the model implementation, the explanatory function of the model would not be affected (at least not in the statistical sense), although its predictive quality would be. The researcher may then wish to seek a different explanation for the users' sensitivities toward modal attributes, possibly in conjunction with a different approach to the individual's lifestyle.

Another aspect of the model operation which should be viewed cautiously is the user's assessment of the relative significance of modal attributes. One may advance *a priori* argument that a user may consider, for example, the comfort attribute to be the most significant for a given trip; but this is only true as long as the trip cost or time does not exceed a certain limit (beyond which cost or time becomes the most significant attribute). Thus, substantial change in the system attribute may lead to different sensitivities among users. This poses further limitations on the use of the model for predictive purposes.

Finally, there are other shortcomings inherent to the theoretical framework of the study which have been hinted at previously. The application of the abstract mode choice theory has practical limitations in that no systematic or objective method is developed to identify the "relevant" system attributes. Should the researcher apply his judgement to select these attributes, or the universe from which these attributes are to be selected--a step which he cannot escape--he is under no conditions certain that he accounted for <u>all</u> the system attributes perceived by the user to be pertinent to the problem of mode choice.

Another shortcoming of the application of the abstract mode approach is that some of the modal attributes are not comparable from one mode to the other. For example, how can one compare the flexibility of routing provided by car use (thus permitting the user to avoid unpleasant routes, pick up or take someone along, etc.) with the fixed transit route which does not offer such a flexibility. This difficulty is inherent to the use of qualitative data in quantitative models. But, needless to say, that many of the system attributes cannot be expressed quantitatively in a scientifically acceptable manner.

5.3. Planning Implications

In its concern with conceptual analysis and model formulation, this study clarifies several problems, identifies others, and present some ideas which can be of benefit to the planner.

The model formulated in the course of this study, if implemented, would expand our knowledge on the relationship between users' mode choices and their sensitivities toward modal attributes, and furthermore, on the relationship between the latter and users' time budget (which is considered in this study to be an expression of certain aspects of the individual's lifestyle). The identification of these complex and interrelated relationships may possibly lead to the definition of the causal relationship underlying users' behaviour.

Since the model also accounts for the relevant attributes of the transportation system, it provides the planner with means of assessing the impact of alternative transportation policies on users' mode choices--possibly in quantitative terms. The following are examples of such alternatives:[3]

(a) increase the cost of car travel by raising the parking charges, road tolls, etc.

(b) increase the travel time by car by reducing the parking space available in the proximity of major destinations, thus prolonging the walking time to and from parking, or by allowing street congestion to occur in parts of the city where transit vehicles operate on a right-of-way.

(c) lower the comfort level of car trips by neglecting road maintenance or improvements, and

(d) reduce transit travel time by providing a greater areal coverage of transit service, increasing its frequency, establishing a separate right-of-way, etc.

The planner may also wish to consider the impact of some of these policies on various mode users in different socio-economic groups. This can possibly give him some indications on the effectiveness of policy changes in areas in the city characterized by, for example, high income or older age residents. With certain modifications in its structural relationships, the model may also be useful for this purpose: all observations are to be initially classified into sub-groups, according to the socio-economic criteria specified (income level, age, etc.). Within each group, users' mode choices can be explained, by means of stochastic functions, on the basis of attributes of the mode choice situation and the socio-economic characteristics, excluding, of course, the variable used as a criterion for the initial classification. A comparison can then be drawn between the behaviour of various groups, and the difference can be attributed to the effect of the variable employed as a classification criterion.

Furthermore, the study's model can also be utilized as a planning tool in introducing a new transit system or improving an existing one. This would require a similar survey design to be conducted in areas for which transit service is planned. In this survey, the planner should seek information on the number or percentage of captive car users who would not shift to transit for any of the reasons discussed in Section 4.3. In addition, other information on the users' characteristics and their travel pattern, as listed in the study's questionnaire, should also be collected. The planner can then proceed to lay the transit routes so as to include a great number of potential users in the "catchment" area of these routes. By estimating walking and travel time for the potential users, a model similar to that introduced here can be employed to estimate the number of users who would shift to the new mode.

Further to these, the mention is made of other applications in the course of the study. In Section 2.3., the use of the abstract mode choice theory for predicting the use of new transportation modes is expounded. Such modes can be reduced to their most significant attributes, and to the extent that these are comparable with attributes of existing modes, the researcher can predict the impact of introducing a new mode on users' behaviour. Likewise, reference is also made to the increased capability of the researcher to investigate or predict the impact of social or economic change, or new trends in lifestyles (as defined in this study). Since the model takes account of the user's personal characteristics, (including his lifestyle) and modal attributes, such changes can be "entered" into the model and its impact on users' behaviour can be identified. Admittedly, however, major social or economic changes, or radically different orientations in the population's lifestyles have behavioural implications which may well produce new patterns of behaviour beyond the predictive range of this or any other model. The researcher, therefore, should exercise his judgement as to the degree of credibility he may be willing to attach to the model performance under these conditions of uncertainty.

5.4. Research Possibilities

This study's approach is different from others in that it places emphasis upon two aspects of user's behaviour:

(a) the relationship between the user's perception of travel disutility and mode choice, and

(b) the relationship between the user's lifestyle and the significance he attaches to individual attributes of the travel mode.

Previous works investigated the first aspect of user's behaviour mentioned above and significant findings are reported in the study. However, as the study points out, there is still a degree of uncertainty in the researcher's mind as to what attributes constitute a travel mode. In other words, we are back to the question posed at the outset of the study (Section 2.3.), and that is how to reduce a travel mode to a "bundle" of attributes in a manner which fully accounts for the user's perception of these modes. This difficulty is compounded when one considers the operational obstacles of formulating a model to account for both quantitative and qualitative data. Yet, improving the state-of-the-art in mode choice analysis requires an appropriate solution to these problems.

In addition, the concept of user's lifestyle introduced here, although it appears a promising conceptual tool, needs further refinement and support of empirical data. To improve its rationale, perhaps a more elaborate conceptual framework is required to relate the individual's time and money budget to his personal values. A fruitful avenue of research would be to consider the pattern of money and time expenditures as an expression of the individual's personal values, and that for the individual to arrive at the equilibrium state defining his pattern of time and money distribution, certain trade-offs must be made between various competing activities, and between goods and activities. As an example, an individual may choose, depending upon his personal values, to spend more time in work and less in travel. Also, an individual may choose to give up a vacation to buy some furniture, for example, thus trading activities for goods. In this context, money and time may then be considered a common resource, which the individual dispenses of in the form of goods and activities in such a manner which maximizes his satisfaction.

This general conceptual framework, being applicable to activities and commodities, may be construed as an elaboration on the existing consumer theory where consideration is given exclusively to the demand and supply of goods, and the concern is with maximizing the consumer's satisfaction under the constraint of financial resources available. Adding to these considerations time as a limited resource, and activities as goods (time and/or time consuming?), the rationalization of the individual's behaviour under these conditions poses challenging conceptual problems which are worthy of the researcher's attention. Since travel is a time- and money-consuming activity, resolving these problems may enhance the theoretical underpinnings of mode choice analysis.

FOOTNOTES

1. A detailed discussion of this approach is documented in Mode Choice Determinants of Selected Socio-Economic Groups, by Brown, pp. 186-223.

2. The discrepancy between predicted mode use on the basis of stated preferences and actual use was identified by David T. Hartgen, Forecasting Remote Park-and-Ride Transit Usage, Research and Applied Systems Section, New York State Department of Transportation, Dec. 72, p. 41.

3. This approach was attempted by Brown, Mode Choice Determinants of Selected Socio-Economic Groups, pp. 166-223, and Hartgen, Forecasting Transit Usage, 1972, as well as many other authors.

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APPENDIX A

EXAMPLE OF BUS USERS' QUESTIONNAIRE

Transit Authority X is conducting a survey on the travelling habits of the residents of this area. Would you please fill in this questionnaire and mail it in the attached envelope. Your cooperation may provide us with the information necessary to improve the transportation system serving this city.

1. Where did you start this trip?
   Address: ______________________

2. Where is the intended destination of this trip?
   Address: ______________________

3. What is the purpose of this trip?
   (a) work ______
   (b) shopping ______
   (c) personal business ______
   (d) social, recreational ______
   (e) school or university ______
   (f) others (specify) ______

4. At which time did the trip start?
   time: ______ a.m. _____ p.m. _____

5. How long did you have to walk to the bus stop?
   ______________minutes

6. How long did you have to wait for the bus?
   ______________minutes

7. How frequent is the bus service at this time?
   every _________minutes

8. How long is this bus ride?
   ______________minutes

9. How would you describe this bus ride?
   (a) very comfortable ______
   (b) comfortable ______
   (c) somewhat comfortable ______
   (d) uncomfortable ______
   (e) very uncomfortable ______

10. Is transfer to another bus line necessary in this trip?
    Yes ______ no ______

    If the answer is yes, please continue, otherwise, go to question number 12.

11. (a) Do you have to walk to get to the next bus stop?
    Yes ______ no ______

    If yes, how long: ______ minutes

    (b) how long do you have to wait at this transfer point?
    __________ minutes

    (c) how frequent is this bus service?
    every ______ minutes

    (d) how long is this bus ride?
    __________ minutes

12. How long do you have to walk from the last bus stop to your destination?
    __________ minutes

13. Do you use a monthly bus pass?
    Yes ______ no ______

14. Could you have taken the car for this trip instead of the bus?
    yes ______ no ______

    If the answer is yes, please continue, otherwise, go to question number 17.

15. In choosing the bus instead of the car, please indicate how important each of the following characteristics of your trip:

    (a) Cost of travel:
    - very important ______
    - important ______
    - somewhat important ______
    - unimportant ______
    - very unimportant ______

    (b) Total travel time:
    - very important ______
    - important ______
    - somewhat impprtant ______
    - unimportant ______
    - very unimportant ______

(c) The length of time spent in walking, waiting and transfer:
- very important _______
- important _______
- somewhat important _______
- unimportant _______
- very unimportant _______

(d) Frequency of the bus service:
- very important _______
- important _______
- somewhat important _______
- unimportant _______
- very unimportant _______

(e) Comfort level of the trip:
- very important _______
- important _______
- somewhat important _______
- unimportant _______
- very unimportant _______

16. Suppose now that you took the car instead of the bus, please tell us, to the best of your knowledge, about your trip:

(a) would you have to pay parking charges or road tolls?
If yes, how much: ______ dollars
(b) how long the car trip would be:
__________ minutes
(c) would you have to walk to or from the parking place?
If yes, how long: __________ minutes
(d) How would you describe the car ride in this case:
(i) very comfortable _______
(ii) comfortable _______
(iii) somewhat comfortable _______
(iv) uncomfortable _______
(v) very uncomfortable _______

In order to have complete information on you as a bus rider, please answer the following questions:

17. Your sex: male _____ female _____

18. Your age:
(a) 16 - 25 _____ (d) 46 - 55 _____
(b) 26 - 35 _____ (e) 56 - 65 _____
(c) 36 - 45 _____ (f) over 65 _____

19. Which of the following categories would describe your occupation best?

(a) clerical, secretarial ______
(b) sales personnel ______
(c) managerial ______
(d) professional ______
(e) labour, trade ______
(f) self-employed ______
(e) student ______
(g) housewife ______
(h) others, (specify) ____________

20. Please indicate the annual income of your household:

(a) less than $6000 ______
(b) $ 6000 to $ 8000 ______
(c) $ 8000 to $10000 ______
(d) $10000 to $12000 ______
(e) $12000 to $14000 ______
(f) $14000 to $16000 ______
(g) over $16000 ______

21. Can you work overtime if you wish?
Yes ______ no ______

22. How many persons are in your household?
__________ persons

23. Now, we would like to know about your way of life and how you generally spend your time, since we think that this may have an effect on your travel habits. Please give us an estimate for the number of <u>weekly</u> hours you spent in the following activities?

(a) at work ______
(b) at home, with family or relatives ______
(c) practising your favorite hobby, pursuing cultural interests, associating with friends _____
(d) sports and outdoor recreation ______

APPENDIX B

CAR USERS QUESTIONNAIRE

The design of this questionnaire can be made similar to that of the bus users' questionnaire, except for the questions concerning the attributes of the transportation system. In this appendix only these questions are mentioned.

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5. How long is this car ride?
   __________ minutes

6. Do you have to walk to or from the parking space?
   If yes, how long: __________ minutes

7. Do you pay parking charges or road tolls?
   If yes, how much: __________ dollars

8. How would you describe your car ride?
   (a) very comfortable ______
   (b) comfortable ______
   (c) somewhat comfortable ______
   (d) uncomfortable ______
   (e) very uncomfortable ______

9. Did you choose the car because:
   (a) you are sharing a car pool, or have to take someone else along, ______
   (b) you needed the package space to carry tools, shopping bags, etc. ______
   (c) you needed the car at the end of the trip to make other trips, ______
   (d) you would be embarrassed to be seen riding the bus, ______
   (e) there is no acceptable bus service to get you to your destination in time. ______

   If the answer to any of the questions a, b, c, d, or e is yes, please go to question 12, otherwise continue.

10. Suppose now that you have taken the bus instead of the car, please estimate, to the best of your knowledge, the following:

(a) how long would you have to walk to the bus stop:
__________ minutes

(b) how long do you have to wait for the bus stop:
__________ minutes

(c) how frequent is the bus service at this time of the day? every __________ minutes

(d) how long would the bus ride be?
__________ minutes

(e) how would you describe this ride?

(i) very comfortable ______
(ii) comfortable ______
(iii) somewhat comfortable ______
(iv) uncomfortable ______
(v) very uncomfortable ______

(f) would a transfer to another bus line be necessary to get to your destination? If yes, please continue, otherwise go to question k below.

(g) would you have to walk to another bus stop for this transfer? If yes, how long _______ minutes

(h) how long would you have to wait for the bus at this stop: __________ minutes

(i) how frequent is the bus service for this line at this time of the day: every _______ minutes

(k) how long would you have to walk to your final destination after you leave the bus:
__________ minutes

11. In choosing the car instead of the bus, please indicate how important each of the following characteristics of your trip:

(a) Cost of travel:
- very important ______
- important ______
- somewhat important ______
- unimportant ______
- very unimportant ______

(b) Total Travel time:
- very important ______
- important ______
- somewhat important ______
- unimportant ______
- very unimportant ______

(c) The length of time spent in walking, or waiting (if applicable):
- very important ______
- important ______
- somewhat important ______
- unimportant ______
- very unimportant ______

(d) Frequency of the bus service (if you consider taking the bus):
- very important ______
- important ______
- somewhat important ______
- unimportant ______
- very unimportant ______

(e) Comfort level of the trip:
- very important ______
- important ______
- somewhat important ______
- unimportant ______
- very unimportant ______

12. ____________