DESIGN OF PROCEDURES TO EVALUATE TRAVELER RESPONSES TO CHANGES IN TRANSPORTATION SYSTEM SUPPLY

Conference Summary and White Papers

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U.S. DEPARTMENT OF TRANSPORTATION
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CONFERENCE SUMMARY

and

WHITE PAPERS

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Conference summary prepared by Dr. Bruce D. Spear.

Design of Procedures to Evaluate Traveler Responses to Changes in Transportation System Supply

Conference Summary

Introduction

It has been recognized for some time by experts in the field of transportation planning that existing techniques of forecasting travel demand are ineffective for evaluating many of the options available to transportation planners. Moreover, there is an urgent need to better understand travel demand behavior in order to develop transportation policies which will achieve desired planning objectives.

As a means of establishing research directions, the U.S. Department of Transportation sponsored the 1972 conference on Urban Travel Demand Forecasting, conducted by the Highway Research Board in Williamsburg, Virginia. Among the recommendations of this conference were:

> Careful monitoring of travel patterns before and after changes in the transportation system can provide major insights into travel behavior and can be very useful in improving travel forecasting methods. In addition, appropriate arrangements should be made for rapid-response funding of well-designed data collection efforts in circumstances where events such as strikes, facility closure due to repairs, or major changes in price provide unique opportunities to observe changes in travel patterns and to gain increased understanding of travel behavior. 1/

In response to these recommendations, the Federal Highway Administration, Urban Planning Division, sponsored a study entitled "Design of Procedures to Evaluate Traveler Response to Changes in Transportation System Supply." The purpose of this study was to establish "an advisory/steering committee in order to obtain suggestions and ideas as to the theoretical bases and designs of data collection efforts for fast response surveys relating to the effects of changes in the supply of transportation service on travel demand." The ultimate objective

1/ Brand, Daniel, and Manheim, Marvin (ed.), Urban Travel Demand Forecasting, conference proceedings, Highway Research Board Special Report 143, page 6.

of this research was to be the development of procedural manuals for data collection which could be used to obtain relevant information on traveler reactions to changes in transportation service.

The conference summarized in this report was designed to provide a forum for the presentation and discussion of ideas relating to appropriate study frameworks and methodologies for these fast response data collection efforts. A list of conference participants is presented below:

Moshe Ben-Akiva
Cambridge Systematics, Inc.,
Cambridge, Massachusetts

Thomas B. Deen, Alan M.
Voorhees & Associates, Inc.,
Mclean, Virginia

Ricardo Dobson, Office of
Highway Planning, Federal
Highway Administration

David S. Gendell, Office of
Highway Planning, Federal
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Marvin Manheim,
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James J. McDonnell, Office
of Highway Planning, Federal
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Richard H. Pratt,
R. H. Pratt Associates, Inc.,
Kensington, Maryland

Louise E. Skinner, Office
of Highway Planning, Federal
Highway Administration

Bruce D. Spear, Office of
Highway Planning, Federal
Highway Administration

Edward Weiner, Office of
Transportation Planning
Analysis, U.S. Department
of Transportation

Prior to this conference several participants were asked to submit "white paper" reports discussing both the theoretical bases for behavioral travel demand studies and definitive methodologies for performing such studies in response to changes in the transportation system. A brief summary of each white paper is presented below.

SUMMARIES OF WHITE PAPERS

Moshe Ben-Akiva with William A. Jessiman, Marvin L. Manheim, and John P. Attanucci

Research in travel behavior needs to be directed at improving the reliability of travel predictions through a better understanding of travel behavior and through the empirical validation of travel demand models. Consequently, surveys of traveler response to changes in transportation system supply should always be carried out in conjunction with an initial behavioral hypothesis, and should be used to verify or update that hypothesis. Data collection efforts should be specifically designed for the models that will be used to insure consistency of data with model requirements and help minimize data collection costs.

Traveler decisions vary in terms of response time to equilibrium and therefore require different behavioral models with different data collection techniques. While short-term travel decisions can be satifactorily modeled with cross-sectional data, long-range mobility decisions require dynamic equilibrium models based on time series data.

When the data collected are intended for model estimation, the sampling frame should be population-based rather than choice-oriented in order to obtain information on alternative choices. If an estimated model already exists and the collected data are to be used to validate the model predictions, then less expensive survey procedures, such as screenline counts or on-board surveys may be used.

Given limited resources available for data collection, studies of large-scale, areawide permanent system changes should be given priority.

A centralized monitoring and updating effort should be instituted by FHWA to assist in the design of new data collection efforts and to analyze the resulting data. This program should also establish several continuing monitoring projects to collect time series data on a number of supply changes.

Thomas B. Deen:

The impact of significant changes in transportation system supply can affect virtually all activities in an urban environment. It is therefore essential that impact measurements be developed on a modular basis so that an analyst can focus on selected impacts.

Most transportation system supply changes can be grouped into one of three categories.

1. Permanent - fixed facility changes
2. Permanent - operational changes
3. Temporary changes

The analysis approach must begin with a hypothsis on the effect of a change, followed by data collection which will allow comparisons between the estimated and observed changes.

Temporary changes may not be worth studying because we have no hypotheses concerning the behavioral impacts of this category of changes. Thus, it is unlikely that transferable information will be obtained. Furthermore, the impacts of temporary changes may be unrelated to impacts of permanent changes.

It is probably not worthwhile to study supply changes whose impacts on travel behavior are likely to be less than our error in measurement. This suggests that only major supply changes should be evaluated. Attitude studies may be useful in testing behavioral hypotheses. These studies should be combined with studies of observed traveler behavior and measurements of system performance to fully develop quantitative relationships between system change and traveler behavior.

Given our present lack of knowledge about the appropriate data to collect, it is recommended that the procedural manuals be developed initially in a tentative form, and that the FHWA conduct pilot studies with the manual in order to gain insights into the relative effectiveness of various types of data and analysis procedures.

Ricardo Dobson:

There is a need for improved methods of planning for short-range, low capital transportation options. This requires the development of better models to assess traveler response to changes in the transportation system and appropriate data collection procedures to provide inputs for those models.

Because different transportation options may require different approaches to data collection, there is a need to develop an understanding of the variables through which different classes of transportation changes influence behavior. It is therefore recommended that a standard typology of transportation changes be developed.

The transportation options under study should set guidelines for any data collection activities. There is no need for large scale population based surveys to be used in studying changes which affect only one segment of the travel market. Before-after surveys seem to be an attractive means of studying user response to short-term planned system changes, particularly when control group strategies are employed.

Data collection activities should concentrate on three types of information: (1) overt travel behavior, (2) traveler preferences for attributes of transportation service, and (3) knowledge of transport alternatives. Behavioral data should be compatible with traditional O-D surveys, but should probe more deeply into the reasons why particular choice decisions are made. More work is needed in the assessment of traveler attitudes and establishing valid linkages between attitudes, perception, and overt behavior. Methodologies derived from psychology, sociology, and marketing analysis should prove useful in this regard.

Richard H. Pratt:

The principal reason for studying the impacts of transportation system changes on traveler behavior is to increase our useful knowledge of that behavior for practical application in planning and system design.

There are three classes of survey which can be used to obtain useful information about travel behavior.

1. Low budget surveys to collect aggregate statistical data for application in simple models and rules of thumb.
2. Specialized studies in controlled situations to collect information on specific traveler response interrelationships.
3. Large scale population based surveys, to collect data on a number of transportation attributes and traveler responses.

Certain standardized data should be collected in all travel behavior studies. These data should provide sufficient background information on the circumstances surrounding the survey activity. The survey questions should not restrict subsequent use of the data to a specific modeling approach or theory of travel behavior. In general, origin-destination trip data should always be collected to permit subsequent evaluation of system attributes using exogenous calculations of trip characteristics. While perceptual data may be useful in pure research, it does not lend itself to the construction of forecasting models and therefore should never be collected without also objectively measuring system data.

Areas in need of study which have been largely overlooked include the travel choice of time of day and analysis of the walk trip as a viable travel choice decision. Efforts should also be made to expand our knowledge about the relative weights placed on utility measure components by the traveler.

There are also some nonchange situations which may contribute to our understanding of travel behavior. These should not be overlooked in our desire to study transportation system changes.

<u>Louise Skinner:</u>

There is a distinction between short-term or temporary supply changes and long-term or permanent changes. Short-term changes will have an influence on easily alterable travel patterns but will not affect longrun decisions like residential location or employment. Long-term changes may affect <u>all</u> travel decisions, in both short- and longrun contexts.

The study design, including type of data collected, the survey instruments, sampling frame, and analysis techniques are all dependent on the type of transportation supply changes being examined.

One part of the study design which might be standardized would be the socioeconomic information collected from individual travelers.

Discussion of Issues

A list of seventeen issues (see figure 1) was presented at the conference for discussion by the participants. The issues presented were based on points brought out in the white papers where it was felt that there was significant disagreement among the authors or where further elaboration seemed appropriate. Due to the time constraints of the conference, it was suggested that the issues be discussed on a priority basis. The list was stratified into two groups, the first group of issues addressing the question of what should be studied, and the second group addressing the problems of methodology. There was unanimous agreement that the first group of issues should receive higher priority in order to establish a basic study framework. Methodological questions could then more appropriately be addressed within this framework.

A general study framework was proposed by Marvin Manheim of Cambridge Systematics, Inc., (see figure 2). Substantive issues of group one are included in boxes 1 and 2 of the study framework, while group two issues are found in box 3. A summary of the discussion and tentative conclusions reached about group one issues is presented below.

Figure 1

Issues for Discussion of Conference

Group 1: Study Framework

1. What aspects of travel behavior do we know least about?
2. What transportation attributes do we know least about?
3. What policy effects do we know least about?
4. What changes significantly affect system performance?
5. Should both short- and long-term changes be studied?
6. Should temporary changes be studied?
7. Should we study either perceived or measured attributes or both?
8. Should attitudes be studied?

Group 2: Study Methodology

9. Should control groups be used in before-after studies?
10. Can household panels be used?
11. What are appropriate sample sizes?
12. What sampling frames should be used?
13. How do we measure system performance?
14. What are appropriate questionnaire designs?
15. What are appropriate survey techniques?
16. Can we study long-term effects by examining the behavior of dwelling units which change occupancy over the course of the survey?
17. How can we achieve good quality control?

FIGURE 2

Study Framework

1. Identify the nature of the change

2. Definition of study

Define a priori hypotheses to be tested

a. Attributes that are likely to change

b. Market segments likely to be affected

c. Probable magnitudes of behavioral changes

1. by time of day

2. by hierarachy of choice

3. Methodology

Examine alternative study designs

a. Appropriate sampling frames

b. Questions and data items

c. Methods

d. Sequential design (type, time frame, change)

e. Organizational issues - who's running it

f. Core hypothesis to be tested

g. Additional hypotheses to be checked

4. Resource Requirements

5. Explicit Institutional Controls

6. Relative Priorities (desirability)

Summary of Issues on Study Directions

Theoretical Issues

1. What aspects of travel behavior should be studied?

   It was generally agreed that equal priority should be given to the investigation of aspects which can easily be measured and about which policy manipulations can be directly related, and those aspects which we know relatively little about, but which have major impacts on overall transportation policy. Specific attributes of interest include:

   a. Trip Frequency - the magnitude of transportation policy effects are unknown. However, trip frequency is a major factor in energy conservation and air pollution.

   b. Destination Choice and the relative value of alternative destinations - this aspect is not well understood, but is a very important attribute of the nonwork trip. Closely associated with this aspect is the phenomenon of trip chaining and its causes.

   c. Mode Split - has the strongest theoretical background of all aspects of travel behavior and seems to be most sensitive to changes in transportation system policy. More effort should be directed to those segments of mode split which have had relatively little study, such as auto occupancy and walk trips.

2. What attributes of transportation should be studied?

   a. Traveltime and cost should continue to be investigated with an increased emphasis on identification of constituent parts which are perceived differently by the traveler.

b. More effort should be devoted to defining and quantifying important qualitiative attributes, particularly reliability, accessibility, comfort and convenience.

- What policy changes should be studied?

    There was not general agreement on this issue. While it was felt that the original intent of the project seemed to indicate that policy changes which affect a limited number of attributes and whose effects are easily identified should be studied, several participants felt that major changes would produce the most visible impacts on travel behavior within an area. The discussion of this issue was closely related to the next issue.

- Should changes which have a relatively minor impact on areawide reaction to system performance be studied?

    It was argued that if one could identify and isolate those segments of the travel market which were most affected by the change, we might be able to significantly increase our understanding of travel behavior by surveying within the group. However, it was strongly emphasized that it would be difficult to expand the results from this type of study to predict the aggregate effects on an entire population.

- Should temporary changes be studied?

    Changes which are perceived by the traveler as temporary might be useful in the investigation of certain special types of behavior, most notably second choice alternatives in mode or route choice, and foregone trip or destination choices. In a general study framework however, investigation of changes in this time frame may lead to results which are not transferable to permanent change situations.

6. Should both short- and long-term changes be studied?

    Long-term changes suffer from confounding effects caused by external influences not directly related to transportation system changes. To overcome these problems, more elaborate dynamic equilibrium models requiring time series data are necessary. Within the context of the original scope of the project, it seems reasonable to restrict the study to short-term effects which can best be studied using simpler before-after study designs.

7. Should either perceived or measured attributes or both be studied?

    Both perceptual and objectively measured data are necessary in order to fully understand travel behavior. We do not presently know the linkages between measured system attributes and how they are perceived by the traveler. Work should be directed to an investigation of this linkage. To aid study in this area, both perceived and measured data should be collected whenever possible.

8. Should attitudes be studied?

    Attitude studies appear to be a promising way to identify and possibly quantify qualitative attributes of transportation. However, attitude studies should always be used in conjunction with behavioral data to identify linkages between attitudes of travelers and their ultimate travel behavior.

<u>Methodological Issues</u>

Although a substantial amount of informal discussion was devoted to the questions of survey methodology, very little in the way of consensus recommendations could be agreed upon by the participants. It was generally concluded that methodological issues could be resolved more appropriately through empirical tests once the overall study framework was made more definitive. It was further agreed that survey design criteria were largely dependent on what changes were being studied and what information was desired. Thus, it would be infeasible to attempt to develop a standardized survey methodology for use in all survey applications.

<u>Final Statements by Participants</u>:

At the close of the conference, participants were invited to present final recommendations on the directions in which this project should be heading. These recommendations are given below:

1. Studies should be directed towards short-term changes which can be measured relatively easily.
2. Efforts should be made to take the maximum advantage of opportunities which present themselves, rather than trying to create opportunities through new demonstration projects.
3. A procedural manual may not be appropiate at this time. It would probably generate more data than we can presently handle, and standardization efforts may result in worthless data.
4. A more reasonable alternative would be the drafting of a "working" procedural manual, subject to updating and revisions which would set guidelines for data collection.
5. The Federal Highway Administration should supervise a number of pilot data collection efforts to determine the feasibility of such studies and problems that are likely to emerge. These studies would provide the framework for the first draft of the working manual.

6. Projects (selected for the pilot studies) should meet the following criteria:

    a. There should be limited prior knowledge of the change by travelers in order to minimize the probability of premature traveler reaction.

    b. The change should have a rapid impact to minimize long-term confounding effects.

    c. The change should be permanent or at least perceived that way by the traveler.

    d. In order to isolate the influence of the change under study, no other major changes should be occurring simultaneously in the study area. If it is impossible to avoid having extraneous, concurrent changes in an area, control groups may have to be established in order to identify the effects of the travel system change being studied.

    e. The market segments which are likely to be impacted by the change must be identified.

    f. The market segments should not be biased in a manner which cannot be easily identified and measured.

    g. The change should be limited with respect to its impact on both the number of system attributes and the number of travel decisions.

    h. The analytical models should investigate those areas where we need to increase our knowledge the most.

    i. The policy changes must be linked to measurable attribute changes.

    j. The method of measuring attribute changes must be sensitive at the <u>level</u> of change expected to occur.

New Project Directions

Based on the discussion and recommendations of the conference participants, it was decided to redirect the project away from the immediate development of a procedural manual for data collection. Instead it was decided to begin a program of monitoring projects involving changes in transportation system supply with the intention of selecting a limited number of them for data collection surveys. The project categories which were considered suitable for study include, but are not limited to:

1. A major contract sponsored by the Federal Highway Administration to study the influence of low capital transportation operating policies on travel behavior.
2. Major demonstration projects involving changes in transportation systems and sponsored by administrations within the U.S. Department of Transportation.
3. Minor transportation system changes which the Federal Highway Administration becomes aware of through monitoring efforts and which meet the necessary project criteria.

These studies would provide an initial input for evaluating the feasibility of a data collection manual, while simultaneously supplying useful data for studying traveler responses to specific changes in transportation system supply.

MEASUREMENT OF TRAVELLER RESPONSE TO CHANGES IN TRANSPORTATION SYSTEM SUPPLY

By

Moshe Ben-Akiva with William A. Jessiman, Marvin L. Manheim and John P. Attanucci

Cambridge Systematics, Inc.

"White Paper" prepared for U.S. Department of Transportation
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1. Introduction

How will travel demand respond to new system alternatives or changes in the transport level of service (supply)? At the present time prediction of travel behavior involves significant uncertainties. Research in travel behavior needs to be directed at improving the reliability of travel predictions in terms of understanding and modelling of travel behavior and in terms of the empirical validation of behavioral theories. Unlike laboratory experiments in chemistry (for example), one cannot readily modify the transport system characteristics (the supply side) to observe the resulting demand behavior -- the transport system is far too large and complex for controlled experiments to be undertaken. A few large-scale transportation experiments have been run, such as the 1964 Mass Transportation Commission demonstration projects in the Boston area, but they all suffer from inability to isolate the effect from a specific level of service variable. In addition, they tend to yield aggregate summary statistics rather than individual behavioral responses.

One avenue which has received considerable attention during the last decade is the attitude survey -- querying respondents on what their travel response would be <u>if</u> this system change were made or that service level were offered or fares were to change. While this circumvents the expense problem of actual experiments and sheds <u>some</u> light on travel behavior, it is logically limited in its conclusiveness: There is often a discrepancy between what an individual reports he will do and what he actually does. Combining this discrepancy with the obviously greater uncertainties inherent in accurately defining a hypothetical set of attributes for the individual to respond to, one can appreciate the limits of attitude surveys even though the state of the art of attitude surveying in transportation is improving.

However, ongoing planned and unplanned transportation supply changes provide us with an opportunity to observe responses to a number of changes in level of service variables, from which we can gain valuable information on travel demand behavior. The fuel crisis with drastic price increases and shortages; several unique public transportation operating concepts like dial-a-ride, jitney, subscription bus service, charter bus service and priority bus lanes and busways; car pooling programs; a variety of transit fare discount plans; several major facility openings, such as a new rapid transit line, and closures, such as the Mystic River Bridge collapse in Boston; and transit strikes, such as the one recently threatened in New York, all provide opportunities to observe changes in travel behavior. Unfortunately, although some superficial or summary data is being assembled in these situations, little is being done to collect true behavioral information from this wealth of supply changes. This is in part due to the expense of the data collection involved, but it is also due in part to uncertainty as to what data to collect and how to collect it.

A certain amount of travel demand behavior can be inferred from cross-sectional data as well, classically a home interview survey on which a demand model can be calibrated. However, behavioral information derived from such a source is seldom as conclusive as that derived from before-and-after observations of travel behavior, at least with respect to the particular transport supply characteristic(s) which is (are) changing. From the latter, one can more conclusively validate cause and effect relationships. This leads to an important consideration in monitoring the effects of changes in transport supply -- one must carefully identify which factors are changing and which factors remain unchanged to correctly determine causal relationships.

Purpose

The purpose of the overall study to which this paper contributes is to help FHWA develop guidelines for data collection procedures and manuals for use in the field for before-and-after and continuous monitoring of the effects of transport supply changes such as facility openings and closures, major price or service changes, new operating concepts, strikes, etc. This paper attempts to develop some thoughts and suggestions on that topic. Specifically, the paper:

(1) derives the theoretical bases for behavioral travel demand responses to supply changes,

(2) categorizes types of supply changes in terms of factors changing, response time, and types of travel behavior changes to monitor,

(3) discusses what data it is desirable to collect to measure travel behavior responses to each of these types of supply changes,

(4) discusses how to most efficiently go about collecting this data, e.g., types of surveys or data collection techniques, sample size, selection of samples, time period over which data is collected, continuing but less extensive data collection efforts thereafter to determine changing behavior patterns, etc.,

(5) discusses any particular problems to beware of in assembling the desired information,

(6) tailors the entire spectrum of possible information collection into an overall program which would permit the assignment of priorities and limitations in the face of scarce monitoring resources.

2. Travel and Mobility Behavior Theory

The purpose of this section is to outline a theoretical framework for analyzing consumer response to transportation system supply changes.[1] Con-

[1] The discussion of travel behavior in this section is based on Ben-Akiva (1973). Note that a theory of consumer response is only a part of a prediction framework; it also includes supply and equilibrium theories. For a discussion of this larger prediction framework, see Manheim (1974).

sumers' market behavior is described by a demand function. A consumer acts in many different markets. We are interested here only in markets that are affected by transportation system supply characteristics, namely the transportation and activity[2] markets. In the transportation market, the consumer's behavior is measured in terms of his consumption of transportation services, or his travel pattern, which on the aggregate level can be expressed in terms of volumes of trips. The actions of the consumer in the activity markets are primarily his locational decisions and other mobility-related characteristics, such as auto ownership.

Travel and Mobility Choices

From the point of view of an individual tripmaker, a trip decision for a specific non-work trip purpose can be described as consisting of the following set of travel choices: choice of trip frequency (i.e., the decision to make the trip or not), choice of destination, choice of time of day, choice of mode, and choice of route. The actions of an individual consumer in the activity markets can be described to include the following set of mobility choices: choice of residence location, choice of housing type, choice of auto ownership level, choice of employment locations, and usual choice of mode to work.

All these choices will be affected by a transportation system supply change. Thus, on the individual consumer level, the demand models of interest should explain consumers' travel and mobility choices.

It is impossible to evaluate how changes will affect each choice without considerations of the complex interactions among the various mobility and travel choices. The travel choices of an individual tripmaker are interdependent, e.g., the choice of a mode depends on the choice of a destination, and the choice of the destination may also be dependent on the choice of a mode. Similarly, the

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[2] An activity system is defined as a non-transport system which affects travel behavior, e.g., population and employment location distirubtions, socio-economic characteristics, etc.

mobility choices are interdependent, e.g., the choice of residence location influences the choice of auto ownership level, and the choice of auto ownership level may also condition the choice of residence location. In addition, the two sets of choices, mobility and travel, are also dependent on each other, e.g., the choice of auto ownership level may influence non-work travel pattern and vice versa.

The consumer typically makes his mobility decisions in a longer time frame than that of his travel decisions. Therefore, in the demand model that predicts the travel choices, the mobility decisions could be assumed to be predetermined. Mobility choices are essentially long-term decisions that are made relatively infrequently but play a vital role in determining overall tripmaking patterns.

Choice Theory

The basic theory addresses the problem of consumer behavior from a choice theory perspective. The analytic details of this methodology are considered in greater detail elsewhere and will not be repeated here.[3] It is sufficient to state here that choice theory is concerned with the behavior of an individual decision-maker confronted with a set of available alternatives from which one and only one must be chosen: The decision-maker is assumed to evaluate each option in terms of its net merits or utility, and select the option from which he derives the greatest utility. However, because there is always some uncertainty in the measurement of this utility function and some variability in behavior even given identical situations, it is impossible to state with certainty which alternative the decision-maker will select; only the probability of selecting a given alternative can be determined. By observing the actual choices, or revealed preferences, of the decision-makers, estimates of the parameters of the utility function can be obtained. The utility function of a given alternative

[3] See for example Charles River Associates (1972), Ben-Akiva (1973), and Cambridge Systematics (1974).

is thus some appropriately weighted combination of values for all the factors which influence travel decisions. Its dimensions are the set of attributes that describe the travel alternative and the socio-economic variables describing the consumer.

Models for Policy Analysis

Implicit in the empirical estimation of the utility function parameters is the hypothesis that the underlying preferences which the utility function represents are reasonably stable over the time period of interest, e.g., that the consumer will not change his value of time. This hypothesis of stable behavior over time is at the heart of any demand analysis. Without it, reliable estimates of a model's parameters can still be obtained, but any attempt to draw inferences about the impacts of alternative policies in the future are meaningless even if all the relevant policy variables are included in the model. In fact, the need for stability of a model is one of the foremost reasons for approaching any analysis from a causal or behavioral perspective. Many existing demand models have relied on correlations between observed variables rather than on a consideration of underlying behavior. It is far more likely that these correlations will change rather than the underlying behavioral decision mechanism. Thus, a model which is firmly rooted in a behavioral theory will be more likely to provide reliable estimates of how various policies will affect mobility and travel choices than a more naive, correlative model. This is particularly true for policies which will make radical changes in the transportation system supply because such changes will in all probability alter the statistical correlations upon which non-causal models are based.

The Behavioral Unit

Clearly, analyses relying on zonal, tract or even nation level aggregations are inappropriate in a behavioral analysis. Travel demand modellers have begun to recognize that "zones do not commute - people commute". However, a more subtle issue is whether the basic behavioral unit for these decisions is the individual or the household.

In many cases, individuals within a household have complete independence with respect to some mobility and travel decisions. However, if the household is narrowly defined as one or more individuals sharing a residence and making joint economic decisions, an individual's decision impacts on the remaining household members. Aside from the obvious possibility of the remaining members being involved in the same decision, the household has also allocated its income to various activities and allocated various activities among members of the household. Thus, it seems appropriate to consider the household as the basic behavioral unit. (This, however, does not preclude the possibility of considering an individual as the behavioral unit for a certain choice that is clearly made independently or with limited interactions with other household decisions.)

A Hierarchy of Choice and Dynamic Behavior

Given that the household is the relevant behavioral unit, the next question to consider is the interactions among the various mobility and travel choices.

As previously hypothesized, there is, apparently, a hierarchy to the mobility and travel choices. For example, the choice of mode for any particular trip is certainly a lower-level decision than the choice of residence location. A higher-level choice seems to condition lower-level ones. That is, once the choice of residence location is firmly made, the choice of mode on a particular trip may be limited.

The hierarchy is essentially a result of the different time frames in which the various choices are made. In the long term we can assume that the consumer has the possibility of changing all his mobility and travel decisions. In the short term we can reasonably assume that the mobility decisions are fixed and only travel choices can vary. However, at any point in time a consumer has different levels of commitment to the different choices previously made. Therefore, given a change in policy, it will take each choice a different time period to respond to or reach its new equilibrium. For example, in response to a change in the transportation level of service, it can be assumed that in the short run only the mode of travel and route can be changed for a work trip. In the medium run, auto ownership level may be altered. In the long run, job and residence locations may also change.

The hierarchy suggested is that the mobility choices are on a higher level than the travel choices. In addition, among the mobility choices, one can suggest that mode to work and auto ownership decisions are on the lowest level, housing type and residence location the next, and employment location finally the highest. Clearly, different hierarchies could be appropriate for different types of consumers, but the one posited here is perhaps the most common and the most logical.

It should be noted that the work trip's place in this hierarchy is different from that of trips for other purposes. The mobility choices determine all the travel choices for the work trip except for possible short-term adjustments of mode, route and perhaps also time of day for employees without fixed working hours. The trip from home to work and return is the most important trip made by the household, and generally has a greater influence on mobility decisions than other trip purposes. Indeed a household's evaluation of a work-place is not independent of the residential location or the usual mode to work decision. Thus, although the choice of mode to work may be a lower-level choice than the choice of, say, residential location, it is a higher-level choice with respect to travel choices for other trip purposes. The choices with respect to trips for non-work purposes, with the possible exclusion of school trips, seem to have a shorter response time than the mobility and the work trip choices.

It is also possible to argue for a hierarchy of choices within the travel choices for non-work trips. For example, one can more rapidly change the choice of mode of travel for a trip to the bank than the choice of destination, which will require a switch of a bank account from one bank to another. However, for most non-work trip purposes it is less clear what a logical hierarchy of the travel choices should be. It has been argued, for example that for short range low capital options only changes in mode and route choice need to be analyzed (HRB, 1973). Evidence from the recent energy crisis suggests that the motorists' short run response to the gasoline shortage was indeed some mode switching, primarily for work trips, but the major change was a reduction in the frequency of non-work trips made by automobile (NORC, 1974), and the chaining of several non-work trips into one combined, multi-purpose trip.

Response lags, or threshold level changes, complicate the modelling of demand response to supply changes, but are typical of human behavior. Response lags may be different for different consumers, and different consumers may exhibit different behavioral patterns. For example, for a young, white collar household the residence location and auto ownership decisions can be assumed to follow the job decision. However, for a blue collar worker, married with children, the residential location decision may precede the job decision.

Note, however, that in this dynamic scenario, it is realistic that when a higher level, or longer response time, choice is made, a consumer may reconsider all his lower level choices and alter them at the same time accordingly. For example, a change in residence location may carry with it a change in all lower level decisions such as auto ownership, housing type, mode choice to work, and frequency, destination and mode choice of trip-making for all other purposes.

The above discussion indicates that following a change in the transportation system supply one will observe lower level choices being adjusted first and then over time changes in higher level choices with a possible simultaneous readjustment of lower level choices. The implication for measurements of impacts from changes in supply is that the elapsed time from the change to the measurement will determine the choices that have been fully adjusted and can thus be analyzed.

Modelling Implications

The modelling implication of the hierarchy of choices is that we should model the consumer behavior over time. Ideally, a dynamic model that "stimulates" or traces adjustments over time is desirable. Note that the model for any given choice should allow for adjustments of all lower level choices. The model that will describe the highest level choice will include all choices, similar to a conventional static long run model. However, the changes that are precipitated by changes in socio-economic characteristics, such as income, by changes in the spatial opportunities, or by changes in transportation level of service characteristics, take time and in general only gradually affect higher level choices.

For lower level choices, therefore, perhaps two types of models are required, one that describes the short run behavior and another that describes long run behavior when a lower level choice is precipitated by a simultaneous higher level choice change.

Clearly, a dynamic adjustment model would be very complex. Our present knowledge of mobility and travel behavior is not sufficiently advanced for the development of operational dynamic models. A prerequisite for any such model is knowledge of the response period for each choice, and for each group of consumers. Response time, in itself, is a most useful piece of information to be collected in improving knowledge of travel behavior and demand response to supply changes. However, as a practical matter independent of the issue of theoretical feasibility, the development of such dynamic models requires very detailed time series data which are not currently available, and would probably be very expensive to collect. Data must be obtained for each consumer either periodically at high frequency or at each point in time where some relevant change was made. In addition to the socio-economic characteristics of each consumer at each point in time, the data should include the spatial opportunity variables, and the transportation level of service variables that existed.

Traditionally, therefore, mobility and travel demand models have been developed using cross-sectional (or, longitudinal) data and a static equilibrium assumption, i.e., the coefficient estimates from such a model should be interpreted as indicating that sufficient time has elapsed to allow any response adjustments to have taken place. The reasonableness of this static equilibrium structure is discussed later in this paper, but logically the response time for certain major changes, e.g., residential location, are sufficiently long that the assumption of observable equilibrium is questionable.

Another modelling issue relates to the sequential structure traditionally assumed in modelling travel behavior. Recongizing the different time lags of the various responses to a change in policy or other relevant factors, one may conclude that there is a logical sequence to travel/mobility decision-making which is in order of decreasing response time. For example, for a choice of mode, it can be assumed that the automobile ownership level is given. For the choice of auto ownership level, the assumption is that residential location is given, and that the auto ownership decision is made independent of trip frequency, destination choice, and mode choice of trips.

How reasonable is this sequential assumption? The question is essentially whether the assumption of a hierarchy of choices based on dynamic considerations justifies a static sequential model in which a higher level choice is made <u>independently</u> of lower level choices, and lower level choices are made <u>conditional</u> upon the higher level choices. For example, we can consider destination choice to precede mode choice in a static sequential model if we assume that the choice of destination is made independently of the actual choice of mode, and the choice of mode is made with the destination assumed as predetermined. However, an assumption of such sequential choice behavior seems to be unrealistic. In the dynamic scenario it was argued that no higher level choice is made independently of other lower level choices. It is more realistic in a static model to assume, for example, that the choices of mode and destination are made together and the choice of one depends on the choice of the other. Therefore, the only totally reasonable assumption in a static model, at least idealistically, is that "trip-making decisions are made simultaneously rather than sequentially", as noted by Kraft and Wohl (1967). This argument applies to all the mobility and travel choices, and it implies a long run model in which all choices are allowed to change simultaneously and all choices are interdependent.

Certain practical compromises can be justified however. Given the true dynamic behavioral process and given that all we can observe is a cross-section of consumers at one point in time, what are the true behavioral models that can be estimated from the data, or what models provide the best approximation of the true processes? A static long run equilibrium never really exists because of the response time lags of the various choices. Changes may have occurred but the consumers may not have brought themselves to the point of adjusting all their choices because of the response lags. Moreover, different consumers at different locations, or with different socio-economic characteristics are responding to different changes and with different lags. Therefore, we not only observe an out-of-equilibrium situation, but we also observe different consumers at different "distances" from their respective equilibrium conditions. This means that from a cross-section we cannot estimate models for choices with long response times, but we can estimate models for choices that have instantaneous, or relatively short, response time. These models for choices with very short response time should assume higher level choices as given.

For choices with relatively longer response time we need to resort to the approximation of a long run static equilibrium assumption. This means that modelling a choice which is not at the bottom of the hierarchy requires a simultaneous structure in which lower level choices can vary and higher level choices are assumed as predetermined.

Thus, if we want to predict the effect of a policy change (using a static model) the time horizon of the prediction will determine what choices should be included in the model. Alternatively, if we want to explain the effects of a change, the period of measurement after the change took place will determine what model should be used to explain the observed change.

It is reasonable to assume, as already indicated, that travel choices for non-work trips have relatively shorter response times than the mobility choices (recalling that the work mode choice was part of the mobility choice). Therefore, these choices could be modelled assuming the mobility choices as fixed. Furthermore, since there is no apparent logical hierarchy for the travel choices, they should always be modelled simultaneously as a joint choice. The modelling of the mobility choices could be done independently of the travel choices for non-work trips based on the assumption that the mobility decisions depend on the overall pattern of these trips and not on specific choices. Thus, a reasonable static approach will be a block recursive structure in which the first block treats the mobility choices simultaneously, but independent of specific travel choices. The second block treats the travel choices for non-work trips simultaneously, conditional on the mobility choices.

The above discussion was based on the assumption that cross-sectional data is all that is available. Static theory restricts any policy conclusions to a discussion of final equilibrium rather than the way in which choices adjust towards that equilibrium. For long-term policies, it is unlikely that the above limitation is of major importance. For example, the transient or response-time effects of any new major transportation facility should be insignificant when compared to those changes occurring over the total life of a new section of roadway or a transit system. However, information with respect to response periods is extremely valuable for the analysis of various short-term policies. Furthermore, models based on time series data and dynamic behavior could considerably reduce the large uncertainty in the prediction from current static modelling approaches. A realistic model that allows for different adjustment behavior for different choices and consumers may be too complex. However, a less realistic model (but still more desirable than a static model) that appears to be feasible would be simply to predict the effect of the choices made at time period t on the choices made at time period t+1. For this model, data is required for a group of consumers for at least two different points in time. Surprisingly, even this type of a simplified dynamic model was never developed for mobility and travel choices.

3. Types of Supply Changes and Responses

Transportation System Supply Changes

Transportation system supply changes are many and varied, but can probably be categorized into several different groups which elicit different traveller responses which should be measured in several different ways. The categories and several examples of each type of supply change are as follows:

(1) Altering roadway capacity - Constructing a new highway, widening, signalization or intersection improvements to streets or roads; closing of urban core streets during certain hours and/or to certain vehicles; closing of certain highway facilities for repairs; changing status of streets to one or two-way; implementing exclusive bus or car pool lanes on previously unrestricted routes.

(2) Changes in parking capacity - Banning or restricting the hours of curb parking on city streets.

(3) Altering transportation pricing - Changing toll charges on certain roads or addition of a new toll; changing fares on a public transportation system; increases in the price of gasoline and other transportation fuels; changing parking charges in different sections of an urban area.

(4) Changes in transit service and operations - Adding new routes; increasing or decreasing the frequency of transit coverage; extending services over more hours of the day or cutting back the hours of service on some routes; introduction of new or improved equipment on transit lines; new marketing programs; introduction of special or innovative transit services (e.g., express or

semi-express runs, Dial-A-Bus, etc.)

(5) Natural disasters and accidents - Facility closures due to floods, landslides, earthquakes or other natural phenomenon; closures or disruptions in service due to fires, accidents or structural failures (e.g., the collapse of the Tobin Bridge in Boston after a truck accident).

(6) Strikes - Labor walk-offs among bridge and tunnel operators, transit workers, taxi operators or truckers which temporarily but drastically affect transportation supply.

(7) Reduced gasoline and energy availability - Spot shortages of gasoline and other fuel; reduced hours and restrictions on gasoline purchases; gasoline rationing and accompanying black market.

The first four categories of supply changes could be either temporary or permanent, but all are anticipated and planned for in advance. The remaining three are mainly largely unanticipated temporary changes after which the supply is returned to its original level. The permanent versus temporary distinction is important because travellers perceive the two types of changes very differently -- permanent changes are accompanied by a much greater search for information about the change, and travel habits are more likely to be reconsidered. Temporary changes are usually perceived as such and responses often minimize the amount of accommodation which must take place. For example, when the Tobin Bridge collapsed, a study of 95 commuters from Lynn, Massachusetts on the North Shore to Boston showed that less than 10% changed commuting modes to Boston, even though auto commuting times jumped significantly (Velazquez et. al., 1974). It is thus important in the collection of data before and after supply changes that these traveller perception differences (between permanent and temporary) are appropriately noted.

Examples of temporary changes in the first four categories would be closing of a highway lane due to maintenance work or a transit demonstration project which is scheduled for a specific time period.

A second important supply change distinction is between anticipated and unanticipated. The former allows for more extensive advance planning, both on the part of the supplying agency (e.g., the designation and signing of detour routes when a highway facility is closed for repairs) and on the part of the consumer (e.g., making arrangements for a second car when a transit facility is being closed for repairs or a transit strike is expected).

Supply changes could also be classified according to the scale of the change and the coverage of the change (i.e., change in a specific route versus a change in the entire network). More important from a consumer behavior point of view would be a classificiation of supply changes according to the travel and mobility choices that are likely to be affected.

Types of Traveller Response

Trip-makers can respond to changes in transportation system supply by altering their mobility and travel choices. The short run travel choices include choices of individual non-work trip destination, frequency, time of day, mode and route for different trip purposes. The mobility choices include the choice of residence and employment location, housing type, auto ownership level and usual (or long-term) mode of travel to work. For example, for the first category of supply changes (altering highway capacity) work trip-makers could choose to travel by a different mode or route and possibly at a different time of day in the short run, but they could change their residential location, job site or numbers of autos owned in the long-run if the capacity changes warranted a major shift in their commuting habits. For other (non-work) purposes, trip-makers could alter all of their travel choices in the short-run after a change in capacity occurred; however, a small change in the transit fare levels is unlikely even in the long-run to significantly affect mobility choices. Table 3.1 summarizes the types of responses expected from travellers for each category of supply change. If the supply change is permanent and very effective, these

Table 3.1

TRAVELLER RESPONSE TO DIFFERENT TYPES OF SUPPLY CHANGES

Supply Changes \ Choices	Employment Location	Residence Location and Housing Type	Automobile Ownership	Work Trips: Mode	Work Trips: Time of Day	Work Trips: Route	Non-Work Trips: Frequency	Non-Work Trips: Destination	Non-Work Trips: Mode	Non-Work Trips: Time of Day	Non-Work Trips: Route
Road Capacity	P	P	P	X	P	X	X	X	X	X	X
Parking Capacity	P	P	P	X	P		X	X	X	X	
Transportation Prices	P	P	P	X	P	X	X	X	X	P	X
Transit Service	P	P	P	X	P	X	X	X	X	P	X
Natural Disasters and Accidents				X	P	X	X	X	X	P	X
Strikes				X	P	X	X	X	X	X	X
Fuel Availability		P	P	X			X	X	X		

X = Possible traveller response

P = Possible traveller response only in certain situations supply changes could encourage changes in all the mobility and travel choices. If, on the other hand, the supply change is temporary, or perceived as such, only a few short run travel choices will probably be affected.

In order to make this table more useful, a finer classification of supply changes is needed. The categories used here are too broad, and therefore most of the table's usefulness is limited. For example, the table allows for an effect on all choices as a result of change in transport prices. However, it is clear that specific price changes such as an increase in gasoline price is unlikely to affect the motorists' choices of time of day. Moreover, any change in the supply of transport services will affect the different aspects of travel behavior over a variety of response times. For example, the recent fuel shortage problem and the associated rapidly rising prices affected travel behavior in many dimensions:

-- In the short term:

- changes in mode choice
- changes in non-work destination choice
- changes in the frequency of travel (by consolidating trips, by eliminating trips, or by substituting communication for transportation)

-- In the medium term:

- changes in automobile ownership, both in terms of type of car and number of cars owned

-- In the longer term:

- changes in residential locations
- changes in job locations
- relocation of business activities

Thus, since different response times apply for different choices, Table 3.1 should also be expanded to include a third dimension -- response time after the supply change. Very little is currently known about the dynamics of traveller response, and therefore observations at several points in time or continuous monitoring after the change are required in order to measure the short and long term traveller response to supply changes.

<u>Data Collection for the Different Supply Changes</u>

Data should be collected for the different types of transportation system supply changes by using two basic sample universes: a "population" or household sample versus a user-oriented sample. The key distinction here is that user-oriented sampling only permits information from those who did use a certain service, not those who did not for whatever reasons. From a travel behavior modelling point of view, a major criticism of data collection on new transit services such as Dial-A-Bus implimentations is that data is being collected for users only. This permits the assembling of a statistical profile on who <u>is</u> using the Dial-A-Bus service, but falls short of providing a data base on which a Dial-A-Bus demand model might be calibrated because there is no information on who <u>is</u> <u>not</u> using the system. Unless data for representatives of both groups are available, no behavioral mode choice model can be developed, only a poorly-founded correlative relationship, such as "10% of the population of the served area will make a trip on Dial-A-Bus in a given day" can be established.

Basically, the choice of the two methodologies depends primarily on the purpose for which data is being collected and the data collection budget available, but is also influenced by the scale of the change, and the number and type of people which it affects.

For example, if the desired question to be answered with respect to the opening of a new urban Interstate Highway link was "how many people are using this facility", a simple (user-oriented) traffic count would suffice. If the issues were the origin-destination pattern of facility users and the previous mode and route, a more complex but still user-oriented roadside survey or license plate trace might be employed. If the questions to be answered included not only the above but also more incisive questions on travel behavior generally such as frequency of trip-making, automobile ownership, mode of travel, which market segments changed behavior and which did not, behavioral reasons for changes, etc., a household sampling in the area of the facility would be in order. Obviously the household sampling is superior in terms of the breadth of uses to which it can be put, but it is also significantly more expensive.

Another example pointing out data collection economics-of-scale considerations is the introduction of an elderly discount-fare on a local bus system. It would only affect a specialized segment of the population, and data collection should be focused on users of the new service. In this case, an area sample would have to be very large in order to detect a measurable change unless some additional information were available to guide which households had potential beneficiaries of such a change. Of the seven types of supply changes, two (price changes and transit service changes) traditionally utilize user surveys. Parking policy changes could require either household or user-oriented data collection, depending on the scale and location of the area affected, while the remaining four categories of change seem to affect a large segment or all of an urban area population equally, and thus a household sample would seem to be more appropriate. Further discussion of data collection issues for the various types of supply changes will follow in sections 5 and 6.

Other Changes

This paper deals only with changes in the transportation system supply. It should be noted, however, that travellers' behavior is also determined by their socio-economic circumstances (income, for example), the available spatial opportunities for the various household activities, and by supply characteristics of housing, automobiles, etc. This implies that:

(a) while evaluating the effect of a change in the transportation system supply one should control for the effect of changes in these other variables that may occur simultaneously or over the time period being monitored, and

(b) a great deal about traveller behavior can also be learned from measurement of traveller responses to changes in these other factors.

4. "Before and After" Studies

The traditional "before and after" experimental design has many serious problems associated with its use in helping to explain travel behavior. These problems can generally be classified into several areas, all of which point to the fact that the idea of determining transportation effects by a type of "controlled experiment" is nearly impossible.[4]

Outside Influences

The before and after design has its origins in controlled laboratory experiments in which the outcome can be solely attributed to the treatment that was performed. A transportation change, on the other hand, is characterized by a lack of control over the experimental conditions, i.e., the difference between the after and the before observations cannot in general be considered as the isolated effect of the transportation change. Effects of other factors contemporaneous with the transportation change will mix together with the effects of the transportation change.

A method that has been used to separate the effects of the experimental treatment -- the transportation change -- from other influences is to perform the before and after measurements on two groups: one group that is subjected to the experiment but is presumably subjected to the same other influences as the first group. This modified design of a before and after study has been used in scientific experiments in fields such as agriculture and education.

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[4]A very detailed discussion of the applicability of before and after studies to transportation is given in Charles River Associates (1972).

The two groups should be identical and historically are usually selected randomly from the same population.

However, even this improved before and after design is not applicable to the study of a major transportation change because it is, in general, impossible to identify a population group which is somewhat identical and yet unaffected by the change.

Often a control group (or area) is used to measure the effects of exogenous influences on the observed values in a "before and after" study and thus isolation of the transportation change effects is presumed to be accomplished. However, a carefully chosen control group at the "before" date may be quite different from the affected group at the "after" date due to exogenous factors which are somewhat different in each group. In addition, a major transportation change in a metropolitan area may easily affect the control area travel and locational patterns even though the area is physically located many miles from the impacted area and presumed to be beyond the range of its effects.

An example which points out the problems in trying to isolate certain effects is an attempt to measure the effects of the gasoline price increase since October, 1973. Obviously no unaffected control group can be identified, and substantial effects from exogenous influences will be compounded with the price impact.

Spatial Limitations

Another area which is problem-laden in many transportation "before and after" studies is the usual spatial limitation of impacts. Responses are usually only analyzed in the immediate vicinity of the transportation supply change or for the most directly affected segment of the population. Area-wide (or, population-wide) changes due to a significant system change are not measured, and a thorough analysis is simply impossible because of all the exogenous factors which are involved and the budget which would be required. If a new road or improvement in road capacity is being studied, the change will definitely have an effect on parallel (or alternative) routes' volumes and travel times and may have an affect on the entire road network. Undoubtedly, a significant transportation change will affect travel behavior and location decisions not only in the directly proximate areas to the change but in a wide area surrounding and paralleling the change.

Temporal Problems

The largest set of problems which are manifested in "before and after" transportation studies are associated with the temporal aspects of a dynamic process such as the response to transportation system change. Changes in travel behavioral and location decisions take time, so that the time period between the before and after observations must be long enough to measure the full effect of the change. However, the longer the time period used, the more exogenous influences enter to contaiminate the measurement of the observed variables. An assumption must usually be made that either the full effect of the transportation change is being measured or just a trend of ongoing effects can be determined, neither of which seems satisfactory since the distribution of effects from such a change would surely be non-uniform.

Another temporal problem is that the choice of a "before" date may not precede the beginning of the response. This will happen if the response is in expectation of the transportation change. For example, one may choose to abandon a second car in poor condition rather than replace it if he is aware of a transit service to be implemented shortly. A before-after survey may miss this effect of the new transit service.

The trade-offs between trying to capture the effect on time-lagged long range decisions and temporary effects, which may not last very long, hamper the choice of an "after" study date. The dynamics of interactions between the transportation system and travel and locational decisions make it probable that the effects of a major change will never stop. The alternative of several time-staged "after" studies to capture different changes is an expensive one.

Attitude Surveys

A special case of "before and after" surveys which is currently being afforded much attention is the use of attitude surveys. Here an interviewee is asked "how would you respond if . . . (a specific change is made)" or "how would you compare this new alternative with these attributes to that existing alternative with those attributes." While the literature would convey that the state-of-the-art of attitude surveying techniques is improving and an attitude survey is clearly less expensive than an actual experiment, we do not believe it currently has much to offer with respect to improving our behavioral understanding of travel demand responses for the two obvious reasons:

(1) There is often a difference between what a respondent says he will do and what he actually would do in certain hypothesized situations. Sometimes this discrepancy is accidental, but frequently it is a purposeful misstatement from the respondent because he has ulterior motives. For example, he may respond that he would use a new transit service, were it available, when in fact he does not use it when it becomes available. This may be because he has misunderstood or underestimated his personal valuation of the impedance of some of the transit service attributes; it may be because the system in-place never measured up to the specifications quoted to him in the attitude survey; it may be because he was not sure whether he would use it or not but had nothing to lose by its being available "just in case"; or it may be because he envisioned a positive response contributing to the service's being implemented, and its presence attracting enough other people to transit to reduce the highway congestion he personally would face.

(2) No matter how carefully worded the questions are, there is often a difference in how the respondent perceives the question or the alternatives or the attributes being described from what was intended.

Limited Applicability and the Need for Modelling

It thus can be concluded that the "before and after" study design is appropriate only for certain specialized transportation change situations which include all or most of the following characteristics:

(1) when the observed travel behavioral impact variables are constant or predictably changing both before and after the change with respect to exogenous factors

(2) when the timing of the effect of the change is somewhat predictable (e.g., a transit fare change)

(3) when the size of the impact is relatively large in a short time period.

The first condition above calls for a mechanism to be able to predict the effect of exogenous factors on the observed travel or locational decisions. This essentially is the description of a mobility and travel demand model for the affected population. Causal models are needed to tell to whom, when and why specific changes have occured. With these models, "before and after" studies can be done and useful information on travel behavior obtained.

Before and after observations (with or without a control group) or any time series data are alone insufficient for making inferences about travel behavior and therefore not useful for prediction purposes except in the crudest of ways, analogous to the correlative relationship of Dial-A-Bus ridership described in an earlier example. These data describe the conditions at different points in time but do not explain the cause and effect relationship among variables that will describe the observed path of changes followed, or changes in the dependent variables between two points in time. Therefore one cannot use these data to reliably predict changes or a path into the future.

For prediction purposes, a behavioral theory and a causal model are required. Data available from before the change should be used to estimate the coefficients of the model. The estimated model should now be able to predict (with a given range of uncertainty that is inherent in any econometric model) consumer response to the change as well as the status at any given point in time had not there being a change. The difference between these two predictions can now be considered as the effect of the change.

Thus, instead of approaching before and after data collection as an experimental design, it should be viewed as a model validation test. Using these data models can be tested for their predictive ability under significant changes in both dependent and independent variables. In this context a control group is not needed to isolate the effects of exogenous influences; however, it can be useful as an additional test of the models for a situation of no (or limited) supply change. This means that the control group needs not be identical to the affected group; it can be randomly selected, insuring that it is not affected in a major way by the supply change.

The discussion in this section of the paper also implies that the behavioral models that are being validated by longitudinal (time-series) data should explicitly treat the dynamics of consumer response. The conventional assumption of a static short run equilibrium for the travel choices and a static long run equilibrium for the mobility choices may require a very long period of observations and an explicit assumption as to what exact points in time constitute these equilibria conditions. These may be hard to achieve in particular with respect to mobility choices which take very long times to adjust. It appears, therefore, that dynamic models, at least for the mobility choices, are essential for the suggested process of theory and model validation using longitudinal data from before and after a transportation system supply change.

Continuous Monitoring

Since the "before and after" design by itself is so limited in its usefulness to study transportation system change effect, it is appropriate to examine other study designs which will complement the use of travel demand models. Models can be built from an initial large sample and continually maintained and updated by smaller samples at later dates. Data from samples in areas which experience transportation system changes should be used to test and refine the explanation of travel behavior -- in short, to update and sensitize the models even further. The models can be specific to the entire population, to a given area, or to a narrow segment of the population. Also, the set of models can include models based on different approaches and models for different time periods. The new data could be used to compare alternative models, to test the predictive reliability of models, to measure response times for different choice changes, to test transferability of models from one area to another and to monitor any longer term shifts in travel behavior that may be subtly taking place. Since the factors influencing travel behavior are so numerous and interrelated, it seems that only through such a continuing process will anything useful be learned from the effects of transportation system supply changes.

Obviously, such continuing monitoring is costly and cannot be undertaken for every supply change. What is needed is for one overview body to see to it that continuous monitoring operations are set up where they would be most cost effective and their results most transferrable or representative. Such continuous monitoring efforts should be chosen to be representative with respect to both type of supply change and geographical/socio-economic considerations. There are some forty Dial-A-Ride services currently in operation in the U.S. Dial-A-Ride is an example of a unique supply change whose demand responses are not behaviorally known because the level of service characteristics of Dial-A-Ride are so different from conventional transit. Not all forty Dial-A-Ride services need to be continuously monitored in depth, but at least a few of them should be, to provide travel behavior information for other present and prospective Dial-A-Ride installations.

5. Data Collection Strategy

The Use of the Data

Before any surveys are designed or data are collected in any form in anticipation or after a transportation system supply change, it is important to identify exactly the purpose for which the data are to be used. This is necessary both for identifying the type of data collection which would be most effective and for suggesting the form of demand model to be used in conjunction with the data collection. As discussed in the previous section, for the purpose of learning about travel behavior, it is necessary to develop a model which attempts to explain *a priori* the traveller's response (a travel demand reaction) to the supply change. This model need not be extremely sophisticated or need not simultaneously explain all of the travel choices; in many cases the scale of the supply change will call for only a simple, short-run mode or route choice model. For example, the implementation of a new Dial-A-Bus system in a suburban town serving the town's shopping areas and connecting with line-haul transit service to the central city CBD is not likely to effect a significant traveller response other than a switch of some travellers from their private autos to the Dial-A-Bus service. (This change could also have the small effect of inducing some extra travel and slightly influencing destination choices, but these effects are likely to be so small that they might be difficult to detect reliably with any sampling design.)

Methodology for selecting a suitable demand model is described in detail in Cambridge Systematics' (1973) UMTA Demand Forecasting Manual. If no adequate demand models exist for the area or market segment which is to be affected by the transportation supply change, data should be collected before the change so that a behavioral model can be estimated describing a stable equilibrium situation. (In those cases when it can be determined that the change will encourage a relatively quick traveller response, such as a transit fare change, an "after" survey with recall questions describing "before the change behavior" should be sufficient to estimate the model. In this way, surveying costs will be reduced although it must be stressed that such methods can only be used when the response to the change stabilizes within four to six months after the change.) In situations where a reasonable causal model already exists, data need only be collected after the change has been implemented. Of course, care must be taken to obtain data in the "after" survey in the same form as was used to estimate the original model. Additional data should also be collected in these situations so that refinements and better estimations of the models can be accomplished.

Types of Data to be Collected

Assuming that travel demand models are to be used in predicting traveller response to supply changes, the data requirements will depend on the relative complexity of the proposed or existing model and the set of travel and mobility choices which it is designed to predict. In general, five types of data are usually required to build a model of travel behavior: travel and mobility choice data, transportation level of service data, socio-economic data, attributes of mobility alternatives, and spatial opportunity data or measures of attractiveness for different destinations. Of course, not all demand models will require all of these types of data; for example, a CBD mode choice model need not have variables measuring the attractiveness of alternative destinations and not all models need a comprehensive set of socio-economic variables. Travel choice data, socio-economic data, and transportation level of service measures are almost always needed, though, to estimate any type of demand model.

Examples of each of these data types are numerous and the amount of detail needed will vary with model requirements and resources available. The following lists the most common variables which are collected for each data category:

Travel Choice Data - Origin and destination, trip purpose, frequency, times of day, mode and route of each trip the household or user makes, preferably broken down into links or distinct portions of each trip.

Mobility Choice Data - Employment locations, residence location, housing type, automobiles owned, and characteristics of the work trip.

Socio-Economic Data - Household and personal income, number of licensed drivers, race, family size and composition, employment status of family members and other occupational data.

Level of Service Data - Door-to-door travel times and costs of all relevant transportation alternatives for each trip made, number of transfers involved in trip, measures of comfort, convenience and reliability, schedule delay, difference between actual and expected waiting times.

Attributes of Mobility Alternatives - Housing and neighborhood characteristics of alternative locations, automobile ownership costs, etc.

Spatial Opportunity Data - Measures of attractiveness of destinations for each trip purpose, such as number of stores, floor space, recreational facilities, etc. (These measures are often hard to define and thus make the estimation of a destination choice model difficult.)

Many examples of survey methods and instruments are generally available with varying levels of detail. The amount and detail of information which can be collected depends on the survey method which is used. For each supply change, the survey design should concentrate on collecting data on those aspects of supply which will be affected.

6. Data Collection Procedures

Survey Instrument

The fundamental premise of this paper is that supply changes afford the opportunity to gain a better knowledge of travel behavior to improve travel prediction capabilities. Therefore all discussion of data collection is with the objective of understanding travel behavior and improved demand models, not for example, collecting just summary statistics. This eliminates many simple data collection techniques such as traffic counts on a highway, license plate traces, transit patronage figures, and transit on-board O-D surveys, which serve some purposes, but do not directly contribute to improvements in travel behavior modelling. Information from individuals in households or individual users is essential if we want to relate transportation supply variables to behavioral response using a causal model. The only way to obtain these data is by using a questionnaire that may be self-administered or administered by an interviewer.

The Survey Base or Sampling Frame

Different types of transportation supply changes will call for somewhat different data collection procedures. In general, the larger the scope of the change and the more traveller response which it can engender, the larger the sampling frame necessary to accurately measure this response. Model development can only be based on a sample taken from a well defined sampling frame.

Those changes which significantly affect the total capacity of a major highway link or transit system will have at least some potential effect on the majority of the population in the area. In these cases, the sampling universe should consist of all (or at least a large segment) of an urban population. (Note that this is the sampling universe; the sampling rate within that universe should be chosen large enough to estimate statistically valid models, but not so large as to be prohibitively expensive).

Using the area population frame, generalizing from a self-weighted (which means that all observations are equally weighted) sample is relatively easy, and reliable information on travel behavior in the area can be obtained with little difficulty. Models which had been estimated previously for the area could be tested (to determine their ability to predict behavioral responses to the supply changes) and then refined to reflect the new information obtained through the recent data collection effort. It is this type of a major supply change, which has an effect on the largest number of people, which provides the most useful and important input into the process of modelling (and thus understanding) travel behavior.

Yet there are many smaller transportation supply changes which affect much smaller segments of the population whose responses would be difficult or expensive to obtain using an area population sampling frame. Such changes might include midday transit price reductions, a change in the frequency of transit service on certain routes, or an extension of the hours of service on specific transit routes. In these case, it would not be efficient to sample from an areal population base because relatively few of the population use the services. A narrowly defined market segment of the most likely transit users should be defined as the sampling frame and a sample chosen randomly from this segment.

Of course, it would be very difficult to generalize this sample (and the information learned from it) to a larger population, since the characteristics of this market segment would be significantly different from the characteristics of the general population. For this reason, the models used to predict the travel response of this market segment are unlikely to be the same demand models which were estimated for the entire area population. Much simpler short run mode choice models can be estimated to incorporate the effects of these smaller supply changes, and a lot can be learned about the travel behavior of particular market segments. This market-oriented behavioral information can then be used to plan future services for the specific market segment.

A user's survey, such as a transit "on board" survey, is based on a sampling frame which is not population or area based but rather determined by some of the choices that we are interested in predicting. Therefore, this type of a survey has limited use for modelling. It cannot be used to estimate a choice model. It could be used to estimate some special purpose simplified models and to test the predictions of an existing choice model. Its advantages are low cost and ability to measure the effect of a change with impact on only a very small or select population.

When to Survey

If the transportation supply change is anticipated in the future and no situation-calibrated behavioral models presently exist which could adequately predict the types of response which could be expected from changes in the transportation system's level of service characteristics, data should be collected prior to the change in order to estimate such a model. Since the purpose of the collection is to determine the causal factors involved in decisions on travel choices, any time before the introduction of the supply change is appropriate to survey. (Anticipation of major supply changes, such as the opening of a new road, could have some effect on the long term mobility choices before the actual implementation of the change, as previously discussed. This behavior would have to be discovered through long term "time series" surveys which could capture long run decisions at an admittedly high cost.) It should be noted that in those cases where adequate models already exist which explain the travel behavior of an area with respect to the variables which are to be observed in an impending supply change, no data collection need be undertaken before the introduction of the change.

The determination of the proper time to survey <u>after</u> the introduction of the supply change depends on the type and impact of the specific change and the response to it which are to be measured. In order to obtain a full measure of the effect on travel behavior of the change, sufficient time must be passed before the data collection begins. In order to correctly gauge this time, it is necessary to make some measurement of the use of the facility or the transportation system which was altered by the supply change. For example, Lassow (1968) took care to insure that the ridership on the New York City transit system had stabilized after a 1966 fare increase before he conducted his survey. This can easily be accomplished by transit boarding or revenue counts or, in the case of highway changes, by lane counts. Once it has been determined that the situation has stabilized somewhat, the data collection effort, be it population or user based, should begin as soon as possible to eliminate future exogenous effects.

As a side comment, the assembling of typical response times to specific types of supply changes would be a most useful project to undertake to provide guidance to the specification of the relevant model and the data requirements.

<u>Sampling Technique and Sample Size</u>

It is recommended that a self-weighted (equally weighted observations) sample be used in any data collection to determine the effects of transportation supply changes. This will allow direct use for model estimation, easier generalization of the sample to the full sampling frame and insure that a stratification will not be biased toward specific parameters. If a before and after survey is necessary, it may be desirable to have some overlap of the specific units sampled to determine individual changes of behavior due to the supply change. The survey sample will undoubtedly be somewhat biased by nonresponse or failure to reach some of the sampling units, but these biases can be estimated by determining their characteristics. Measurement errors, such as interviewer effects, reporting instrument effects, recall errors, and inaccurate recall, must be considered in the survey design to obtain an acceptable sample. For recording short-term changes in traveller behavior in response to supply changes, a single day trip record should be sufficient, although a longer trip diary or additional questions about "usual" travel pattern would be more useful if the resources are available to obtain it. Changes in mobility choice components might require more event-oriented questions, such as "when did you last change your automobile ownership status and why?".

An issue which is closely bound in with the selection of sampling technique is the selection of sample size. This is, of course, basically a statistical question which is a function of the desired levels of confidence of the survey results. It is important to note, however, that the requirements for sample size are also very closely tied to the model for which the data is required, most particularly the level of aggregation with which the model operates. If the models are based on disaggregate data, the sample size can be much smaller than comparable aggregate zonal models. For example, a typical household mode choice model needs only between 200 and 500 observations to obtain a stable and reliable estimation result (Ben-Akiva and Richards, 1974).

Interview Methods and Problems

Different interview methods are available for data collection on travel behavior. Among the types of interviews which are appropriate to the population and user based sampling frames are: household interviews, telephone interviews, mail questionnaires, and rider or station surveys. Table 6.1 summarizes the major characteristics and problems of each of these interview methods. Experience to date suggests that, whenever resources permit, an area population based survey should be conducted by home interviews in order to obtain the highest response rate, most unbiased sample and most complete information. Telephone surveys are slightly less expensive than home interviews per unit of useful

Table 6.1

CHARACTERISTICS OF THE DIFFERENT INTERVIEW METHODS[1]

Interview Method	Approximate Cost Per Survey	Typical Response Rates	Advantages or Problems
Household Interview	$25-50	70%	Quality of data; better control of measurement errors
Telephone Interviews	$10-15	30%	Nonlisted numbers bias; low response rate; lack of visual materials display
Mail Questionnaires	$1	15%	Very low response rates; many measurement errors
Rider Surveys	$1	15% (with mail-back)	Low response rate with mail-back; very limited quantity of data without

[1]Source: Charles River Associates (1972)

information, but the ability of the interviewer to keep the interviewee's attention and gauge any confusion are impaired somewhat. Therefore, there seems to be no advantage to using this method over a household interview method. If funds for data collection are scarce, a mail survey is definitely preferable, but much greater care must be taken with the actual survey design in this case to avoid confusion of the questions, incomplete responses and a bias in returns. Rider surveys must be used for the user-oriented sampling bases and they can often be backed up by a mail survey to obtain more complete information.

Other Methods of Data Collection

User based surveys can also be made on highway facilities if specific information on users of particular routes is desired. It must be noted, though, that highway users surveys often exhibit somewhat undefined sampling frames, since it is difficult to predict the population who could use a particular facility. Three methods have mainly been used to obtain road user interviews: traditional roadside interviews, the voluntary return postcard technique and the license plate tracing technique (FHWA, 1973). The roadside interview and postcard technique are necessarily limited as to the amount of data which can be obtained, but a good summary of origins and destinations can be compiled from these methods and changes in the geographic distribution of users can be monitored. The license plate technique consists of manually, or with the use of cameras, recording the plate numbers of automobiles (passing through a cordon or screen line, parked at a given area), obtaining the home addresses from existing records and perhaps mailing them a questionnaire to be returned. (This method is analogous to the mail-back transit rider survey). The questionnaires are required in order to get socio-economic and more specific travel data that are essential for modelling. The mail-back techniques suffer from low response rate and return bias but are again the least expensive methods.

There seems to be a trade-off between the length (detail) of the mail questionnaires and the response rate, i.e., the shorter the survey, the higher the response rate. License plate checks have also been used to measure transit park-and-ride diversions with the opening of a new suburban rapid transit extension and the tracing of a particular vehicle from entry point to exit from a particular facility. In general, these methods are recommended only in cases when small highway capacity supply changes are to be monitored, since a population-based sample may not pick up the small impact.

Traffic and transit ridership counts will give some measure of aggregate elasticity (or percentage change in usage per percent change in a supply variable) for most supply changes, but these figures do little more than show the most obvious effects of the change. Nothing about travel behavior that is useful for other situations can be surmised from these counts, other than as an overall control check, so that they only should be used in conjunction with some type of interview survey.

7. Conclusions

(1) Due to the limitations of the "before and after" experimental design, very little can be learned about travel behavior from observations of traveller reaction to supply changes unless these observations are used in conjunction with a behavioral model that explains traveller response. In every situation, some model should be used to try to predict responses in advance, and their actual observations should be used to refine or validate that model and thus improve our behavioral understanding and prediction capabilities of travel demand.

(2) Different travel decisions have different response times to equilibrium. Therefore, different measurement periods after the supply change require different behavioral models, and thus require different data collection techniques.

Short term travel choice decisions (non-work trip frequency and destination choice, work or non-work trip mode choice and route choice) have quick response times and can be modelled satisfactorily with cross-section data from a given point in time. Mobility choice decisions (employment location, residential location and automobile ownership level) have longer term responses and dynamic models and time series data are required to measure them behaviorally.

(3) The modelling of any demand change requires some prior knowledge of the response time required for that particular response to a supply change to be completed (system equilibrium to set in). This leads to two conclusions:

   (a) FHWA should consider a study of previously observed response times from other supply-change situations to prepare an overall table of approximate response times for each type of demand response to each type of supply change so as to provide guidance to model specification and data collection.

   (b) Auxiliary monitoring techniques might be used, such as daily traffic counts or daily transit ridership counts, to determine when a stable situation has been reached so that the "after" survey can be conducted.

(4) Every new data collection effort should be designed specifically for the model(s) that will be used. This will insure consistency of data with model requirements and will minimize data collection costs (usually a lot of data are collected that are never used).

(5) The parallel use of behavioral models has several important implications: A valid generalizable model can only be estimated from a sample that is taken from a carefully designed sampling frame. A "users" sampling frame cannot be used to estimate choice models because observations are required from consumers who made different choices as well to allow the model to sort out the behavioral or causal trade-offs. A "population" sampling frame is required to provide the necessary data, and the required data

can only be collected using a questionnaire. A home interview survey questionnaire is generally superior to a telephone survey, postcard survey, or mail-back survey.

(6) Given limited resources for data collection, the following supply changes should be given priority:

(a) permanent over temporary

(b) large scale over small scale

(c) area-wide over localized

(7) In every supply change situation, the range and depth of data which could be collected is enormous, and consequently so is the spectrum of resources required to collect that data. One should trade off the value of the information to be gained against the costs of collection in each situation separately, rather than follow any universal rules such as, "do this, don't do that." The following should be given priority:

(a) "population" sample over "users" sample

(b) factual information over attitudinal data

(8) Since the local agencies who will perform the data collection are unlikely to be involved in model development, a centralized monitoring and updating program should be instituted. This could be done at DOT or at any other organization that has capabilities in both data collection and modelling. The functions of this program will be to aid in the design of new data collection efforts and to analyze the data to test and improve travel demand models.

In addition to providing overall guidance on specific supply-change data collection projects, this centralized monitoring body should establish several continuing monitoring projects to collect time series data for a number of demand responses and a number of supply changes. This would insure the availability of time series data for any research project which requires it; would provide information on long-response time changes such as residential location which are, behaviorally, poorly understood and inadequately modelled; would provide a data base for comparing alternative models; would provide further data on response times; would provide geographically and socio-economically separate data bases to test the transferability of models from one area to another; and would provide indications of longer-term shifts in travel behavior and related mobility decisions which may be subtly taking place beyond those caused by the subject supply change.

(9) All of the foregoing give rise to the following general guidelines for a supply-change data collection framework or strategy:

(a) Specify the supply change and its scope geographically, temporally, and socio-economically.

(b) Identify probable demand responses and variables affected; make sure that the effects from exogenous factors on travel demand change can be identified.

(c) Hypothesize behavioral models for predicting each demand change; determine if similar supply-change effects have been measured in depth elsewhere, and the extent to which that data and those models are transferrable and applicable.

(d) Determine alternative methods of measuring (collecting data on) each demand effect and the associated data collection costs for various levels of statistical reliability; determine if suitable "before" data, and accompanying behavioral models, exist or whether that also needs to be collected.

(e) Select an appropriate data collection program, encompassing measurements of each type of demand response, on the basis of the tradeoff between the value of information to be gained versus resource requirements (or, alternatively, maximizing the value of information to be gained within a fixed budget). Among other considerations, this decision should be made with an awareness of:

- consistency of data collection with model requirements,
- ability to identify effects of exogenous factors on the demand response,
- other previous similar data collection efforts,
- uncertainty and bias in response, depending on data collection technique employed,
- the percent sample required to achieve statistical validity in testing the behavioral hypothesis,
- the differential incidence of and response to supply change among different market segments,
- the importance of measuring demand responses to the subject supply change from a policy point of view.

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COLLECTION OF DATA DESIGNED TO PROVIDE INSIGHTS INTO THE IMPACT OF SYSTEM CHANGES ON TRAVEL BEHAVIOR

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WHITE PAPER

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"DESIGN OF PROCEDURES TO EVALUATE TRAVELER RESPONSE TO CHANGES IN TRANSPORTATION SYSTEM SUPPLY"

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COLLECTION OF DATA DESIGNED TO PROVIDE INSIGHTS INTO THE IMPACT OF SYSTEM CHANGES ON TRAVEL BEHAVIOR

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GENERAL

Decision making related to investments in transport facilities and the development of appropriate operational policies requires knowledge of factors which influence travel behavior. Much has been learned in recent years concerning relationships between selected socio-economic characteristics of the population and the propensity for trip making. Such variables as car ownership, income, average family size, number of workers per family and others have been shown to exhibit strong relationships to trip generation. These and other variables related to network performance have been shown to be strongly related to choice of travel mode and the distribution of trips between origins and destinations. Most of these relationships have been developed from cross section data; that is, data collected at one point in time over an extensive geographic area. Relatively little has been done to test the resulting hypothesis on a time series basis. Yet the need for more work on the direct impact over time of changes in system supply is required if we are to make significant progress in our understanding of travel behavior. The conduct of time series analysis is complex however and suffers from the lack of a long term strategy for development of appropriate data, as well as analysis procedures. It is difficult to sift out the longer term secular and other external influences in order to determine causal relationships with system supply.

The Department of Housing and Urban Development and later, the Urban Mass Transit Administration has, over the past decade, sponsored numerous demonstrations designed to determine the effect on travel demand of changes in the level of transit service. Most of these demonstrations have had their results documented in voluminous reports. However, little can be learned from these reports with respect to travel behavior information that is transferrable to other locations and situations. There have been a few other serious efforts[1/] to determine supply-behavior relationships but these and others have suffered from the lack of a systematic methodology for conducting such studies.

For all these reasons the FHWA is proposing to conduct research into this area simultaneously moving toward one or more "in depth" case studies involving supply changes. At the same time they propose to prepare procedural manuals for use in local and state agencies which will specify data collection methodologies appropriate to determination of supply change impacts. These manuals thus must be general purpose -- that is they will not be aimed at any specific supply change -- and contain procedures capable of implementation by regular agency employees with a relatively short lead time. This paper has been prepared as a first step to the preparation of the manuals, and is for the purpose of setting forth major issues and suggestions relevant to this subject.

SUPPLY CHANGES

Transportation system supply changes range over such a wide span in type, size, and importance that it is necessary to develop some system of categorizing them for analysis purposes. Basically it's believed that most supply changes can be grouped into one of the following three categories:

<u>Permanent -- fixed facility changes:</u> this would include the effect of the opening or closing of large fixed facilities,

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1/ Included are: (1) Demand studies related to the Cleveland Airport Rapid Transit Extension; (2) The New York City Studies related to the 1966 transit strike; and (3) The 1973 Atlanta Transit Fare Reductions.

including rail rapid transit, major highways, busways, transit stations, etc. Such changes probably have the greatest effect both in the short and long term than those in other categories. The necessity of properly evaluating their impact is also more important because of the very large investment required in such facilities.

Permanent -- operational changes: these include changes due to traffic control shifts, road toll changes, transit fare changes, fuel price changes, carpool programs, and others which rely not so much on fixed facilities, but rather on management of the system itself. Such changes tend to be smaller in impact than the fixed facility changes; however, some can have even greater impact. For example, major fuel price changes could have significant impacts on travel requirements areawide.

Temporary changes: these changes include all changes to the system supply which are known at the outset to be temporary, such as construction detours, transit strikes, and demonstration programs with limited time commitments.

Table 1 lists these types of supply changes, along with typical examples of each.

Geographic Extent

Another useful stratification of supply changes has to do with the geographical extent of the effect of the change. Most changes are probably site specific -- that is, they have limited coverage such that many trips within an urban area or other large section may not be subject to the influence of change.

TABLE 1

SYSTEM SUPPLY CHANGES RELATED TO TYPES OF IMPACTS

Type	Description	Normal 1/ Lead Time	Geographical 2/ Extent (Usual)	Travel Demand Short Term	Travel Demand Long Term	Economic Short Term	Economic Long Term	Social Short Term	Social Long Term	Environmental Short Term	Environmental Long Term	Land Use Short Term	Land Use Long Term
Permanent-Fixed Facilities	New Road Opening or Closing	L	L	X	X	X	X	X	X	X	X	X	X
	New Passenger Rail Line	L	L	X	X	X	X	X	X	X	X	X	X
	New Busway	L	L	X	X	X	X	X	X	X	X	X	X
	New Transit Station	L	L	X	X	X	X	X	X	X	X	X	X
	Road Widening	L	L	X	X	X	X	X	X	X	X	X	X
Permanent-Operational	Traffic Control Changes	S-L	L	X	-	-	-	-	-	-	-	-	-
	Road Toll Changes	S-L	L	X	-	X	-	-	-	-	-	-	-
	Fare Changes	S-L	A	X	-	X	-	X	X	-	-	-	-
	Bus Route & Schedule	S-L	L	X	-	-	-	-	-	-	-	-	-
	Reserved Bus Lanes	S-L	L	X	X	X	-	-	-	-	-	-	-
	Fuel Price Changes	S-L	A	X	X	X	X	-	-	-	X	-	-
	Car Pool Programs	S-L	L-A	X	X	X	X	-	X	-	X	-	-
	Cessation of All Transit Service	S-L	A	X	X	X	-	X	-	-	-	-	-
Temporary	Construction Detours	S	L	X	-	X	-	-	-	-	-	-	-
	Gas Rationing	S	A	X	-	X	X	X	-	X	-	-	-
	Transit Strike	S	A	X	-	X	-	X	-	-	-	-	-
	Demonstration Programs	S-L	L-A	X	-	X	-	-	-	-	-	-	-

1/ L-Long; S-Short

2/ A-Areawide; L-Limited

For example, a newly opened section of road will likely be located such that many trips in the urban area are not affected by it. On the other hand, certain changes are areawide -- that is, all trips in the area are potentially subject to the influence of change. Gas rationing or substantial changes in transit fares would fall into this category.

From the standpoint of "before and after" data collection with site specific changes it is possible to designate a control group for observation at the same time measurements are made of the impact group, and comparison of the difference in reaction between these two groups will allow a filtering out of secular and external effects. With areawide changes obtaining an adequate control group may be impossible.

Table 1 shows various types and examples of supply changes with designation of their geographic extent.

TYPES OF IMPACTS

Transportation supply changes, if large enough, can affect almost everything going on in an urban area. Thus the problem of measuring impacts in a comprehensive way can become enormous. However, the major changes can be classified into five groups as follows:

- Demand: changes in transportation supply can affect transportation demand as to its total magnitude, characteristics, and geographical patterns
- Economic: supply changes can affect economic development (1) in a micro sense in the vicinity of the change, or (2) in a macro sense concerning overall development of the area

- Social: transportation supply changes can affect social development in a variety of ways, including the distribution of its costs and benefits differentially between income classes, influences on land prices (with resultant social effects on home ownership, living patterns, etc.), providing new opportunities for access to educational, health, and other benefits available in the area, reducing or eliminating travel patterns of established social interrelationships, as well as the direct effects of distribution of homes and businesses removed to provide room for new transport facilities
- Environmental: supply changes can affect, in an obvious way, the noise level, air pollution level, and, in some cases, water supply, wildlife, historical sites, etc.
- Land Use: supply changes can affect the intensity, character and location of various types of land use in both positive and negative ways. Land use changes can in turn affect transportation demand.

It is useful to note that supply changes can have different impacts on any of the above categories depending on whether the impact is short or long term. Temporary changes would tend to have only short term effects, whereas permanent, fixed facility changes would tend to have both short and long term effects.

SUPPLY CHANGES RELATED TO TYPES OF IMPACTS

Table 1 relates various classes of supply changes to types of impacts. The relations in Table 1 are based on the normal values of the types of changes involved. For example, transit fare increases normally are small and the effect fairly immediate with long term effects either nil or non measurable. However, in a large city it's conceivable that a very large increase in transit fares could have both long and short term effects.

Efforts to verify hypotheses concerning the nature of any of these impacts as they relate to changes in system supply will be much assisted by careful collection and analysis of "before and after" data. However, as suggested by Table 1, many supply changes have the potential for changing virtually "everything" both in the short and long term. To measure all potential impacts in each case puts impossible demands on research resources. Rather the approach must be selective and procedures for impact measurements should be subdivided so that the analyst can preselect those likely major impacts of interest before collection or analysis of data based on his budget and time constraints balanced against the basic focus of his inquiry. Procedures and approaches thus need to be developed in a modular form so that any single or combination of impacts can be selected.

Most of the impacts related to economic, social, environmental and land use effects are correlated to the effect on travel demand. For example, any positive economic benefits of a new road or a transit facility will be in direct proportion to the degree of its impact on demand. Thus any significant improvement in our ability to measure any impacts will in turn be related to the improvement of our ability to estimate demand. Thus it is appropriate that initial efforts be given to analysis of supply demand relationships.

THEORETICAL BASIS

That supply changes can and do influence travel behavior has a substantial basis, both from an empirical and theoretical viewpoint. Travel literature, as well as numerous results of ad hoc studies conducted by local agencies have demonstrated a direct correlation between new travel facilities and demand influences. HUD, and later DOT have conducted many demonstrations during the 60's and early 70's directed at learning of the impact of changes in transit service on demand. One can question whether much has been learned concerning the "why's" of the changes in demand but the question of whether there were changes cannot be doubted.

Theoretically, such supply and demand relationships find their roots in classical economic theory which suggests that for most goods and services an inverse elasticity exists between price and demand. Figure 1 shows this relationship.

The price as perceived by the typical traveler however is not a simple variable but a composite made up of travel time, money costs (fares, fuel, etc.), inconvenience, discomfort, uncertainty, and other factors, all of which can be subsumed into a "generalized cost" function. In accordance with Figure 1 then, if generalized cost (or the price as perceived by the user) is reduced, demand for travel will increase. However, as more travel is generated, travel facilities become more congested resulting in greater time and operating costs per unit of travel. Figure 2 shows the resulting supply costs increasing as travel increases. The system comes to equilibrium at point E_1.

Changes to system supply of any type alters the generalized cost of the trip for all people using the facilities affected by the change. The case of a supply change that reduces generalized cost (e.g., a change which reduces congestion and speeds up flow of traffic) is shown as the lowered supply cost curve in Figure 2. Such a change causes each potential

FIGURE 1

TRANSPORTATION DEMAND-PRICE RELATIONSHIP

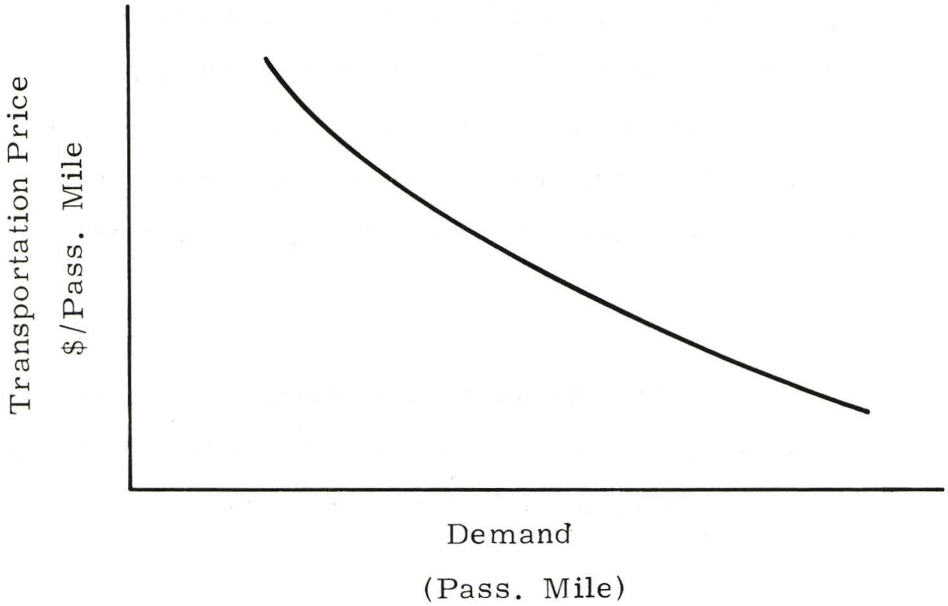
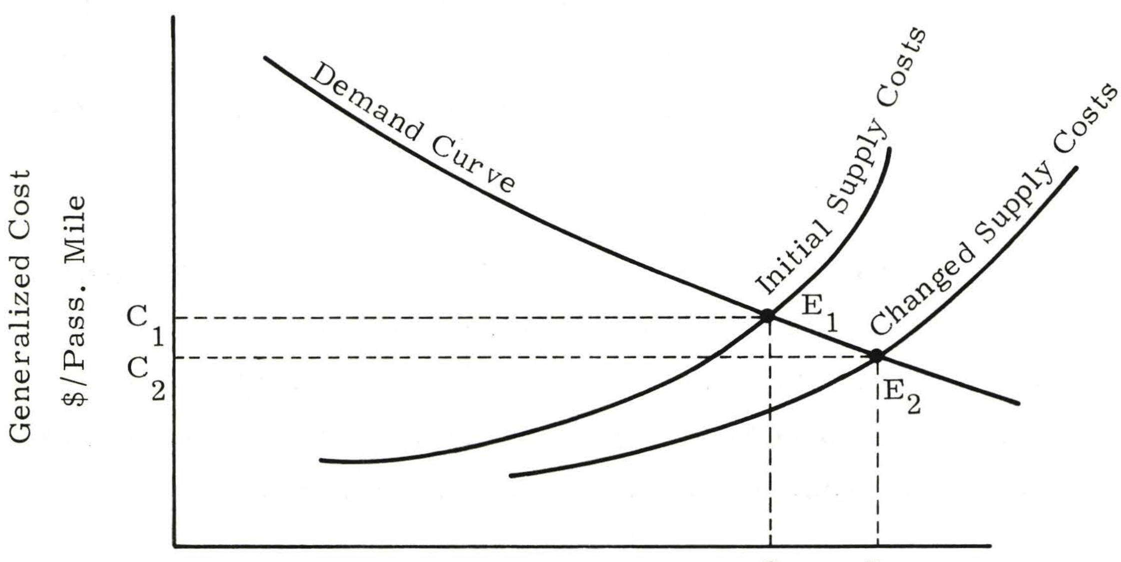


FIGURE 2

TRANSPORTATION DEMAND-SUPPLY-PRICE-RELATIONSHIPS



traveler to reevaluate his opportunities and alternatives and his potential benefits from travel versus his new costs and perhaps alter his travel decisions based on the outcome of this analysis. The aggregate effect of these alterations eventually leads to the establishment of a new equilibrium at point E_2 with travel volumes at Q_2 and costs C_2.

Traveler Response to Demand Changes

Figure 2 does not suggest that the singular response of the potential traveler to system changes is to redecide whether or not to make the trip. Depending on the nature of the change, individual potential travelers could respond in many ways. For example, suppose a new road was built through a major portion of a large city, reducing generalized costs between many points. The effects could be as follows:

1. Some people who had concluded that the trip was simply too costly (i.e., too congested, inconvenient, etc.) might decide now that it was worth it; new trips would thus be generated.
2. Some existing motorists might shift their path of travel to take advantage of the new facility while maintaining their current origin to destination points.
3. Some people using public transit might decide to use their car resulting in a modal shift.
4. Some might decide to purchase a car where formerly they had concluded it was not worth it.
5. Some who were deferring their trips to less congested periods to avoid high generalized costs of peak hour travel might shift back to the peak period resulting in a shift in hourly variation of travel.
6. Some might decide to travel to more distant destinations resulting in a longer average trip length.

7. Some might (over time) alter their decision about places of residences or employment to take advantage of changed travel conditions.

While this list doesn't exhaust the possibilities, it does indicate the nature of changed travel demands which might be expected from supply changes. In the aggregate these can be expressed as

1. Changes in trips generated
   - total number
   - purpose of travel
   - characteristics of persons traveling
   - time of day of travel
2. Mode and path of travel
3. Length of trip
4. Alterations of the origin and destination pattern (geographical shifts)
5. Land use shifts
   - type
   - intensity
6. Ownership of automobiles

Some of these travel characteristics can be expected to be subject to alteration in the short term (say within a month or so after the traveler is aware of the change and has time to reassess his alternatives). Thus mode and path of travel, as well as increased trip frequency might result within the first 6-9 months after a change as all potential travelers have time to become acquainted with it. However, shifts in auto ownership could take longer, and alterations of residence location and job location could take much longer.

APPROACH TO ANALYSIS

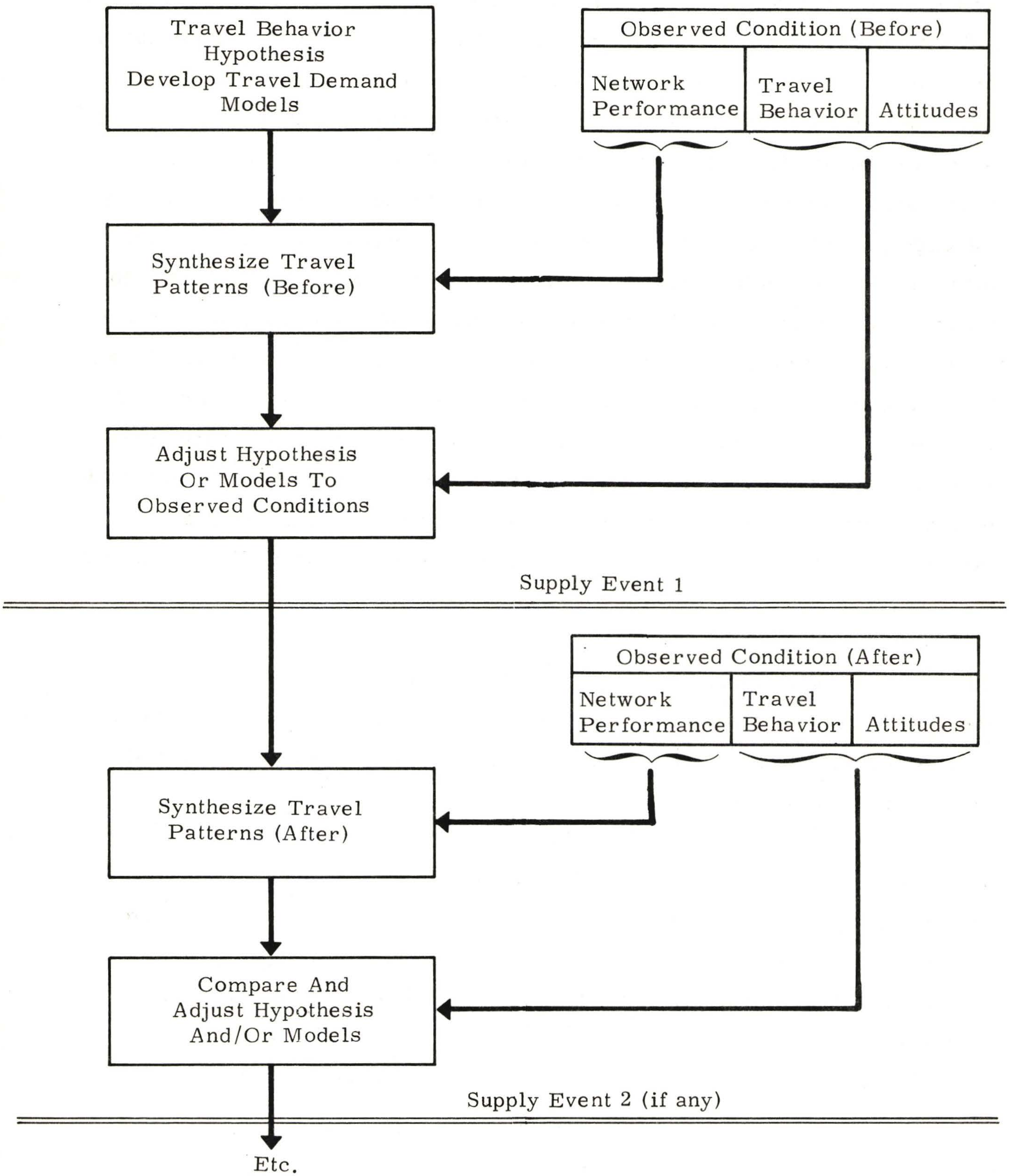
It is very simple to measure some of the travel impacts that can occur with changes in supply, but quite difficult to do so in a manner which provides a basis for cause and effect determination, a necessary aspect of information or conclusions that are to be transferrable to other locations. The problem essentially is that numerous factors influence the nature and character of the perceived generalized cost of travel to the potential traveler and, as noted in an earlier section, his response can emerge in numerous ways. Knowing the aggregate effect of all travelers to the change is not enough to assist in disecting what is really happening to whom and why. Thus, the approach to analysis must begin with a hypothesis that will allow an estimate of the effect of the change; followed by data collection which will allow comparisons between the estimated and the actual change. Depending on the nature of the change it is desirable that the comparisons should extend over a range of characteristics including generation rates, modes, trip length, O-D shifts, and car ownership effects. Interpretation of observed changes, as well as guidance in altering hypothesis suggests that attitudes of potential travelers who could be influenced be explored and compared to observed behavior.

Finally network performance characteristics -- the quantative measure of how the system performs both before and after the change -- must be dimensioned so that quantative relationships between travel behavior and the amount of change can be developed.

Figure 3 shows in schematic form how these three types of data -- network performance, travel behavior and attitude information -- may be integrated into a process which would allow a disaggregate analysis into causative variables. Essential to this approach is a hypothesis of travel behavior which relates socio-economic and network characteristics into quantitative relationships explaining travel behavior. Ideally, several behavioral

FIGURE 3

APPROACH TO ANALYSIS OF TIME SERIES TRAVEL DEMAND DATA



hypothesis and related models could be employed, synthesizing existing travel demand. After the change events these same models could be used to synthesize travel patterns and a comparison with observed conditions made so as to reject, modify, or otherwise alter the hypothesis and related models.

SOME ISSURES RELATED TO DATA COLLECTION

The consideration of specific general purpose data collection procedures appropriate for before and after studies related to system supply changes raises a number of general issues which require elaboration before proceeding further.

Conflict Between Efficiency and Generality

Clearly one of the major objectives of standardized data collection procedures must be efficiency, i.e., that unnecessary data is not collected, and that maximum accuracy and coverage of the phenomenon is accomplished with the minimum expenditure of funds. This normally requires that a clear and explicit purpose for the data and how it is to be used has been established so that collection can be closely geared to the analysis to follow.

In the case of supply changes we are dealing with much diversity even within the categories specified in Table 1. Efficient data collection to measure the impact of a new transit facility will probably be quite different than if the change in supply were car pool programs or gasoline price increases. Even more important is the diversity of the analysis which might follow depending on the focus of the research, the travel hypothesis being followed and the degree of refinement desired.

Nevertheless, the nature of things does not always allow time for preparation of a complete study design; and to insist on it in every case is often to lose the entire opportunity. It must be recognized that quick response time must mean a potential loss of efficiency in the data collection process.

Impact of Timing of Data Collection

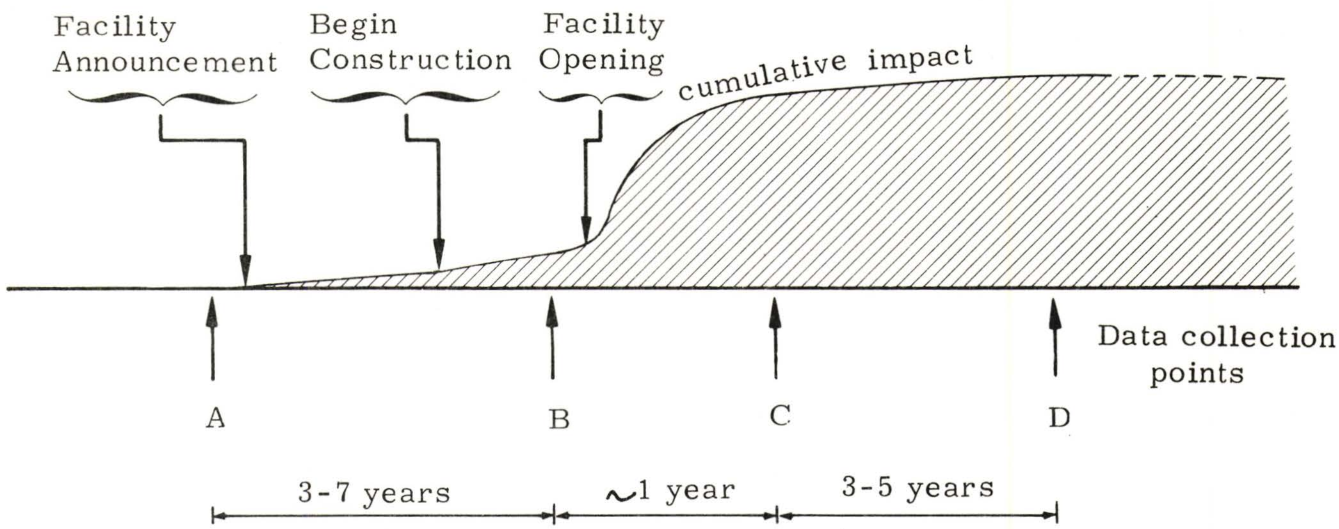
Figure 4 graphically describes the timing of major events surrounding a significant change in the system, say the opening of a new road or transit facility. Some alteration in demand may begin soon after the facility is announced and it is certain that implementation will take place. Decisions covering development (e.g., the San Francisco CBD development after BARTD was announced and funded) can be made at that point; after construction starts this pre-opening impact could grow at an increasing rate. The largest rates of impact change occur immediately after opening and additional impact changes can occur indefinitely, although at a decreasing rate.

A complete analysis of all of these impacts would require observations just prior to the announcement (point A), just prior to opening (point B), after the short term impact has occurred (point C), and after the facility has fully matured (point D). However, the impact of secular and external changes also affecting demand will also be felt during the relatively long periods A-B and C-D so that measuring impacts during these periods may be difficult. The best points for measurement would be at points B and C. If only one point could be observed point C should be selected with special efforts made in the interviewing process to elicit information on "before" behavior as well as after.

Operational supply changes would tend to have a relatively smaller aggregate impact and the impact before opening or beyond a year after opening might be considered negligible. Thus, only points B and C need be considered for operational changes.

FIGURE 4

TIMING OF DATA COLLECTION



If collection limited to 1 point in time, use C
If collection limited to 2 points in time, use B & C
If collection limited to 3 points in time, use B, C & D
If collection limited to 4 points in time, use A, B, C & D

Measurement of Network Performance Data

Experience in measuring network performance data, especially highway travel time information by links, has been shown to be difficult even when no pertabation of the system has taken place. Travel times vary from moment to moment and from day to day depending on micro variations in travel volume, weather, breakdowns, accidents and countless other factors. Many measurements are required to obtain satisfactory averages within say 10% of the true mean speed of a link.

If the supply change is small, that is it is not likely to impact transport level of service in the corridor by more than 5-10%, it may not be worth the effort to try to measure the impact. Clearly, if measurements cannot specify the system performance change, there is little value in trying to measure the impact of the change on travel behavior in any quantative sense. This suggests then that only major supply changes be evaluated. Difficulties in measurement of both behavior and performance are sufficiently great as to preclude efforts on small pertabations.

While this conclusion seems reasonable if the anticipated behavioral change is related to all travelers, it may not hold if the change can reasonably be assigned to only a segment of total travel. For example, the addition of an express (limited stop) premium fare bus line with 15 minute headways over the same route of an existing local bus line may be very significant to the transit level of service in that corridor and studies which focus on the effect of this on existing transit riders (e.g., relative effect of extra walking distance, vs extra fare, vs shorter in vehicle time) could lead to useful results. However, this extra service at best would only be carrying 200 passengers per hour which is only 1% of travel in a corridor with 20,000 trips per hour and thus quite unmeasurable (as well as unpredictable) in terms of total corridor modal split. Modal split probably shifts more than this each day in response to random effects of weather and other unknown factors. In any case, trying to measure minute shifts with available sample survey techniques is likely futile. Thus it is essential that studies be conducted on changes that are large compared to an identifiable segment of the travel market which can be surveyed with sufficient intensity to measure behavioral shifts.

Analysis Procedure Gap

Part of the difficulty in making a definitive determination of data requirements is that the methodologies to be employed in its analysis are so fuzzy and ill defined. The procedure for analysis depicted in Figure 3 is about as rigorous as we are likely to accomplish at present and more rigorous than is normally done; yet even it becomes a fishing expedition at the point of the last box where comparisons and improvements in hypotheses and models are to be prescribed. More typically, where data is collected and analyzed without the benefit of behavioral hypotheses and models, the entire exercise becomes a fishing expedition, often without results. If our purpose is to confirm already well established hypotheses about travel behavior, then perhaps all that's required is collecting counts that show how much difference there is between the estimated and the actual change and if there are differences we would know the one or two areas where we might be in error and thus know how to make corrections. Actually our situation is that we are still not certain that we have very valid hypotheses; thus noting the amount of error in the aggregate could mean problems in numerous places and with only aggregate data from counts it is impossible to know how to make corrections. It appears that in order to obtain useful results, that is results that are both quantifiable and transferrable given the present status of knowledge, that we must err in the direction of over collection and over analysis.

To this end consideration should be given to developing the procedure manuals initially in a tentative form and that in the first two instances of their use that FHWA invest time and money in immediate analysis of results in order to gain insights into the relative effectiveness of various types of data and analysis procedures. Failure to proceed in this way could result in a number of data surveys conducted in attempts to measure the impact of various changes only to find when time for analysis comes that much of the data was not useful, that emphasis had been misplaced or at the worst, that the information cannot lead to useful conclusions.

All of this also indicates that little may be gained from the analysis of changes related to "temporary" supply changes such as strikes or detours. We have virtually no hypothesis concerning behavioral impacts of such phenomena and little need to estimate such impacts. The lack of hypothesis makes it unlikely that transferrable information will be obtained; further the behavioral impact of temporary changes may tell us little about impacts of permanent changes.

METHODS OF DATA COLLECTION

As noted on Figure 3, there are basically three types of data required: travel behavior data, network performance data and attitudinal data. Travel behavior data includes not only information about travel performed, but also social and economic data about the traveler.

Travel Behavior Data

It is possible to classify most behavioral data collection methods for our purposes into three groups: Traffic Counts, Interviews of Travelers Sampled While Enroute, and Interviews of Travelers Sampled While at Their Origin or Destination.

Traffic Counts -- Traffic counts can be made in a variety of ways, either refined or aggregated. Aggregated counts would include total daily counts of total vehicles on each link, or total transit passengers on the system or across a screenline. Refined counts would include stratification of count data by time of day, type of vehicle, vehicle occupancy, number of total persons and by turning maneuver. Counts represent the most useful way of getting large amounts of aggregate data as opposed to the small sample rates associated with methods which get more "in depth" data. Screenline counts will likely be especially useful since changes in system supply often result in travelers altering their path of travel; by properly locating screenlines such deviations can be detected and accounted for.

Earlier portions of this paper have stressed the need to get disaggregate data if we are to make interpretations of travel behavior and respond to changes in system supply, and count data by itself does not satisfy this need. It can provide the total magnitude of change in behavior and even the modal mix changes in some instances. It generally cannot get at changes in generation rates, purpose information, trip length data or other socio-economic changes which might have resulted. Traffic counts can probably be most useful when used as control for other small sample interview methods to be discussed below.

Interviews of Travelers Sampled Enroute -- This type of data collection is generally identified as a "screenline interview survey" if highway travel is involved, or as an "on board" survey if it is concerned with transit travel. Actual personal interviews can be made, or self-administered questionnaires can be passed out, or in some cases license plates are recorded and used as a basis for mailing questionnaires to homes. This method could be used both for "after" data or "before" data (refer to Figure 4).

Such a survey can provide a significant amount of information on trip purpose, modal mix, car ownership, trip length and socio-economic characteristics of trip makers. Usually the costs of data collection are significantly more than when only count data is obtained (often complete count data is required anyway in order to control and expand the interview data), but less than with home interview data.

It is characteristic of this type of survey, that it is complex and sometimes impossible to obtain information on the total universe of trip maker and trips, with the influence area. Relatively complete information is obtained on the majority of impacted trips from a supply change, but little or nothing on the impact on other trips if any. Expansion of socio-economic data on all potential trip makers is also difficult. Since most travel demand models require information about the total travel activity of households, workers or persons, this is sometimes a significant deficiency.

The screenline methodology would seem to have the most promise in measurement of changes which had limited geographic impact. For example, the effect of a newly opened road could be measured by observing all the trips crossing a perpindicular screenline. However, the impact of an areawide car pooling program, or an increase in gasoline price would be more difficult since multiple screenlines would be required and complexities involved in filtering out double and triple screenline crossings; and in getting interview refusals from persons asked for information twice or more times.

Some of the difficulties related to use of screenline methods can perhaps be overcome when coupled with the analysis process shown in Figure 3, and when used in an area that had had a home interview survey within the past 5-8 years. The home interview could be used to calibrate the initial models and the screenline information used to calibrate the update to current "before" conditions and to adjust for the "after" conditions. Some methodology for calibration of models based on screenline data has been developed; an example is attached as Appendix A.

Even at best however, when descrepancies are noted between model estimates and observed data, if the only information available is from screenlines, the problem of realigning, modifying or otherwise adjusting the models and hypotheses is a good deal more complex than if the same problem was faced with the more universal information provided by home interview data.

One other difficulty of the screenline interview concerns the lack of data obtainable from each sample. If roadside interviews are used, the time available for questions is limited and if questionnaires are presented, respondents may get discourated if too many questions are employed. If the license plate, mail out questionnaire is used, perhaps more data can be obtained. However, it may be more desirable to use a more universal sample basis if this is the preferred technique. In this case the method becomes a home interview survey discussed in the next section. This basic difficulty with screenline surveys probably precludes it from being used in a case where data is to be collected only in the "after" mode.

Except for the work trip it may be impossible to obtain "before" information when the question is being asked anywhere from 6 months to a year after the trip; it also would be very difficult to frame a useful comprehensible question concerning how the respondent made "this" shopping trip (or social or business, etc.) before the change.

Interviews of Travelers Sampled at Point of Origin or Destination -- Information obtained from travelers sampled at the point of origin or destination has much to commend it for a number of reasons:

- the respondent is not rushed during the interview and can usually give enough time to provide detailed information
- the information even from a small sample, if carefully drawn, can be expanded to provide the information on the total universe of trips, both those which would expected to be impacted by supply changes and others
- most of the basic information and hypothesis concerning travel demand have been developed primarily from home interview surveys. Such information then is easily compared as between cities and surveys.

Basis for sample design can either be at the residence end of the trip or at the non-residential end (employment location, shopping location, recreation location, etc.). Generally speaking, data obtained from samples drawn at non-residence end is more difficult to expand than residence end samples. Also resident end samples can provide information on trips for all purposes, whereas non-resident end travel is often specialized to a particular purpose. However, there no doubt are some types of supply changes which could be most appropriately sampled from the non-home end. For example, looking through the results of employee sponsored carpool programs, could doubtless be more effectively done by drawing a sample from employer locations.

Data can be collected either by personal interviews, by questionnaires (self administered), or by telephone, or by a combination of all of the above. Probably the most efficient would be from telephone surveys in those areas which have sufficiently high telephone ownership. Even in areas of spotty telephone ownership, if sufficient data are available such that an unbiased sample can be drawn, then much of the data may be actually obtained by telephone, whereas non-telephone households could be interviewed in person.

The home interview or employment end survey can provide information on

- total number of trips made
- purpose of all trips (impacted or non-impacted)
- trip length
- car ownership
- modal mix
- socio-economic characteristics of travelers
- etc.

:ontrols can be established on total population, cars owned, total employment, r screenline information, all data which are obtained independently of the ousehold interview and usually available from other sources, although the creenline data will have to be taken especially for this purpose.

he main objection to household surveys generally has been their costs. omprehensive transportation studies have for years used the household terview as the basic survey mechanisms for obtaining information on trip aking in local areas. The need to develop trip tables and get a reasonable atistical stability on numbers of trips between individual traffic zones have

TABLE 2

SAMPLING RECOMMENDATIONS

Metropolitan Population	Full Survey 1/	Limited Survey 2/
Under 50,000	1 in 5 households (20%)	10%
50,000 to 150,000	1 in 8 households (12%)	5%
150,000 to 300,000	1 in 10 households (10%)	3%
300,000 to 500,000	1 in 15 households (6-2/3%)	2%
500,000 to 1,000,000	1 in 20 households (5%)	1-1/2%
Over 1,000,000	1 in 25 households (4%)	1%

1/ "Conducting a Home Interview Origin-Destination Survey," Procedure Manual 2B, U.S. Department of Commerce, Bureau of Public Roads, Public Administration Service, Chicago, Illinois, p. 3, October 1954.

2/ "Origin-Destination and Land Use," Procedure Manual 2A, National Committee on Urban Transportation, Public Administration Service, Chicago, Illinois, p. 15, 1958.

required that sample rates be reasonably high. For example, as shown in Table 2, a supply change which impacted a 100,000 people would, by conventional standards, require a sample rate of between 5% and 12%, or become between 1,500 to 3,600 interviews.

If home interviews, including drawing the sample, collecting the data and coding the information correctly, costs $30.00 per interview the minimum cost then for such a survey would be $45,000. However, in this case it is not clear that such sample rates are required, since the concern of the studies on system supply impact are related more to aggregate changes in travel characteristics.

The relationship between the relevant variables associated with sample rate is:

$$N = \frac{1 - r}{r} \left(\frac{1.96}{a} \right)^2 C_v^{\;2} \quad \underline{1/}$$

a	=	acceptable margin of error
r	=	sample rate
N	=	number of dwelling units in the area for which data is desired ($N \geq 50$)
C_v	=	coefficient of variation of a population attribute

(Note: The constant of 1.96 is appropriate for a confidence level of 95%)

Since most of the trip characteristics in which we are interested can be expected to have values of $C_v \leq 1.0$ 2/, then the above formula suggests that about 400 interviews are appropriate for accuracy of ± 10% for a wide

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1/ Gary D. Long, "Accuracy of Dwelling Unit Surveys In Travel Forecasting, Traffic Engineering, February 1974.

2/ Ibid., p. 56.

range in the size of the impacted areas. Such a survey would cost about $12,000 at $30.00 per interview. Considering the costs associated with the analysis of the data, this would seem to be appropriate to the scale of the problem. Costs could go higher if the supply change is small such that the probability of any one dwelling unit being impacted is small. In this case a "screening question" could be used over a large number of samples and detailed interviews conducted only for impacted dwelling units.

As noted earlier, extensive screenline counts designed to maximize the catchment of impacted trips should also be conducted along with the dwelling unit survey for control. There also could be a problem with some types of supply changes in certain areas with "external" trips; that is, those which are generated outside the impact area. Where these are believed to be a problem a very low sample roadside interview simply determining the proportion should be adequate. In those cases where significant numbers of trips impacted or generated beyond any reasonable zone of influence, then roadside surveys are the only alternative.

The problems with defining an "influence" area immediately becomes evident as sample design for dwelling unit surveys takes place. In the case of new transport facilities, a set of "trees" for a selected link would very quickly identify the influence area. Some selected manual tree building would also determine the influence area in the absence of a computerized network.

It's recommended that the dwelling unit survey be conducted both before and after the supply change. However, in the event that this is impossible, it may be possible to get adequate data by interviewing only "after" particularly if work and school trips are the main focus of the investigation. As noted before, however, it seems unlikely that one can obtain valid comparisons of other trip purposes by interviewing only "after." It may be appropriate to use the same sample dwelling units both before and after and if interviews are to be conducted to accommodate multiple changes it may be appropriate to pay such respondents in order to obtain continued cooperation. Such "contract" households could simplify the process of sample design.

Network Performance Data

Network performance data is relevant to the question of defining or quantifying the actual system supply change which has taken place. Certain kinds of supply changes are related simply to an adjustment in the monetary price of transportation to the user (e. g., transit fare changes, toll changes, gasoline price changes, etc.). In these cases, network performance information is not required. Normally, however speed data on major links of the transit and highway system will be required both before and after the change. Transportation literature is replete with methodology for conducting such data collection efforts. In some cases, information will also be required on parking costs and availability, terminal times, walking times, etc. As noted earlier, obtaining information on changes in system supply performance is difficult because of the "noise variations" inherent in most urban networks. This probably means that only <u>major</u> system supply changes can be evaluated as a practical matter, unless as noted earlier, a segment of the travel market can be identified and surveyed for which the change is major.

Our knowledge of how to coherently measure the nature of the supply change is lacking in certain instances, particularly with certain para transit schemes. Dial-A-Bus level of service and attractiveness can vary greatly depending on fare, delay time for pick up and route directness. A measurement hypothesis is necessary if we are to construct useful demand models for such service.

Attitude Data

The need for attitudinal data as a valuable assist to the interpretation of differences between observed and model estimated travel behavior changes is clear at a superficial level. Many such attitudinal surveys have been conducted, results published, but the amount of transferrable and quantifiable data has been extremely limited. People cannot always explain why they make particular choices no matter how artfully questions are posed, particularly in an environment in which the choice is made as a result of multiple factors as they are in transportation choices. In general, observing actual behavior has been a more fruitful approach.

However, attitudinal data when coupled with the procedures described in Figure 3 -- that is, where both observed and estimated data based on specific hypothesis is brought to bear on the question might be more fruitful if we know the behavioral model is going awry for a particular purpose or for a particular class of people or for people who choose particular modes attitudinal data might be able to bring into focus reasons for the deficiency. This means that the additional data should be obtained from the same individuals for which behavioral information is obtained so that cross classification is possible between attitudes and behavior. Perhaps the best way to obtain this is to submit a portion of total home interview respondents to attitudinal questions. Attitudinal data and ways to obtain it would be a particularly rich research area itself and should be the subject of the first two pilot projects conducted in accordance with recommendations made earlier. It should be noted that in any case, certain questions which are not behavioral nor attitudinal should be obtained. This would include questions on the extent to which behavior is based on erronous or lack of information concerning the system supply change. For instance, the question "did you know the new road was in operation?" would seem to be a must in any of the home interview data efforts.

CONCLUSIONS

1) The total impact of significant changes in system supply can be enormous -- that is, it can affect virtually all activities in an urban environment. The problem of measuring such broad scale impacts is sufficiently large that it is essential that impact measurements be developed on a modular basis; that is, the analyst will be able to determine what impacts are to be the subject of his focus at the outset and select data collection methods which measure them.

2) It may be that little can be gained from the analysis of changes related to "temporary" supply alterations such as strikes or detours. We have virtually no hypothesis concerning behavioral impacts of such phenomena and little need to estimate such impacts. The lack of hypothesis makes it unlikely that transferrable information will be obtained; further the behavioral impact of temporary changes may tell us little about the impact of permanent changes.

3) The complexities of getting accurate measurements of changes in the system's network performance and travel demand information is such that it may be impractical to analyze any supply changes

other than those of significant size to an identifiable and surveyable segment of the travel market. Travel time data, for example, on networks is difficult to obtain even in the absence of pertubations due to random variations in the weather, accidents, mix of traffic, time shifts, etc. System supply changes then that result in less than 5% to 10% changes in total generalized cost may be not worth the effort; and if generalized cost information is not obtainable there is little point in determining travel behavior information.

4) It is suggested that procedure manuals for data collection be developed in a tentative basis initially and that FHWA make extensive efforts during the first attempts to use the manuals to carry through analysis of the data in order to refine collection procedures.

5) It is believed that the combination of network count data, travel time data, and very small sample home interviews in the impacted area may be the most efficient method of obtaining data. Sample rates lower than normal will probably be appropriate since only aggregate characteristics of travel demand are required (as opposed to information on origins and destinations).

6) In developing this program it is important that both analysis procedures and resources be assured. Concentration on data collection alone, is to risk the development of numerous data sets in local agencies that may never be analyzed. It is believed that there are many surveys already in local files that have never been analyzed, documented or used because of lack of interest and resources available for such purposes.

APPENDIX A

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A Travel Estimation Model Based on Screenline Interviews

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The development of a model which adequately represents the trip generation and distribution characteristics of commercial vehicles has been plagued with problems and a disproportionate amount of data collection. In the Sheffield and Rotherham Study, a synthetic approach has been adopted which obviates the need for both development of the traditional survey frame and much of the costly survey work. The method produces an order of accuracy compatible with other stages of the travel forecasting process and is as good as the usual methods of predicting commercial vehicle travel.

The only necessary survey work consists of driver interviews at screenline stations. In Sheffield, this was done as part of the roadside interview program. These interviews yield a part-filled matrix of observations, and the properties of this matrix are used to synthesize a complete trip matrix.

FORM OF THE MODEL

Recent theoretical studies have shown that a partial matrix, suitably derived, exhibits the properties of the full-movement matrix in terms of trip length distribution, distribution function, and the row and column balancing factors of distribution. This can be demonstrated mathematically.

The procedure requires calibration of a distribution function for the partial observations. Having done this, properties of the gravity model allow the development of factors which are used to compute the full matrix. The following paragraphs describe the way these factors are derived, using the standard gravity model procedure.

The gravity model is often written in the form

$$T_{ij}{}^{E} = a_i P_i b_j A_j F_{ij}$$

where $T_{ij}{}^{E}$ is the estimated number of trips produced in zone i which are attracted to zone j.

P_i is the total number of trips produced in zone i

A_j is the total number of trips attracted to zone j

F_{ij} is a function of the generalized cost of traveling from i to j

and a_i and b_j are constants that are derived such that

$$\Sigma_j T_{ij}{}^{E} = P_i \quad \text{and} \quad \Sigma_i T_{ij}{}^{E} = A_j.$$

(a_i and b_j are in fact the products of the row and column balancing factors respectively over the number of iterations required to make the gravity model converge).

In order to use the model, the row and column balancing factors must be retained from a synthetic distribution of the partial P's and A's. To clarify this, the steps of iteration can be represented as follows:

(1) $T_{ij}^{1} = \frac{P_i A_j F_{ij}}{\Sigma_j A_j F_{ij}}$ which is the singly constrained gravity model

(2) $T_{ij}^{2} = \frac{A_j T_{ij}^{1}}{\Sigma_i T_{ij}^{1}}$ which can be written ${}_2C_j T_{ij}^{1}$ i.e., a column balancing factor times the original formula

(3) $T_{ij}^{3} = \frac{P_i T_{ij}^{2}}{\Sigma_j T_{ij}^{2}}$ which can be written ${}_3R_i T_{ij}^{2}$

or ${}_3R_i\ ({}_2C_j T_{ij}^{1})$

where ${}_3R_i$ is a row balancing factor for the third iteration

and so on until $T_{ij}^{2n+1} = T_{ij}^{2n}$ (i.e., row and column equilibrium is achieved) - when R_i and C_j will remain constant

Then

$$T_{ij}^{2n} = T_{ij}^{2n-1}\ {}_{2n}C_j$$

$$T_{ij}^{2n+1} = T_{ij}^{2n}\ {}_{2n+1}R_i$$

Substituting in the last equation

$$T_{ij}^{2n+1} = T_{ij}^{1} \times \left[{}_3R_i \times {}_5R_i \times \ldots \times {}_{2n+1}R_i\right] \times \left[{}_2C_j \times {}_4C_j \times \ldots \times {}_{2n}C_j\right]$$

$$\text{or } T_{ij}^{2n+1} = \frac{P_i A_j F_{ij}}{\Sigma_j A_j F_{ij}} \left[{}_3R_i \times {}_5R_i \times \ldots \times {}_{2n+1}R_i\right] \times \left[{}_2C_j \times {}_4C_j \times \ldots \times {}_{2n}C_j\right]$$

$$\text{or } T_{ij}^{2n+1} = P_i A_j F_{ij} \times [a_i] \times [b_j]$$

where a_i and b_j are the products of the row and column balancing factors respectively.

$$\text{where} \quad a_i = \frac{{}_3R_i \times {}_5R_i \times \ldots \times {}_{2n+1}R_i}{\Sigma_j A_j F_{ij}}$$

$$b_j = {}_2C_j \times {}_4C_j \times \ldots \times {}_{2n}C_j$$

This is the form of the gravity model given previously which can be expressed as

$$T_{ij}^{2n+1} = R_i C_j F_{ij}$$

The values R_i and C_j are unique values for particular production and attraction zones if the partial matrix theory holds and, having calculated R_i and C_j for each zone using the partial distribution, these values may be used in the above equation to synthesize the number of trips occurring in each cell (ij) of the full matrix.

In actual operation of the model, the partial distribution is constrained over three iterations to the matrix cells which are appropriate to the screenline survey stations using zero K-factors. On the fourth iteration the constraint is relaxed and, having retained the R_i and C_j values, the cell values of the entire matrix are computed. This is done using a new OPTION in AVGM called KANCEL, which causes K-factors to be ignored on the last iteration.

In the final iteration the trip totals are not controlled to the partial P and A values although these contribute to the final totals since they form part of R_i and C_j. Matrix cells which were previously filled from the partial observations retain approximately the same value, while new cells are filled, thereby increasing the row and column totals.

CALIBRATION AND APPLICATION OF THE MODEL

Full synthetic matrices have been developed for light goods (LGV) and heavy goods vehicles (HGV) separately. The calibration was conducted at (150) district level and the steps of the calibration were as follows:

a) Create observed partial LGV and HGV matrices from survey data. It is critical that trips should not appear in these matrices if they would not have crossed a screenline or if there is ambiguity about their crossing or not. It is safest, therefore, to zero illegal cells with OVMOD. This is necessary because non-zero cells do not gain any more trips in the model.

b) Create partial matrix P and A values using PADECT=T in OVTESM.

c) Create district level generalized cost matrix from zonal skim trees. Skim trees were based on the off-peak highway network using the generalized cost formula:

$$GC_{ij} = \text{time}_{ij}\ (\text{minutes}) + 2 \times \text{distance}_{ij}\ (\text{km})$$

d) Derive distribution functions and calibrate for the partial observations in the usual fashion. The distribution functions used are shown in Figure 1.

e) Run gravity model using calibrated functions to create full matrices as described above—compare with screenline counts.

The synthetic full matrices reproduced the observed trip length distributions very well as can be seen in Figures 2 and 3. In addition, the synthetic screenline crossings compare favorably with observed counts.

Once the full matrices have been developed, it is possible to obtain the row and column totals using OVTESM, which gives the total trips produced and attracted by zone. Using standard regression analysis it is then possible to derive trip generation equations in terms of employees by industry type and residents by zone. The usual trip generation and distribution procedures can then be used for travel forecasts.

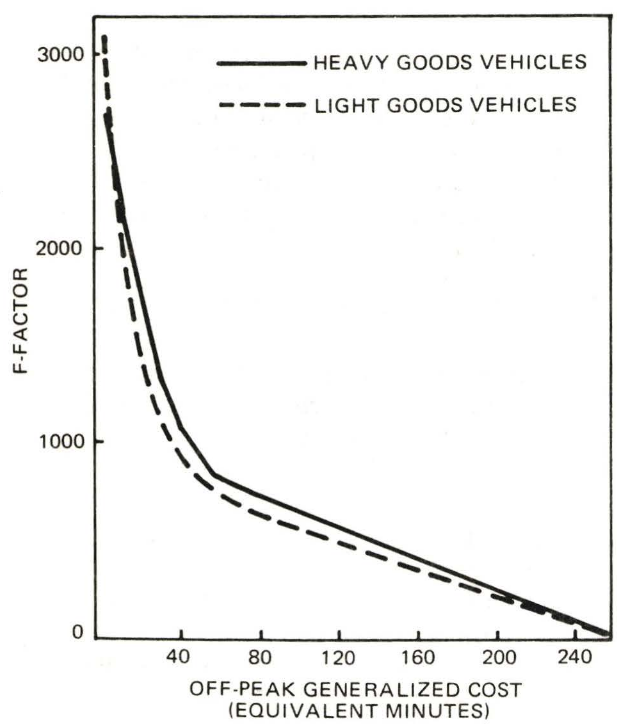

Figure 1. Commercial Vehicle Trip Deterrence Functions

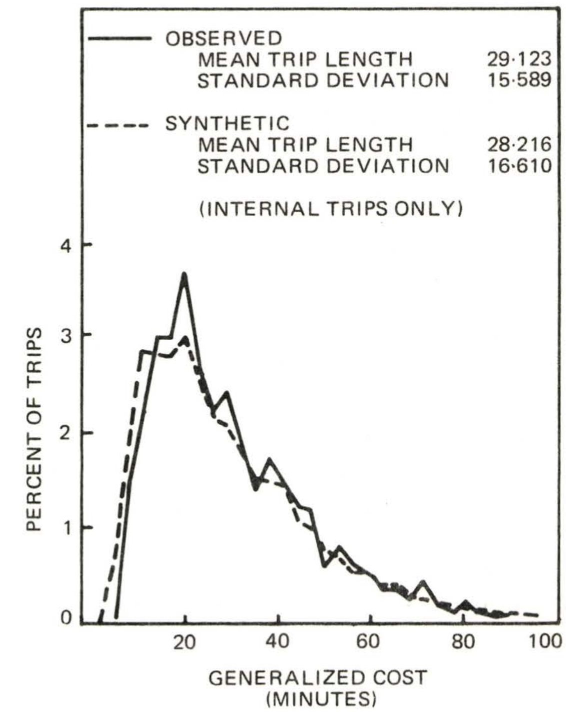

Figure 2. Trip Length Distributions—Light Goods Vehicles

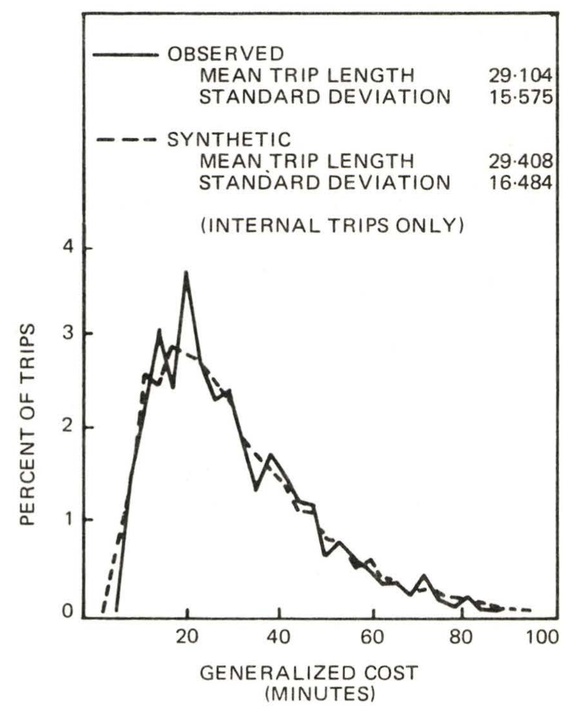

Figure 3. Trip Length Distributions—Heavy Goods Vehicles

Tech Notes

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On the Assessment of Attitudinal and Behavioral Responses to Transportation System Characteristics

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On the Assessment of Attitudinal and Behavioral Responses to Transportation System Characteristics

INTRODUCTION

There is a need for improved planning methods with respect to short-range and low-capital options, such as preferential lanes for buses and carpools, pedestrian malls, parking management practices, etc. Computer and data collection procedures for the urban transportation planning process center on a planning horizon of 20 years, and these techniques therefore tend to be unresponsive to the issues, options, and scale of questions involved in short-range and low-capital options. Nevertheless, the traditional planning methods provide a framework in which to coordinate planning for short-range issues with objectives that need to be satisfied over a more extended time frame.

The requirements of planning methods for short-range and low-capital options are predicated on the responsibilities and backgrounds of various actor groups in the planning process (e.g., transportation planners, transit operators, and political decisionmakers). While it may not be strictly necessary for the detailed computer techniques of the new procedures to be readily understandable, it is imperative that the procedures generate credible forecasts which are linked to meaningful variables for the actor groups in the planning process. The procedures should be capable of implementation within reasonable time and cost limitations. At a more substantive level, there is a need for techniques which can reveal the effects of qualitative variables, such as comfort and convenience. In addition, it is essential to be able to forecast behavioral responses to innovations or evolutions of transportation service which include, but are not necessarily limited to, demand scheduling, carpool priorities, and door-to-door bus pickup. From a political perspective, it is desirable that the new procedures be able to isolate the behavioral reactions and the benefits anticipated by various socio-economic segments of the population. There is an emerging body of literature which shows the relevance of the last issue to the planning process (Dobson and Nicolaidis, 1974; Stopher and Lavender, 1972; Shinn, 1972).

At the present time, the data requirements for the improved planning procedures are not completely specified. The general issue is nevertheless receiving increasing attention. For example, Charles River Associates (1972) reviewed a wide variety of alternative measurement and data collection procedures for assessing the effects of transportation system changes. In addition, Golob and Dobson (1974) proposed a general schema for the assessment of preferences and perceptions towards the attributes of transportation alternatives. While both reports adequately reviewed and criticized measurement and data collection procedures from several different disciplines, neither attempted to recommend specific steps to be taken to gather the necessary data for planning techniques such as those described above. The current report will attempt to provide a basis for such recommendations.

The present report has two primary objectives. In the first place, it will illustrate a methodology for deriving a typology of transportation system changes. These changes include, but are not strictly limited to, the short-range, low-capital options described above. This typology methodology will permit the incorporation of behavioral principles as well as more traditional systems analysis and planning factors. Once a typology is ultimately derived, it will place natural constraints on the data requirements for planning models of transportation options included in the typology. Furthermore, results which are found with respect to one aspect of the typology will have meaningful interrelationships to other aspects of the typology.

Secondly, the report will review and contrast alternative methodologies for assessing the behavioral consequences of transportation changes. The methodological considerations range from sample frame designation and experimental design to modeling procedures appropriate for the output from various questionnaire formats. There will be no attempt to provide an exhaustive list of such techniques, but selected guidelines for implementing data collection with respect to short-range and low-capital transportation options will be carefully reviewed.

Towards a Behavioral Systems Analysis of Transportation Changes

One difficulty associated with formulating guidelines for the assessment of behavioral responses to transportation system changes is the absence of a cohesive framework in which to interpret results found by any methodology. The economic concepts of supply and demand are certainly relevant, but they are insufficient by themselves. The understanding that attitudes can form a basis for emitting one response instead of another is interesting, but only incipient efforts have been made toward empirically testing this understanding in transportation planning contexts. Furthermore, the appropriate temporal period in which to anticipate behavioral responses to transportation system changes has been addressed almost exclusively by noting that adaptation to change is dynamic.

One specific framework for explaining human behavior is provided by Skinner (1953). From his viewpoint, transportation system changes, as indeed changes in any aspect of our physical environment, cause behavior. A particular class of behaviors, such as use of transit or the private automobile, can be increased or decreased by the administration of positive or negative reinforcers, respectively. A positive reinforcer increases the probability of the immediately preceding behavior, and a negative reinforcer decreases the probability of the immediately preceding behavior. In order for a class of behaviors to be positively or negatively reinforced, it must be emitted by an individual, either directly or vicariously.

In transportation planning contexts, use of transit and use of a private automobile can be conceived of as two competing classes of behavior. Although the dichotomy is unnecessarily simple for some applications, it will serve the purposes of the present exposition. If transit fare is increased, then it is likely that some transit passengers will switch to alternate modes while others may limit the extent of their travel behavior by transit. Conversely, if transit fare is decreased, it is likely that some of those using a competing mode will switch to transit and that previous transit passengers will increase the extent of their travel behavior as appropriate. Similar examples can be developed for use of the private automobile and parking fees. An increase in parking fees or transit fares represents a negative reinforcer for use of the private automobile and transit, respectively; decreases of these items represent positive reinforcers.

Table 1 lists a variety of positive and negative reinforcers for use of transit and the private automobile. Because these two classes of behavior compete with each other in part, it is possible to amplify the increase in probability of a behavioral response which results from administration of a positive reinforcer to one class of travel behavior (e.g., use of transit) by applying a negative reinforcer to the other class.(e.g., used of the private automobile). For example, a reduction in transit fare can lead to an increase in transit patronage, but a concurrent increase in parking fees can possibly lead to an even greater increase in transit patronage. Empirical investigations should collect data which would permit the modeling of these phenomena according to synergistic and/or catalytic paradigms.

Students of Skinner's teaching have tended to ignore magnitude of reinforcement effects in order to study other behavioral processes, but in transportation planning contexts information on magnitude of reinforcement effects is essential. While it is interesting to know that both parking fees and transit fares influence transit patronage, it is equally important to know what percentage change in patronage can be anticipated from a shift in the parking fee or transit fare. Fortunately, economists have addressed this issue in the concepts of direct and cross demand elasticities. These economic tools provide a quantitative theoretical framework in which to address magnitude of reinforcement effects in transportation planning contexts.

Reinforcement theory was developed from research with animal subjects, such as rats, pigeons, and chimpanzees. In order for a reinforcer to have a behavioral consequence when it is used with animals, it is necessary for the subject to emit an appropriate response. With humans subjects, it may not be strictly necessary for the subject to emit a response in order for a programed reinforcer to have a behavioral consequence. The subject, or potential transit patron in the context of the present discussion, should become cognizant of the change in his

Table 1
Positive and Negative Reinforcers for Use of Transit and the Private Automobile

Reinforcer Type For	Transit	Private Automobiles
Positive	.Fare reduction .Bus mall .Reduced headways	.Preferential lanes for carpools .Widening a highway
Negative	.Fare increase .Reduced service	.Parking fee surtax .Auto-free zone

transportation environment. In a sense, humans can vicariously develop an appreciation for the change if it is effectively communicated to them. Research by Hovland (1958) and others (Miller and Campbell, 1959; Wilson and Miller, 1968) supports this supposition. Transit advertising and general information campaigns can thus serve a useful role when they are used in coordination with the manipulation of positive and negative reinforcers.

The relevance of user-group specific effects to short-term and low-capital transportation planning models was mentioned above. Within the context of a behavioral systems analysis of transportation changes, user-group specific effects interrelate to reinforcement properties and information campaigns.

A variety of procedures are available for defining user groups. One simple method, which was tested by Stopher and Lavender (1972), involves forming groups on the basis of arbitrary levels of socio-economic characteristics. Dobson and his colleagues (Costantino, Dobson, and Canty, 1974; Dobson and Kehoe, 1974; Dobson and Nicolaidis, 1974) have investigated the suitability of several multivariate statistical and psychometric techniques for defining homogeneous user groups. The results of the above research show improved accuracy of prediction or greater insights about the travel preferences of individuals as a function of segmenting a sample of respondents into homogeneous population groups. Typical stratification variables for forming the homogeneous groups are age, sex, job status, and race. More research is required to reveal unambiguously the relative advantages and disadvantages of alternative procedures for defining user groups.

User-group specific effects relate to reinforcement because the preference for short-term and low-capital transportation options are not invariant across different population segments. For example, carpooling priorities might be moderately attractive (i.e., reinforcing) to one class of users but be irrelevant to another class of individuals. Transit fare reductions and improved transit service represent two other variables which may not have equal appeal to all population segments. Furthermore, it is entirely possible that the number and composition of user groups can vary according to which transportation system change is being examined. Data collection activities for short-term, low-capital options should be designed to take these issues into account. One way of satisfying the latter objective is through appropriate sample design specification.

The temporal course of behavioral adaptation to transportation system changes is not clearly understood at this time. Charles River Associates (1972) addressed the general issue while discussing how to measure the full range of effects induced by transportation changes. For behavioral studies, three classes of temporal effects seem particularly relevant; these can be designated transient, short-term, and long-term. Before-after designs, or whatever other data collection paradigm is ultimately used, should be planned so they can identify which or how many different temporal effects are being assessed.

The transient effects are those behavioral adaptations which result in an initial response to a transportation change which is followed by a relatively rapid return to the approximate response level observed before the change. The temporary closing of a bridge could induce such a change. It is also possible that transient behavioral responses could result from some information campaigns. The latter outcome is particularly likely when the information campaign is not associated with a significant adjustment of the transportation options available to individuals.

Short-term effects are similar to transient behavioral adaptions in that the response to the transportation change is relatively rapid. However, the two effects are different in that short-term effects are relatively long lasting in comparison to transient effects. A transit fare reduction which is coordinated with an effective information campaign is likely to result in a relatively short-term increase in transit patronage. The designation of auto-free zones in segments of the central business district is likely to result in similar short-term effects.

Long-term effects represent a particular difficulty for measurement since they do not occur until a relatively long time period after the implementation of the transportation system change. The intervening duration between the implementation of the change and the ultimate manifestation of the long-term effect permit the occurence of confounding events. Because of these confounding events, it is precarious to assert unequivocally that any observed long-term effects are a consequence of the implemented transportation system change. The installation of a limited access road facility or a subway line is likely to result in long-term behavioral adaptations.

It is unlikely that long-term effects are very relevant to planning for most short-term and low-cost transportation options. These options are attractive from a planning perspective just because their effects are not long-term ones. In any event, when long-term effects do become relevant, careful control features should be interjected into the measurement design to guard against misinterpreting the influence of confounding events.

Towards a Typology of Transportation System Changes

Typologies are important because they help to identify similarities and differences while they set bounds on the sorts of generalizations which are appropriate. Three previous transportation system option typologies will be discussed in this section. In addition, a procedure for deriving a typology for low-cost and short-term transportation options will be presented. The typology which could follow from the application of the procedure can help to structure data collection activities for planning models of short-term, low-cost transportation options.

The Texas Transportation Institute (1972) developed a four-class grouping of transportation changes as part of their research for the Urban Corridor Demonstration Program. The four classes were as follows: (1) line-haul system improvements; (2) low density collection-distribution system improvements; (3) central business district collection-distribution system improvements; and (4) other types of system improvements. In general, it can be seen that the classification scheme was developed along functional lines. In the latter regard, the fourth class is an anomaly because it included transit marketing programs, carpools, signal preemption by buses, and staggered work hours.

In comparing and evaluating 21 low-cost urban transportation alternatives, Dupree and Pratt (1973) reported a three-class typology. These analysts rated each alternative on a series of 13 criteria which included user price impacts, operating costs, effects on disadvantaged, institutional background, environmental impact, and implementation costs. The three classes of the typology were designated (1) all-around most promising techniques, (2) less generally promising techniques, and (3) least useful to achieve project objectives. Perhaps because of the heterogeneous nature of the evaluation criteria, the classes tended to be non-functionally oriented. For example, the second category was comprised of paved railroad right-of-way, freeway metering, and urban goods movement improvements among other items.

Charles River Associates (1972) implicitly developed a typology as a consequence of their research on the measurement of transportation system changes. Their review of a variety of empirical investigations resulted in the three classes of (1) highway studies, (2) transit studies, and (3) demonstration programs. This typology was predicated largely on the modal characteristics of the transportation alternatives.

From the review of the above typologies, it is obvious that there is no standard rule for forming a classification scheme of transportation options. One scheme was based primarily on functional characteristics, another used these characteristics along with institutional, cost, and service variables, but the last typology was based almost exclusively on modal characteristics. Since typologies are rarely created for their own sake but rather to satisfy some other objective, it is reasonable that a typology should be consistent with the features of a general objective.

The objective in the present case is the assessment of behavioral responses to low-cost, short-term transportation system options. Therefore, the typology should be predicated on <u>principles which govern behavioral responses to transportation system changes</u>. Table 2 lists some possible attributes for evaluating options included in the typology; these attributes are drawn largely from the previous discussion of a behavioral systems analysis of transportation changes. The table does not include specific characteristics of transportation service because it is believed that most of these characteristics influence behavior through the more general attributes which appear in Table 2. For the sake of completeness, however, Table 3 lists some specific aspects of transportation service which probably affect behavioral adaptation to transportation system changes.

Table 2
Attributes of Transportation System Options

- Positive reinforcer for transit use
- Negative reinforcer for transit use
- Positive reinforcer for carpool use
- Negative reinforcer for carpool use
- Positive reinforcer for use of private automobile
- Negative reinforcer for use of private automobile
- Transient effect
- Short-term effect
- Long-term effect
- Affects peak-hour trips
- Affects non-peak-hour trips
- Affects travel time
- Affects travel cost
- Affects convenience of travel
- Affects comfort while traveling
- Indirect reinforcer of transient use
- Indirect reinforcer of carpool use

Table 3
Specific Aspects of Transportation Service

Same day-to-day travel time
Arriving when planned
Short rush-hour travel time
Short wait time
Short walking times from parking lot
Short time finding a parking spot
Short travel time
Less time spent walking to a pick-up point
Ease of finding where to go
Stations near home and/or work
Not having to transfer
Direct route
Able to get to many places
Reduced or increased fare
High parking cost
Low toll charge
Low operating cost (e.g. parking, gas, etc.)
Low purchase cost for vehicle (it is influenced by tax on automobiles)
Convenient method of paying fare
Comfortable seats in the vehicle
Protection from weather
Uncrowded in vehicle
Able to get seats at all times
Clean vehicle
More chance of riding in privacy
Less chance of meeting people who make you feel insecure
Pollution reduction
Reduced congestion
Not having to drive
Increased or decreased degree of independence
Chance to relax during trip

Some items which might be included in the typology of low-cost, short-term transportation options are listed in Table 4. The entries in the table were culled from a variety of sources such as the previous listings of Dupree and Pratt (1973) and the Texas Transportation Institute (1972). The order of the transportation options is arbitrary.

The procedure for generating a typology requires a coding sheet such as the one shown in Figure 1. Each transportation option should be evaluated with respect to its relevance to every attribute. Using a method illustrated by Dobson and Kehoe(1974), it is possible to compute a matrix of dissimilarity scores between the full set of $m(m-1)/2$ pairs of transportation options. When more than one expert evaluates the transportation options, their resulting dissimilarity score matrices should be averaged to form one matrix. It is possible to apply any of several clustering algorithms to this matrix so that groups of similar transportation options are determined. These groups of options will be specified in terms of the attributes on which they were initially evaluated.

Since the dissimilarity scores are based directly on the attributes selected for evaluating the transportation options, the typology is necessarily sensitive to the criteria important to the investigators. By noting which attributes are particularly relevant to a given category of transportation options, it is possible to deduce guidelines for the collection of data with respect to options in the category. Related taxonomies of transportation options can be generated from the same technique by varying the attributes and/or the options evaluated.

This general approach for constructing typologies is relatively standard in the social science literature. Two previous examples are demonstrated by D'Andrade, Quinn, Nerlove, and Romney (1972) and Rapoport and Fillenbaum (1972). It should be stressed that the approach is not specific to any particular set of attributes or transportation options. However, the outcome is sensitive to the experts. Different groups of experts can produce different typologies even when they use the same attributes and transportation options.

Some Data Collection Considerations: Sample Selection and Experimental Considerations

As mentioned above, this report is not concerned with developing an exhaustive list of data collection procedures, for transportation planning or any related purpose. However, in this section selected considerations will be presented with respect to sample frame selection, experimental design, and questionnaire specification. Detailed treatments of these topics can be found in other sources (Cannell and Kahn, 1953; Kerlinger,

Table 4
Transportation System Options

Preferential freeway lanes for buses and carpools
Priority metered ramps
Widening of highways
Researved lanes at toll plazas
Contraflow bus lanes
Express bus service
Increased coverage of transit service
Reduced headway for transit
Bus only streets in the central business district
Scheduled local bus service
Demand responsive local bus service
Central business district shuttle service
Signal preemption by buses
Auto-free zones
Preferential parking schemes for carpools
Restriction of on-street parking supply
Transit fare reductions
Parking fee surtaxes
Tolls for low-occupancy vehicles
Information campaigns for transit service
Transit marketing
Carpool matching programs
Work schedule changes

Transportation Attributes

Transportation Options

	A_1	A_2	A_3	...	A_n
O_1	1	3	1	...	2
O_2	2	3	1	...	1
O_3	3	1	2	...	1
.				...	
.				...	
.				...	
O_m	1	1	1		3

Evaluation Code

1 - very relevant
2 - of intermediate relevance
3 - not relevant at all

Figure 1. A coding sheet for the generation of a typology of transportation options.

1973; Kish, 1965; Lansing and Morgan, 1971; Lindquist, 1953). In addition, specific illustrations of questionnaires used to collect behavioral and attitudinal data abound in the transportation literature. Specific examples can be found in the work of Dobson (1973), Golob (1970), Lovelock (1973), Nicolaidis (1974), Spear (1974), and Wachs (1967).

When collecting behavioral and attitudinal data for low-cost, short-term transportation planning policies, it is imperative that the particular options under study set guidelines for any data collection activities. For example, some transport policies, such as express bus service, relate only to peak-hour work trips. In the latter case, the sample frame should be comprised exclusively of individuals who make such trips even if the sample designation procedure results in a departure from standard practice (e.g., obtaining a probability sample). Leslie (1972) has reported that a **large representative sample may not be necessary when the population** being examined is relatively homogeneous. It is known that on-board surveys recover biased samples for the population of urban travelers. However, if it is necessary to study perceptions and preferences of travelers who shifted to transit from the private automobile as a function of the manipulation of a transport policy, it may be appropriate to cheaply screen on-board respondents to find a sample of individuals who shifted modes.

The collection of data with respect to transportation changes should be particularly sensitive to induced or latent demand and foregone trips. For example, the introduction of dial-a-bus service might increase the trip generation rate of nondrivers . On the other hand, a parking fee surtax might result in a decline of trips directed toward certain sections of a metropolitan area. Sample and experimental designs should be structured so they can readily assess such behavioral adaptations to transportation changes.

The discussion of a behavioral systems analysis for transportation change stressed the linkages between travel behavior, preferences for attributes of transportation service, and knowledge about the characteristics of the existing transport supply. Data collection activities should emphasize the same three classes of variables. It is important to collect information about the transportation alternative actually selected, but data on existing unselected alternatives and planned future options will no doubt be helpful in developing accurate models for planning purposes. The data on selected, unselected, and planned alternatives should include information on attributes of the options which are responsible for their choice by various user groups. When an information campaign is being studied, the media exposure of user groups is critical because it suggests how to organize the campaign as well as who to include in the sample design.

Experimental design is as important as sample specificaiton for many data collection activities. Campbell (1957) and later Campbell and Stanley (1966) discussed before-after designs and their relationships to the validity of experiments in social settings. Charles River Associates (1972) illustrated some weaknesses of the designs recommended by Campbell for social experiments, including those in transportation research. The two main criticisms were selection bias and long-term confounding events. For the low-cost, short-term planning options being examined in this report, long-term effects are not of central concern.

Selection bias describes a situation in which experimental and control groups are different in other respects besides the implementation of the experimental manipulation. For example, if the experimental group were more prone to use transit than the control group, then selection bias would be exhibited. When it can be assumed that the experimental and control groups will respond similarly to time-dependent but irrelevant variables, then the before-after design, which is illustrated in Figure 2, can produce valid results; the former assumption will hold most readily for transient and short-term behavioral adaptations to transport system changes. The difference between G12 and G11 with respect to the difference between G22 and G21 measures the magnitude of the behavioral response to the policy manipulation. Time-dependent but irrelevant effects are adjusted for by the the comparison.

<u>Some Data Collection Considerations: The Assessment of Behavior, Subjective Reactions, and Information</u>

Whenever it is possible and feasible, travel behavior data should be collected in a format which is compatible with urban origin-destination surveys (U.S. Department of Transportation, 1973). By this procedure, it may be possible to coordinate the planning for low-cost, short-term transportation options with the 3-C urban transportation planning process. To the extent that the short-term and long-term planning data bases are compatible, it will also facilitate the generalization of results found in one urban area to other urban areas. However, it is urged that data collection of travel behavior extend beyond that for the origin-destination questionnaire, especially with respect to alternative modes and route choice.

Another area in which origin-destination surveys are in need of extension with respect to the collection of data for short-term planning options is individuals' subjective reactions. The term subjective reactions is used to designate a class of verbal statements which include (1) the perception of similarity among transportation-related alternatives and their attributes, (2) the expression of preference for transportation-related alternatives and their attributes, (3) the evaluation of satisfaction with transportation-related alternatives in general and with respect to specific attributes, and (4) the behavioral intention to select a transportation-related alternative. Some or all of these subjective reactions presumably exert influence over individuals' overt behavior toward transport alternatives. The specification of the relevant relationships will greatly enhance the facility with which effective plans can be developed for short-term, low-cost options. The collection of data on subjective reactions is a necessary first step to the specification of the desired relationships.

	time period 1		time period 2
Group 1	G11 ---------->	X ----------->	G12
Group 2	G21 ---------->	----------->	G22

Figure 2. A before-after study design recommended by Campbell and Stanley (1966). X denotes the implementation of a policy change for group 1. There is a blank between time periods 1 and 2 for group 2; this blank denotes no change in transport policy.

Both because of the multifaceted nature of subjective reactions and the variety of quantitative models available to process subjective reactions, there are numerous formats, with associated advantages and disadvantages, for the collection of data. Among those which have been applied in transportation research are (1) rating scales, of the category or ratio response type, (2) ranking, (3) paired comparisons, (4) pick k on n-1, and (5) semantic differential forms. An example of each response format will be presented as it is discussed.

In the rating scale format, a response, either a category or a ratio judgment, is assigned by the respondent to each item to be evaluated. Figure 3 shows sample instructions for a category rating task (Dobson, 1973). In the example shown, there are seven response categories; research by Green and Rao (1970) suggest that this number of categories is optimal from at least one perspective. The number of response categories should probably stay within plus or minus two of seven.

The ratio scale rating format has not been as widely applied in transportation research as the category scaling procedure. Although the ratio scaling format has been touted by Stevens in numerous publications (Steven, 1956; 1957; 1966; 1969; Stevens and Galanter, 1957), it has only been applied by a couple of transportation researchers to the author's knowledge (Ewing, 1973; Shinn, 1972). While the ratio scale format can be used to derive a more meaningful scale of subjective reactions than can be obtained with a category scale format, it requires a more sophisticated judgment from the respondent. If the respondent cannot make the more sophisticated response reliably, then the data collected with a ratio scale format can be useless.

Data collected with either category or ratio response formats can be processed in a variety of ways. Several simple tabular and graphical techniques for processing category data are illustrated by Ryan, Nedwek, and Beimborn (1972) in the context of a transportation planning problem. A more exotic econometric treatment of category data is illustrated by Sherret (1971). Finally, Golob, Dobson, and Sheth (1973) used multivariate psychometric procedures to determine what factors were most preferred by individuals in the private automobile and transit.

When the number of items to be evaluated by a respondent is relatively small, a ranking task is easy for the respondent and produces data which are acceptable to nonmetric multidimensional scaling models (Kruskal, 1964(a), 1964(b)). Nicolaidis (1974) applied the ranking task to help define a comfort index for various transport modes; sample ranking instructions are shown in Figure 4.

Ranking tasks have a certain appeal because they require the subject to make a weaker judgment than either ratio or category scale formats. As the number of alternatives to be evaluated grows large, the ranking task can become infeasible because of the excessive number of camparisons required. While ranking data are suitable for a variety of computer

Thinking about when I would use Public Transportation for longer trips and where I might go-This Feature is This Important to Me:	Extremely Important	Very Important	Somewhat Important	Neither Important Nor Unimportant	Somewhat Unimportant	Very Unimportant	Extremely Unimportant
Having a short time waiting for a vehicle	7	6	5	4	3	2	1
Having short travel times	7	6	5	4	3	2	1
Having low fares	7	6	5	4	3	2	1
Having a comfortable ride in a quiet vehicle	7	6	5	4	3	2	1
Having a driver instead of a completely automatic system	7	6	5	4	3	2	1
Having my own private section in the vehicle	7	6	5	4	3	2	1
Being able to get where I want to go on time	7	6	5	4	3	2	1
Being safe from harm by others and from vehicle accidents	7	6	5	4	3	2	1
Having room for strollers or wheel chairs	7	6	5	4	3	2	1
Being able to get to many places in the Detroit area using the guideway	7	6	5	4	3	2	1
Having refreshments and newspapers for sale at stations	7	6	5	4	3	2	1
Having control of temperature in the vehicle	7	6	5	4	3	2	1

Figure 3. Sample instructions and response sheet for a category rating task.

Question 1.

Each of the means of travel stated in the list, will be singled out in turn. In table 1. below, Automobile was first singled out, then Taxi, followed by Walking, Hitching, Bus, Mortocycle, and Bicycle was last. For each reference means of travel, select from those remaining the one that you think is most similar to the reference item, in respect of the comfort feelings generated by these means of travel upon you. Put its identification letter in the rank-1 position. Then find the means of travel which is next most similar to the reference item and put its identification letter in the rank-2 position, and so on. Please state your judgments as they relate to your home to work trip.

Example.

In table 1. below, Automobile was first singled out, so Automobile is the first reference item. The remaining means of travel are: Taxi, Bus, Bicycle, Motorcycle, Walking and Hitching. Select from those, the one that you think is most similar to Automobile in respect to comfort, and put its identification letter in the box immediately below Automobile indicated by 1 ( ). Once you have filled all 6 boxes below the Automobile, proceed to the next reference item, Taxi and so on.

We would like you to consider the following definition of comfort when stating your judgments:

"Comfort represents a measure of satisfaction associated with the environment within which one is traveling and the extent to which a trip is enjoyed or not."

Table 1.

A. Automobile	B. Taxi	F. Walking	G. Hitching	C. Bus	E. Motorcycle
1 ( )	1 ( )	1 ( )	1 ( )	1 ( )	1 ( )
2 ( )	2 ( )	2 ( )	2 ( )	2 ( )	2 ( )
3 ( )	3 ( )	3 ( )	3 ( )	3 ( )	3 ( )
4 ( )	4 ( )	4 ( )	4 ( )	4 ( )	4 ( )
5 ( )	5 ( )	5 ( )	5 ( )	5 ( )	5 ( )
6 ( )	6 ( )	6 ( )	6 ( )	6 ( )	6 ( )

D. Bicycle
1 ( )
2 ( )
3 ( )
4 ( )
5 ( )
6 ( )

Figure 4. Sample instructions and response sheet for a ranking task.

programs designed to implement nonmetric models (Kruskal and Carmone, 1969; McGee, 1966; Young and Dobson, 1972; Young and Torgerson, 1967), it has recently been suggested that nonmetric models may be subject to greater computational cost, vulnerability to degeneracy, and undue sensitivity to error variance (Kruskal and Shepard, 1974).

Paired comparison tasks involve pairing each item with every other item to be evaluated. The rater's responsibility is to select the item which is most preferred in each pair. Golob, Canty, Gustafson and Vitt (1972) applied a modification of this technique to measure preference for attributes of dial-a-bus service via Thurstone's law of comparative judgment (1927). A sample segment of their questionnaire is shown in Figure 5.

One difficulty associated with the unmodified paired comparison procedure is that the number of judgments increases as a function of the square of the number of items. For a large number of items, the paired comparison task would require too many judgments. However, by not requiring the respondent to evaluate each pair of items, it is possible to appreciably reduce the number of comparisons. While the latter procedure is effective in achieving its stated goal, it has the undesirable side-effect of generating missing data. This property can be important in the context of certain applications.

The response formats considered so far have been used to collect dominance data. Respondents were instructed to (1) rate items on a "1" to "7" importance scale, (2) rank transport modes for their comfort, or (3) select the most preferred of two attributes. Perceptual similarity data are different from dominance data in that entities are not evaluated for how they satisfy some criterion but rather for how they relate to each other. Empirical studies by Cooper (1973) and McDermott (1969) have shown that dominance and similarity data reveal different characteristics for a set of entities, and Cliff, Bradley and Girard (1973) have speculated that perceptual similarity may form a basis for dominance data.

Dobson and Kehoe (1974) have used multidimensional scaling models applied to perceptual similarity to account for satisfaction judgments with innovative urban transport technologies. They used a pick k of n-1 task. That is, responsents were asked to indicate how many of n-1 attributes were similar to the nth attribute; in general, k attributes are selected as similar. The value of k is bounded in the range, $0 \leq k \leq n-1$. Figure 6 shows a page from the booklet which was used to collect the similarity data.

While there are alternate ways to collect perceptual similarity data, the pick k of n-1 task has the virtue of being more rapid to complete. In addition, it requires only a simple yes-no judgment from the respondent. Finally, it is possible to modify the pick k of n-1 response format shown in Figure 6 to facilitate the collection of dominance data as well.

The semantic differential technique was originated by Osgood, Suci, and Tannenbaum (1957) as a combined data collection and data analytic procedure.

GROUP C

This set of decisions deals with the interior design and structure of the vehicle that might be used in a new transportation system. For example, some of the choices will involve the amount of light, air, heat and sound around you in the vehicle, the exit and entry ways and several more.

Again, select your choice by circling the letter A or B, whichever is appropriate.

1\.
A. Ability to adjust the amount of light, air, heat and sound around you in the vehicle.
or
B. Easier entry and exit from the vehicle.

2\.
A. Easier entry and exit from the vehicle.
or
B. Lower fare for passengers.

Figure 5. Sample instructions and response sheet for a paired comparison task.

Please read the feature enclosed in the box at the top of this page. Then read each feature listed below it. If you feel the two features are alike "X" the "yes" box. If you feel the two features are not alike "X" the "no" box. Please "X" either "yes" or "no" for every feature listed below.

Is **BEING ABLE TO GET WHERE I WANTED TO GO ON TIME** like:

	Whether This Is Like the Feature Above:	
Having my own private section in the vehicle	yes ☐	no ☐
Having short travel times	yes ☐	no ☐
Having a short waiting for a vehicle	yes ☐	no ☐
Having low fares	yes ☐	no ☐
Having a comfortable ride in a quiet vehicle	yes ☐	no ☐
Having a driver instead of a completely automatic system .	yes ☐	no ☐
Being safe from harm by others and from vehicle accidents	yes ☐	no ☐
Having room for strollers or wheel chairs	yes ☐	no ☐
Being able to get to many places in the Detroit area using the guideway	yes ☐	no ☐
Having refreshments and newspapers for sale at stations. .	yes ☐	no ☐
Having control of temperature in the vehicle	yes ☐	no ☐

Figure 6. Sample instructions and response sheet for a pick k of n-1 task.

As a response task, the semantic differential requires the respondent to evaluate a concept, for example travel by transit, in terms of a series bipolar attributes. Figure 7 shows a semantic differential response sheet used in a transit market survey for the Orange County Transit District 1/. It can be seen that each line of the semantic differential sheet is bounded by two adjectives with opposite meaning; these adjective pairs are described as bipolar. The semantic differential employs a category scaling response procedure within the context of a series of bipolar scales.

The seven-point bipolar rating scale is easy to administer to respondents, and it yields data which can be readily analyzed by traditional factor analytic procedures (Dobson and Hepper, 1974; Horst, 1965) as well as more innovative procedures (Carroll and Chang, 1970; Tucker, 1966, 1972). It is possible that a respondent would not view a particular scale as bipolar. In such a case, the data from the respondent would be useless. When the adjective pairs are carefully chosen by the analyst this is an unlikely outcome.

Measuring subjective reactions to transport alternatives is important since such reactions presumably form the basis for reactions to the alternatives. The measurements are not an end in themselves. They form guidelines for the development of socially acceptable transportation plans. However, unless users are aware of the positive and negative reinforcers built into a plan to modify travel behavior, they are unlikely to change their overt behavior to transport alternatives.

The above set of relationships places emphasis on assessing the differential media exposure of alternative population segments and on the degree to which an information campaign reaches specific population segments. By linking a profile of subjective reactions for a population segment to the media exposure of the segment, it will be possible to structure an information campaign around appropriate themes and to display the campaign so that it attains the greatest possible exposure with the intended audience.

Lovelock (1973) was able to report on the basis of a cross-sectional sampling procedure that there was a positive relationship between an individual's knowledge of transit and his use of transit. One interesting application of behavioral assessment to transportation system changes would be the empirical testing of the latter finding in a longitudinal sample design which is coordinated with an information campaign. Since information campaigns are likely to be linked to varying modifications of system operating policies, it is reasonable to repeat the empirical test under a range of different transportation system changes.

1/. The transit market survey was kindly provided by Douglas P. Blankenship, Associate Transportation Planner, Orange County Transit District.

YOUR OPINION OF BUS TRAVEL IN ORANGE COUNTY

BUS TRAVEL CHARACTERISTICS

	1	2	3	4	5	6	7	
comfortable	___	___	___	___	___	___	___	uncomfortable
late	___	___	___	___	___	___	___	on time
simple to use	___	___	___	___	___	___	___	complicated
safe	___	___	___	___	___	___	___	dangerous
old-fashioned	___	___	___	___	___	___	___	modern
slow rush hour trip	___	___	___	___	___	___	___	fast rush hour trip
high status	___	___	___	___	___	___	___	low status
inconvenient	___	___	___	___	___	___	___	convenient
fast non-rush hour trip	___	___	___	___	___	___	___	slow non-rush hour trip
unenjoyable	___	___	___	___	___	___	___	enjoyable
inexpensive	___	___	___	___	___	___	___	expensive
unreliable	___	___	___	___	___	___	___	reliable
relaxed	___	___	___	___	___	___	___	tense

Figure 7. Sample semantic differential response sheet.

Summary: Recommendations

The overall goal for this report is the provision of a basis for setting standards for the collection of data with respect to short-term and low-cost transportation options. In attempting to provide a basis, it was necessary to discuss principles which might ultimately lead to a behavioral systems analysis of transportation change. In any event, it is strongly urged that data collection activities for short-term, low-cost options not be solely bounded by ad hoc positions predicated on contingencies which will vary from one situation to the next, but that they be bounded by a variety of well-founded theoretical frameworks.

It is recognized that not all transportation options will require the same approach to data collection. An understanding of the unique variables through which different classes of transportation changes influence behavior needs to develop. In the latter regard, a procedure for arriving at typologies of transportation changes is recommended. The procedure is analytical, and it thereby avoids some possible biases associated with human judgment. At the same time, the procedure can be reapplied to test the sensitivity of the typology to (1) the insertion and omission of different transportation options, (2) the specification of varying attribute sets for the options, and (3) the composition of the experts who judge the relevance of the attributes to the options.

While an adequate typology of transportation changes will help to set guidelines for data collection activities, it is also necessary to consider sample specification and experimental design. Before-after studies represent an attractive means of studying behavioral adaptations to short-term, low-cost transport options. Charles River Associates (1972) have identified several weaknesses of these designs for long-term effects. Alternative control group strategies should be evaluated for their usefulness in any particular transportation planning context. One design, which is likely to be very useful in many contexts, is described above.

It is stressed that data collection activities for short-term, low-cost options should revolve around (1) travel behavior, (2) subjective reactions to transportation-related alternatives and their attributes, and (3) knowledge of transport alternatives. When travel behavior is collected it should be compatible, insofar as is possible, with traditional urban origin-destination surveys. Nevertheless, there is a clear need to go beyond what has been done before. The latter is particularly evident with respect to alternative modes, route choice, subjective reactions which can mediate overt behavioral responses, and knowledge of transportation-related alternatives.

The art of behavioral assessment in transportation research is still too primitive to make any dogmatic assertions. However, it does appear that certain data collection formats may be superior to others in a transportation planning context. Three formats, namely category scaling tasks, pick k of n-1 tasks, and semantic differential tasks, appear to be more robust than ranking and paired comparison tasks in terms of the ease with which respondents can use them and the class of models which can be conveniently applied to the resulting data. It is strongly recommended that data collection activities gather similarity as well as dominance data. It is likely that both classes of data play meaningful roles in mediating overt travel behavior.

In closing, it is urged that data collection activities be structured so that they are compatible with a variety of theoretical formulations of travel behavior; the theme of multiple theoretical perspectives was previously developed in considerable depth by Golob and Dobson (1974). The assessment of alternative urban transportation plans should benefit from an examination according to more than one viewpoint. It is in these multiple viewpoints that a basis for the assessment of behavioral adaptation to transportation changes can ultimately be derived.

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DESIGN OF PROCEDURES TO EVALUATE TRAVELER RESPONSE TO CHANGES IN TRANSPORTATION SYSTEM SUPPLY

A WHITE PAPER

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THE PURPOSE OF TRAVEL BEHAVIOR ANALYSIS

The objective in conducting "before and after" studies of the impact transportation system changes have on traveler behavior is to increase our useful knowledge of that behavior. Knowledge of travel behavior can be expressed in the form of travel demand forecasting techniques, mathematical/behavioral models, and statements of findings. All of these have their place in the practical application of travel behavior information.

It is important to understand that practical applications of travel behavior knowledge are many and varied. The extent of these applications defines the breadth of information that is needed concerning travel behavior. Uses of travel behavior knowledge include:

- Choice and design of transportation facilities, including placement for maximum service and sizing for adequate accommodation of demand.
- Design and operation of transportation services, such as bus service, for maximum cost effective benefit and attractiveness.
- Selection of transportation policies and strategies, whether these be to minimize vehicular pollution, conserve energy, maximize use of existing transportation investment, or promote beneficial land use.
- Analysis of social or environmental benefits or disbenefits of alternate transportation decisions, as an aid to decision making.
- Prediction of travel demand, revenues and costs to assist in the development of transportation related financial programs.

THE THEORETICAL BASIS OF TRAVELER RESPONSE

To obtain maximum utility from future surveys and investigations of traveler behavior, it is imperative to make the most of existing knowledge to insure sound survey and research design. Toward this end, this section and the next provide brief discussions of travel behavior theory and travel response variables.

The Nature of Traveler Response

The preponderance of evidence suggests that most travel behavior is rational. The choices made appear to be largely economic. Most urban travel is undertaken to achieve some objective at the end of the trip, and in deciding if and when to go, where to go, and how to travel, the individual appears to be seeking the least cost choice compatible with his trip objective. The terms "economic" and "cost" are of course used here in the broad sense, covering time, convenience and related factors as well as monetary expense.

The travel choice must necessarily be made according to an individual's own perception of travel costs. The choice may therefor be affected by lack of information and inaccuracy of measurement on the part of the individual, and will reflect differing attitudes and value systems among individuals. This does complicate analysis of travel demand as a rational response. However, individual responses appear to follow a pattern that can be described statistically using standard formulations for variances within populations. Thus a framework for behavioral analysis and forecasting of travel demand does exist, and has already been used extensively.

Determinants of Traveler Response

Traveler response is shaped by the needs which must be met by trip making, the circumstances of the trip maker, and the transportation system afforded him. In travel demand analysis these are commonly accounted for by considering the household and individual characteristics of the trip maker, the travel options available for the trip, and general characteristics of the transportation system that may impact the decision mechanism. These are the household variables, trip maker variables, trip variables, and non-trip specific system variables of the travel demand estimation process. The next section covers travel demand variables in more detail.

Manifestations of Traveler Response

Traveler response manifests itself in the decision to make or not make a trip, the selection of a destination, the selection of a time to travel, the selection of a mode, and the selection of a route within that mode. Selection of a time to make the trip is an aspect of traveler response that has been largely overlooked other than to treat it in the aggregate with experience based factors. The other aspects of traveler response equate to the trip generation, trip distribution and mode choice/route choice elements of sequential travel modeling. Even if one is attempting to model traveler response in a single equation, as in direct demand travel forecasting, it is useful to recognize the involvement of trip generation, distribution, and mode choice.

Figure 1 has been prepared to emphasize the possible manifestations of traveler response, and to illustrate how they can all be considered as possible consequences of an economic decision process. Figure 1 uses the work purpose trip of a resident in "Zone A" as an example. The concept of disutility is introduced to describe the basis for economic choice. Disutility is something to be minimized. It represents the time, inconvenience and monetary cost of travel and any limitations accepted in meeting the desired trip objective.

Consider the member of the labor force in Figure 1 who chooses to work in Zone B and travel via Transit Route "a." He finds Transit Route "a" to have the least disutility of the modes and routes available to him (mode and route choice). He accepts the disutility of job competition at Zone B by others convenient to that area, and he accepts whatever disutility is involved in not choosing from among the jobs in Zone C in order to avoid larger travel disutilities (distribution choice). He prefers the total disutility of his response (disutility $p + v + x$) to the disutility of having no job (generation choice). Choosing unemployment and making no trip is one of the possible traveler response manifestations, as is choosing possible underemployment in order to work in an easy to get to area. Comparable choices apply as well to non-work purpose trips.

THE VARIABLES OF TRAVEL DEMAND

Discussion of the variables actually used or studied in connection with travel demand forecasting requires a drawing back from the preceding theoretical discussion to the realities of travel response knowledge as it exists today. Relatively little has been done with examining the underlying needs that cause urban travel. The incidence of travel is simply forecast as a function of land use and household descriptors, with infrequent inclusion of transportation system variables. Even when it comes to estimating the distribution and mode choice of travel, given that it will occur in some form, there are significant gaps in the knowledge of the many complex factors and interrelationships involved.

Nevertheless, there is a large body of knowledge already available as to demand variables and their effect. Table 1 attempts to list the travel demand variables along with an indication of what is known concerning their influence on travel response.[1/] Study of this tabulation will serve to indicate not only areas needing investigation but also, and most importantly, the complexity of variables and interrelationships that must be taken into account in designing procedures to evaluate traveler response.

1/ This tabulation has been produced without benefit of extended review of the literature. A number of the unknowns indicated may well have been addressed in published research. Indeed, this tabulation and its deficiencies point up the need for a literature review directed to the categorization and abstracting of travel response findings already available.

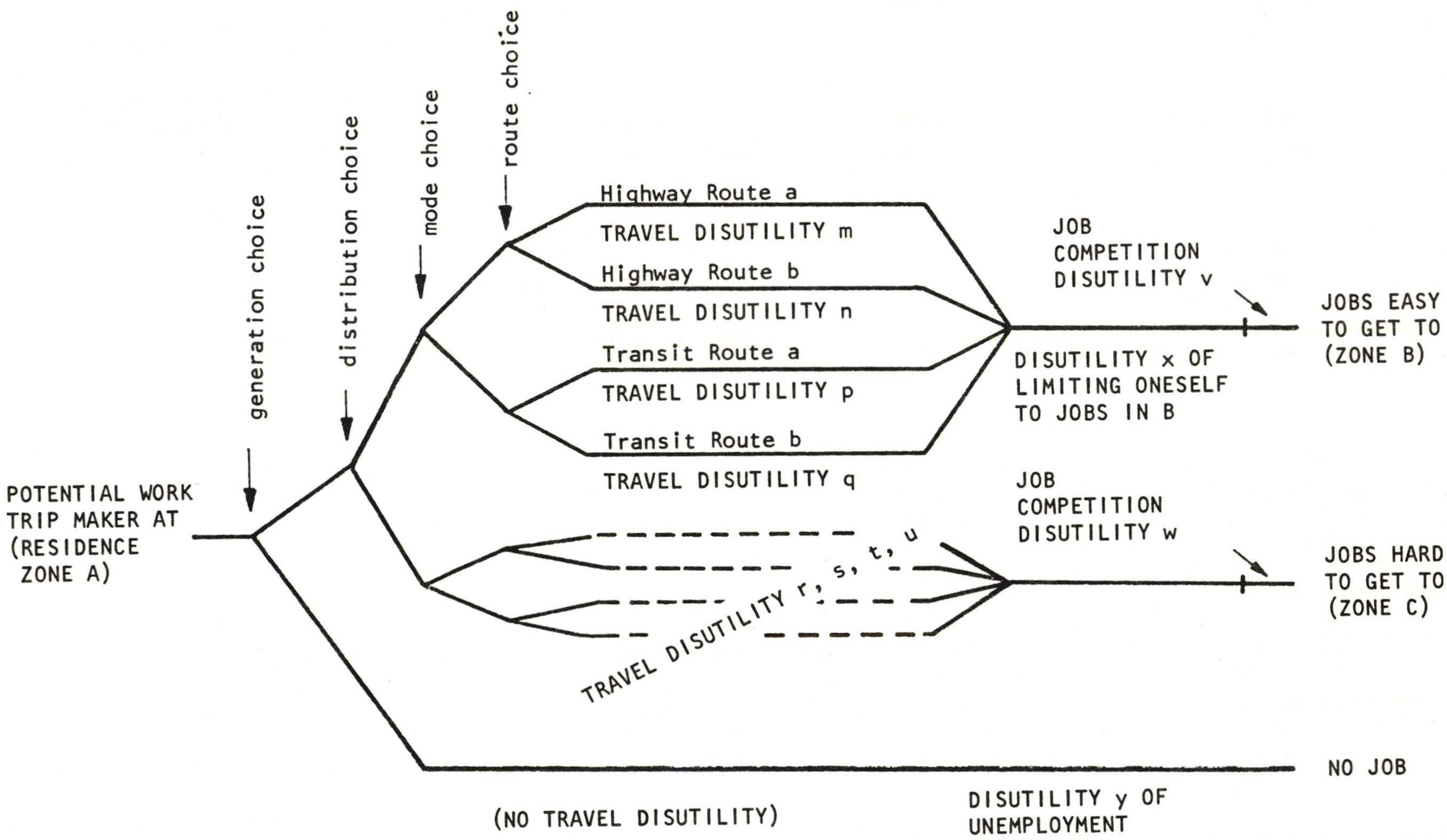

Figure 1. Manifestations of Traveler Response--Shown as a Trip Generation Through Route Choice Decision Tree

TABLE 1

VARIABLES AND THEIR EFFECT ON TRAVEL RESPONSE

Variable	Effect on (and status of knowledge concerning)			
	Trip Generation	Trip Distribution	Mode and Route Choice	Comments
HOUSEHOLD VARIABLES:				
HOUSEHOLD INCOME Worker Income Home Value/Rent	Known that higher trip generation is associated with higher income. Not known extent to which this is direct function of income vs. income acting as surrogate for auto ownership and residential location.	Known that work trip linkages involve matching of worker and job income. Not known to what extent income influences willingness to trade off satisfaction of trip objectives against trip cost savings.	Known that monetary trip cost weighed less by higher incomes whereas trip time may be weighed more. Transit/Auto Passenger captivity higher and Auto Driver captivity apparently lower for low incomes. More quantification needed.	Effects calculation of utility measures. Predictive problem in that public agencies tend to estimate high. Problem of choosing worker vs. household income. Useful in examining social value of transportation services.
AUTO OWNERSHIP Licensed Drivers in Household	Known that higher trip generation is associated with higher auto ownership. Not known to what extent this would still be true if walk trips counted.	Auto availability required for full use of travel opportunities in interchanges with little or no transit service.	Influences degree of transit captivity.	Requires careful prediction using essentially the same basic inputs as travel models themselves.
FAMILY COMPOSITION Number of Persons in Household Number of Workers in Household	Family needs and therefore trip generation are affected by stage in family life cycle. Not well studied.	Effect, if any, unknown.	Effect, if any, unknown	Not normally predicted.

TABLE 1

VARIABLES AND THEIR EFFECT ON TRAVEL RESPONSE (Cont'd)

Variable	Effect on (and status of knowledge concerning)			
	Trip Generation	Trip Distribution	Mode and Route Choice	Comments
RESIDENTIAL DENSITY Type of Residence	Known that lower trip generation associated with higher density. Not known to what extent density is a surrogate for family composition and/or walk trip prevalence.	Effect, if any, unknown.	Known that higher transit use generally associated with higher density. Thought to be a surrogate for short walk distances to transit, high transit accessibility, and other factors.	Relatively easy to predict and thus often used as a surrogate.
SOCIO-ECONOMIC STATUS Race	Effect, if any, not known (aside from effect of income or occupation).	Effect, if any, not known (aside from effect of income or occupation).	Not known extent to which "acceptability" of mode influences mode or route choice.	Many but not all effects can be identified through use of the income variable.
<u>TRIP MAKER VARIABLES:</u>				
OCCUPATION Employment Classification	Known that trip production is higher for higher ranking occupations, but with dissimilarities primarily related to income.	Real world work trip linkages involve matching of worker and job classification.	Not known extent to which reported low usage of transit by blue collar workers is other than simply the effect of trip distribution and other exogenous factors.	Not normally used or studied as a predictive travel demand variable.

TABLE 1

VARIABLES AND THEIR EFFECT ON TRAVEL RESPONSE (Cont'd)

Variable	Effect on (and status of knowledge concerning)			
	Trip Generation	Trip Distribution	Mode and Route Choice	Comments
AGE	Young and old make fewer work trips; other trips may be more influenced by transit accessibility than average. Not well studied, especially impact on serve passenger trips.	Effect unknown.	Known that young, older and old use transit more. In the 40-65 age group, not known if higher transit use is a function of captivity, trip distribution or habit.	Not normally used or studied as a predictive travel demand variable. Useful in bus service design and in understanding social value of special transportation services.
SEX	Not well studied.	Not well studied.	Known that women use local transit more. Not known if this is a function of auto availability, trip distribution or different perception of modal attributes.	Not normally used or studied as a predictive travel demand variable.
DRIVER'S LICENSE	Non-licensed may be more influenced by transit accessibility than average. May cause serve passenger trips. (See also "Auto Ownership.")	Travel by non-licensed restricted in interchanges with little or no transit service.	Known as a determinant of transit captivity, however, the trade-offs between the transit and auto passenger travel options for non-licensed are not well studied.	Not normally predicted. Useful in understanding social value of transportation services.

TABLE 1

VARIABLES AND THEIR EFFECT ON TRAVEL RESPONSE (Cont'd)

Variable	Effect on (and status of knowledge concerning)			
	Trip Generation	Trip Distribution	Mode and Route Choice	Comments
HANDICAPS Disadvantaged Group Categories	Known that trip generation is lower for handicapped persons. Thought to be affected by transportation system attributes. Not well understood.	Not well studied.	Known to increase mode captivity, both transit and auto, depending on handicap.	Not normally used or studied as a predictive travel demand variable. Useful in understanding social value of transportation services.
AUTO AVAILABILITY	(See "Auto Ownership")			Not well defined as to what constitutes auto availability. Often totally lacks definition as a survey question.
TRIP VARIABLES:				
ORIGIN DESTINATION Production Zone Attraction Zone	Defined by the trip generation estimate or act.	Defined by the trip distribution estimate or act.	Modes and routes available and associated trip specific transportation system characteristics are a function of the origin and destination. (See other trip variables for effect.)	Proper O.D. information allows systematic calculation of trip specific system variables.

TABLE 1

VARIABLES AND THEIR EFFECT ON TRAVEL RESPONSE (Cont'd)

Variable	Effect on (and status of knowledge concerning)			
	Trip Generation	Trip Distribution	Mode and Route Choice	Comments
MODE	Logically affected by mode availability. Not known extent to which mode choice is made prior to trip decision.	Logically affected by mode availability. Not known extent to which mode choice is made prior to destination decision.	Defined by the mode and route choice estimate or act.	Multi-mode trips (e.g. park and ride) cause definitional problems and are not as well understood as single mode trips.
AUTO OCCUPANCY Carpooling Number of passengers	(See "Mode")			Often poorly defined as a survey question.
PURPOSE	Defined by the trip generation estimate or act. Relationship of trip generation, importance of trip, and travel impedances not well understood.	Known that work trips are longest, shop trips shortest, other trips intermediate presumably because of relative difficulty or ease of trip purpose satisfaction. Relationship of trip length, travel impedences & ease of trip purpose satisfaction not well understood.	Known that mode choice differs among the trip purposes, even for equivalent mode options. Not known extent to which this is function of auto availability, flexibility of destination choice, or different perception or needs concerning modal attributes.	A basic predictive variable. Also useful in understanding social value of transportation services.
TRAVEL TIME	(See "In-Vehicle Travel Time" and "Out-of-Vehicle Travel Time")			The full extent of door-to-door travel time is pertinent.

TABLE 1

VARIABLES AND THEIR EFFECT ON TRAVEL RESPONSE (Cont'd)

Variable	Effect on (and status of knowledge concerning)			
	Trip Generation	Trip Distribution	Mode and Route Choice	Comments
IN-VEHICLE TRAVEL TIME	Effect not well understood.	Known that desire to minimize travel time is a significant factor in trip distribution. Quantification presently empirical only.	Known that desire to minimize travel time is a significant factor in mode choice. Value of time open to discusstion especially as it may differ with income and trip purpose.	A component of the utility measure. Extent & nature of any deviations from a linear value of time are not known. Impact of serve passenger time in carpooling & demand activated transit not well understood.
OUT-OF-VEHICLE TRAVEL TIME Excess Time Convenience (See also following individual out-of-vehicle time components)	Effect, in general, not known.	Logical that desire to minimize out of vehicle time is a factor in trip distribution. Actual effect not known.	Accumulated evidence indicates that desire to minimize out-of-vehicle travel time is in mode choice weighed 2 to 3 times as heavily as desire to minimize in-vehicle travel time.	A component of the utility measure. Weights of sub-components within the out-of-vehicle travel time category have not been investigated individually.
WALK TIME Walk Time to Transit Walk Time from Transit Walk Time from Parking	Might have threshold type effect.	Might have threshold type effect.	Some evidence that may have threshold type effect.	Extent and nature of any deviations from a linear value of walk time are not known.

TABLE 1

VARIABLES AND THEIR EFFECT ON TRAVEL RESPONSE (Cont'd)

Variable	Effect on (and status of knowledge concerning)			
	Trip Generation	Trip Distribution	Mode and Route Choice	Comments
WAIT TIME Wait Time for Transit Wait Time for Parking	Some evidence that new trips are attracted with lower wait times.	Any "new" trips attracted with lower wait times (or any modal improvement) may be trips diverted from other destinations.	No attempt has been made to analyze the restrictions on personal schedule imposed by carpooling. For transit, not known extent to which wait time applies given doorstep service or in respect to hypothetical wait time not actually spent at transit stop in the case of infrequent headway.	Commonly estimated at half the headway for transit. Extent and nature of any deviations from a linear value of wait time are not known.
TRANSFER TIME			Act of transferring may be perceived as involving a fixed penalty.	Commonly estimated at half the transit headway. Extent & nature of any deviations from a linear value of transfer time are not known.
TRAVEL COST (See also following individual travel cost components)	Effect not well understood.	Thought that desire to minimize travel cost is a factor in trip distribution. Not well studied.	Known that desire to minimize travel cost is a significant factor in mode choice. Lower incomes appear to weigh cost more.	A component of the utility measure.

TABLE 1

VARIABLES AND THEIR EFFECT ON TRAVEL RESPONSE (Cont'd)

Variable	Effect on (and status of knowledge concerning)			
	Trip Generation	Trip Distribution	Mode and Route Choice	Comments
TRANSIT FARE	Known that low fares attract trips from the walk mode (not a true change in generation.) Some evidence that other new trips are generated.			Some suspicion that there is a threshold below which fares have little impact.
AUTO OPERATING COST			Preferred treatment of auto cost in respect to its possible allocation among auto occupants has not been established.	Fixed costs not commonly included, but some question remains as to preferred approach and as to which out of pocket costs are actually perceived by the trip maker.
PARKING COST			(See Auto Operating Cost)	Question of how to treat free or subsidized employee parking in combination with market price parking deserves careful attention.
TOLLS			(See Auto Operating Cost)	
COMFORT Quality of Ride Air Conditioning Seat Availability Age of Equipment Cleanliness of Equip. Perceived Speed	Effect, if any, unknown.	Effect, if any, unknown.	Thought to marginally affect mode or at least route choice. Comfort factors have been ranked but never quantified.	Impacts poorly quantified or understood.

TABLE 1

VARIABLES AND THEIR EFFECT ON TRAVEL RESPONSE (Cont'd)

Variable	Effect on (and status of knowledge concerning)			
	Trip Generation	Trip Distribution	Mode and Route Choice	Comments
RELIABILITY	Effect not known.	Effect not known.	Possibility that reliability deficiencies account for some of the penalty assigned to wait and transfer times.	Measures of reliability needed. Impacts poorly identified.
TRIP DENSITY	Effect not known.	Effect not known.	Evidence exists that opportunities for and occurrance of carpooling are quantifiably enhanced by presence of larger trip volumes in an interchange.	Measured as person trips per unit origin and destination zone area (trips per origin area x destination area).
INFORMATION	Effect not known.	Effect not known.	Postulated to equate to increased trip density in calculating the opportunity for carpooling.	Should serve to improve individual perception of travel parameters. Impacts poorly quantified or understood.
ADVERTISING OF TRANSIT Carpool Promotion	Effect not known.	Effect not known.	Thought to marginally affect mode choice but never quantified.	May serve to influence individual perception of travel parameters. Impacts poorly quantified or understood.
CAPACITY CONSTRAINTS	Effect not known.	Parking constraints thought to affect destination choice for the shop trip and possibly others.	Deterrence to auto use of parking constraints (lack of space) lacks quantification.	Capacity constraints enroute should be taken care of in other measures such as travel time & comfort. Parking constraints may be translatable into parking costs & walk time. Impacts poorly identified.

TABLE 1

VARIABLES AND THEIR EFFECT ON TRAVEL RESPONSE (Cont'd)

Variable	Effect on (and status of knowledge concerning			
	Trip Generation	Trip Distribution	Mode and Route Choice	Comments
<u>SYSTEM VARIABLES</u> (Non-Trip-Specific):				
ACCESSIBILITY VIA TRANSIT	Effect, if any, not satisfactorily quantified. High accessibility via transit can act as a surrogate for high density and related high incidence of walk trips, which equates to low vehicle trip generation. Logically, high accessibility by all modes should relate to high trip generation if walk trips are counted.	Important in describing the relative attractiveness of a single interchange in respect to the whole, as in the Gravity Model formulation.	Evidence exists that high transit accessibility increases choice of the transit mode even for a given set of trip maker characteristics and trip-specific travel options and system characteristics. Postulated that such decisions as auto ownership are predicated on overall accessibility and thus influence individual trip choice.	Gravity Model derivation need not be used. Can be measured as percent of regional employment (or D.U.'s, commercial area, trip attractions, etc.) within given number of minutes travel time from location of interest.
ACCESSIBILITY VIA HIGHWAY	Effect, if any, not satisfactorily quantified.	(See Accessibility Via Transit)	Effect, if any, not satisfactorily quantified. May not be a significant factor given typical North American auto accessibility levels.	(See Accessibility Via Transit)
LAND USE	The primary determinant of trip generation.	Land use arrangement is a basic factor in trip distribution.	Known that dense mix of land uses can shorten some percentage of trips to where walk mode can be used. Not well quantified.	Land use arrangement is a factor in accessibility.

As an example of complexity and interrelationships, consider the system variable "Accessibility Via Transit." This variable is a measure of how well transit service connects the traffic zone of interest to the activities of a region. As indicated in Table 1, evidence exists that trips from zones of high transit accessibility are more likely to use the transit mode than trips from zones of low transit accessibility, even when trips with similar differences between modal options are considered. As one example of what this implies concerning evaluations, it appears that it may not be enough to study only trips directly impacted by a facility change. It may be necessary to examine all trip making within the impact area. It also may be necessary to conduct the evaluations over time. Transit accessibility is thought to be closely interrelated with such factors as automobile ownership, which in turn will likely change only gradually in any response to system changes.

As an example of areas needing investigation, note that several relationships discussed in Table 1 would be better understood if walk trips had been surveyed and studied in the past. This circumstance is mentioned in particular with reference to the effect on trip generation of the variables "Auto Ownership," "Residential Density," "Transit Fare," and "Accessibility Via Transit." The walk trip data deficiency may well warrant, among other things, modification of the standard home interview survey approach to include more than just the home to work walk trip. Serious consideration should be given to covering all non-vehicular trips to institutional, industrial, office and commercial activities, even if these are located in the same building. Some specialized surveys could even benefit from including all walk, bike and elevator trips, even to playfields and homes or apartments of neighbors. Such trips often involve vehicular travel, including "chauferring" by parents, whenever the objective is out of reach of normal walking.

Comments in Table 1 reference a number of variables as affecting or being included in the calculation of utility measures. Utility measures are receiving fairly frequent use now as a means to combine the several trip impedance or disutility variables in a single measure. Use of a single impedance measure assists markedly in the simplification of travel demand model structures and in allowing model structures that reflect behavioral relationships based on logic and the statistics of population variances.

Use of the utility measure involves equating all travel impedances for each trip/mode/route alternate to a single common denominator by means of coefficients or "weights." In-vehicle trip time is the most frequently used common denominator, with out-of-vehicle time and monetary costs being converted to in-vehicle time equivalents and added in. The utility measure could be modified to include additional factors such as comfort if they could in fact be quantified. One aspect of traveler response deserving significant attention is the expansion of knowledge concerning traveler weighting of present and potential utility measure components.

In addition to taking into account the complexity and interrelationships of travel demand variables, it is necessary to be concerned with how they are defined and measured in the field. In particular, consistency is needed between the measurements of variables as they are used in forecasting and as they are obtained in surveys. For example, future travel time is normally obtained from coded networks. The analyst who needs a model for use with networks thus must have survey year network-derived travel times for the purpose of model development. It does the analyst little good to have only the surveyed trip maker's perception of the travel time. It alone provides no basis for translation into either actual travel times or network derived travel times. Similarly the analyst needs a means for aggregating the survey data when his models and/or future year predictive capabilities require it.

Consistency can best be provided by using exogenously calculated data wherever possible. Thus some of the most important information that can be obtained in a survey is that information necessary for the calculation of other data. For example, the trip origin, destination and approximate starting time will allow network calculation of auto driver and transit travel times and costs. This is not to say that the trip maker's report of travel time (or whatever) should not be obtained as well. Such information may be useful in pure research and in developing better exogenous measurement techniques as, for instance, are needed for evaluating auto passenger impacts on travel time and costs.

SOME IMPLICATIONS CONCERNING ANALYSIS PROCEDURES

The preceding discussion of the theoretical basis of traveler response and the variables involved presents a picture of a multiplicity of variables and complex interrelationships that must be explored in the quest for understanding of traveler behavior. Such a picture is on the one hand appropriate, to the extent that it depicts the care with which surveys should be structured and the detail which may be necessary in certain selected research endeavors. On the other hand, this same picture clearly raises the potential of excess complexity when in fact simplicity and brevity are desirable characteristics for surveys and analyses that ultimately are to be performed by numerous agencies of varying sophistication and training. It would appear that a critical step in development of procedures is development of an approach that will keep the analyses at a manageable scale while at the same time meeting the key information objectives.

The Need for Specialization

Not all uses of traveler response knowledge require application of sophisticated behavioral travel demand models to meet study objectives. There is definite applicability for aggregate traveler response data intended for use in very simple models and "rule of thumb" type calculations. Similarly, not all advances in knowledge concerning travel behavior require complex data covering all travel response variables. It should be feasible to examine individual aspects one at a time, so long as each problem is properly circumscribed with external relationships adequately accounted for.

These opportunities for simplification do require before and after survey and analysis specialization. The following three basic categories should suffice to cover most of the important analysis opportunities:

1. Evaluations designed for obtaining information that can be applied directly through use of simple models and rules of thumb.

2. Controlled situation behavioral evaluations designed to advance knowledge concerning specific traveler response interrelationships.

3. Full scale behavioral evaluations structured to encompass all aspects of traveler response including all major interrelationships among travel demand variables.

Further definition of these categories follows.

Evaluations for Direct Application

This category of evaluations should be structured to produce information that can be readily used in those design and analysis situations where full scale behavioral travel demand analyses are not justified, too expensive, or too time consuming. Examples of such situations include design of most small city bus systems, transportation services for the aged and handicapped, low cost operation programs such as single employer carpooling, and emergency measures such as possible air quality episode transportation controls.

Informational needs for design of small city bus systems serve to illustrate the type of before and after data that can be extremely useful even though simple. Small city travel patterns normally reflect a straightforward interconnection of homes with employment, stores, schools and like activities. The potential for bus ridership should be amenable to prediction on the basis of such before and after descriptors as population served (preferably stratified by income or employment classification), percentage of employment in the central business district, type and frequency of bus service, bus fares, and school transportation arrangements. Such refinements as origin-destination trip data would not seem necessary, although information on trip purposes and trip maker characteristics would help in the assessment of benefits

Controlled Situation Behavioral Evaluations

Controlled situation evaluations would be structured to expand knowledge of specific elements in travel behavior and modeling. In terms of sequential modeling, the subject of study would generally encompass only the area of concern of a single model, such as trip generation or mode choice. This type of investigation should be useful in such endeavors as learning more about how travelers evaluate trip costs and establishing the validity (or lack thereof) of effects predicted by regional travel models.

Investigation of submode choice in an effort to better establish trip cost coefficients used in utility measures is an example of a controlled situation evaluation. Such an evaluation might examine a service change improving or introducing a competing submode within the transit mode. Parameters of interest in a before and after survey would include transit trip maker origins and destinations, travel purpose and starting time data, possibly certain trip maker characteristics, and definitely full information on trip characteristics via competing submodes including trip in-vehicle and out-of-vehicle times, walk distances, transfers, fares, comfort measures and reliability measures. In addition, effects not related to submode choice would be singled out and identified, such as the number of trips attracted from other modes or destinations or newly generated as a result of the service improvement. Note that this type of evaluation would have to be tailored to the specific controlled situation and travel modeling element under study.

Full Scale Behavioral Evaluation

Full scale travel response evaluations would be applied to expanding the knowledge of both specific elements and the total structure of traveler response. They would in all likelihood entail in-depth home interview surveys patterned after the standard Bureau of Public Roads format but with both augmentation of questions and provision for follow-up. The surveys might well be restricted to a limited set of traffic zones, however, to keep costs down while allowing higher sampling rates in a carefully selected cross section of impact areas. Full scale evaluations would appear most pertinent to evaluating the traveler response impact to major facility changes, such as freeway or rapid transit openings, or significant implementation of transportation control strategies as are contemplated in certain air quality plans.

Standard Technical Requirements

The apparent need for specialization in the travel response evaluations limits the extent of standardization possible. Certain elements of the data gathering process should be made common to all or most evaluations, however.

In all but the evaluations designed for direct application, origin-destination trip data should be gathered as a matter of course. The information concerning origin and destination should be adequate to allow coding to both the block and traffic zone levels of detail. The coding for both need not be carried out, but the information will be there for the researcher who needs it. True origin and destination identification should always be provided. The data should never be limited to the boarding and alighting or entering and leaving points of a particular service or facility. The existence of true origin and destination data will insure, among other things, that most travel parameters for all trip options can be estimated exogenous to the survey.

Surveys will have to be kept brief enough for practical application and adequate response. At the same time, the questions asked should not be such as to unreasonably limit the subsequent analysis to a specific modeling approach or theoretical explanation of traveler response. The survey designer should be mindful of the needs of the researcher who wishes to work with aggregate or disaggregate data, direct demand or sequential modeling, and utility measures or use of individual variables. The place for concentration of effort to a single researcher's interests is in the analysis phase. Another researcher should be able to parallel or reasonably diverge from the first analysis without having to redo the survey, something that aside from the expense is rarely possible in before and after evaluations.

There should be a fully documented background description of study area conditions and system characteristics in both the before and after condition, quantified as much as possible. The completeness and accuracy of this description is essential to the usefulness of evaluations intended for direct application with simple modeling or rule of thumb calculations. This description should be extremely helpful in assuring the valid use of all evaluations, however. The example of a form for such background descriptions, provided on page 31 in Figure 2, should help illustrate the intent of this informational device.

CIRCUMSTANCES DESERVING EVALUATION

The attempt is made in Table 2 to identify by example a broad range of changes in transportation system supply or conditions that are deserving of evaluation in an effort to better quantify and understand traveler response. The meat of discussion concerning these potential opportunities for fruitful evaluation is contained within Table 2 itself.

Each example is identified using a brief hypothetical description of the transportation system change. The primary categories of information to be gained from the particular example are noted. The example is categorized as to which one of the three basic types of evaluations discussed in the preceding section seems the most appropriate, and basic survey techniques likely to be suitable are noted. Comments are provided as to items of particular interest or concern.

Not all traveler responses are best examined in situations of change, prescribed as the primary emphasis of this paper. Table 3, in format similar to Table 2, identifies by way of illustration three separate circumstances of stable situations deserving of travel demand evaluation. Provision should be made for such examinations as part of any overall program to expand knowledge of travel behavior.

TABLE 2

SOME CHANGES IN TRANSPORTATION DESERVING EVALUATION

Example	Circumstance	Information of Interest	Evaluation Category	Special Considerations
1.	City of 50,000 population, without bus service for a year, institutes a well designed conventional bus system.	Transit ridership given city, population & service characteristics. Rider characteristics, trip purposes, and prior means of satisfying trip needs.	Direct Application (Background description, bus trip passenger counts, rider questionnaire).	Deserves evaluation both shortly after implementation and a year later.
2.	City of 250,000 population with comprehensive bus service institutes a fare reduction favoring short trips and off-peak travel.	New transit ridership given city, population, service & prior ridership characteristics, new ridership characteristics, trip purposes, trip starting times & prior means of satisfying trip needs.	Direct Application (Background description, before and after bus trip passenger counts and maximum load point counts, rider questionnaire).	Same as Example 1.
3.	City of 50,000 replaces entire 20 year old bus fleet with new buses.	New transit ridership given city, population, service & prior ridership characteristics, new ridership characteristics, trip purposes, & prior means of satisfying trip needs.	Direct Application (Background description, before and after passenger counts, rider questionnaire).	Ridership trends should be furnished one year before and after.
4.	City of 250,000 replaces evening and Sunday fixed route bus service with demand responsive bus service.	Before and after evening & Sunday transit ridership given city, population, service, and all day ridership characteristics. Before & after evening and Sunday rider characteristics, trip purposes, trip starting times and prior means of satisfying trip needs for new riders.	Same as Example 3.	Same as Example 1.

TABLE 2

SOME CHANGES IN TRANSPORTATION DESERVING EVALUATION (Cont'd)

Example	Circumstance	Information of Interest	Evaluation Category	Special Considerations
5.	Rural area without bus service institutes interurban bus operation with emphasis on service to elderly, poor, etc.	Same as Example 1.	Same as Example 1.	Same as Example 1.
6.	City of 1,000,000 population institutes a specialized demand responsive bus service available to the handicapped.	Same as Example 1.	Same as Example 1.	Same as Example 1. Also, particular attention should be given to describing the physical needs and accommodation of the handicapped, and to relating these to system use.
7.	Residential community institutes a subscription type bus service to a major employment area.	Subscription service ridership given employment area, residential area, population, prior service, & competing service characteristics. Rider characteristics & prior means of satisfying trip needs.	Same as Example 1.	Same as Example 1. Percentage and absolute density and numbers of community population working in serviced employment area should be determined.
8.	Major employer institutes a carpooling locator service without incentives.	Before and after auto occupancy and mode choice given program, employee, employer, and regional characteristics.	Direct Application (Background description, before & after auto & auto passenger counts, before & after employee questionnaire).	Same as Example 1.
9.	Metropolitan Area institutes transportation control strategies	Reduction in vehicle miles of travel, degree of compliance with emergency	Direct Application (Background description; before, during &	Results should be identified by day and extent of episode.

TABLE 2

SOME CHANGES IN TRANSPORTATION DESERVING EVALUATION (Cont'd)

Example	Circumstance	Information of Interest	Evaluation Category	Special Considerations
	for use only during serious air quality episodes, including reduced transit fares, restriction of major arterials to carpools and buses, and extensive public service publicity.	carpool usage, effect on transit usage, effect on commerce and industry.	after arterial and local street traffic counts & auto occupancy counts; transit ridership counts; surveys concerning absenteeism and sales as compared to normal.	
10.	Transit operator establishes, changes or removes fare differential between express and local transit service.	Relative importance of fare (monetary cost) in comparison with other travel impedances.	Controlled Situation (Before & after O.D. survey of riders on express route & competing local routes).	Route choice shifts would provide the primary quantitative basis for analysis. Mode choice, trip distribution & trip generation shifts should also be identified.
11.	Transit operator increases frequencies on one transit route closely parallel to other routes not modified.	Relative importance of wait time vis-a-vis walk time & other travel impedances.	Controlled Situation (Before & after O.D. survey of riders on affected transit route & parallel transit routes).	Same as Example 10.
12.	Transit operator replaces 20 year old equipment on one transit route closely parallel to other routes with no equipment change. Running time changes are minimal.	Relative importance of equipment age and riding qualities in comparison with time & cost travel impedances.	Same as Example 11.	Same as Example 10.

TABLE 2

SOME CHANGES IN TRANSPORTATION DESERVING EVALUATION (Cont'd)

Example	Circumstance	Information of Interest	Evaluation Category	Special Considerations
13.	Transit operator replaces standard buses with high capacity double deck or articulated buses on one transit route closely parallel to other routes with no equipment change. Frequency changes are minimal such that passenger loading factors are significantly altered.	Relative importance of seat availability and lack of crowding in comparison with time and cost travel impedances.	Same as Example 11.	Same as Example 10.
14.	Major repairs to a fixed rail transit facility adversely affect reliability for an extended period. Parallel transit facilities are not affected.	Relative importance of reliability in comparison with time and cost travel impedances.	Controlled Situation (During & after O.D. survey of riders on affected transit route & parallel routes).	Same as Example 10.
15.	Transit operator mounts a massive transit advertising & informational campaign not tied to service, fare or equipment changes.	Relative importance & effectiveness of transit advertising and informational campaigns.	Controlled Situation (Attitudinal surveys, before & after O.D. surveys of selected populations).	Same as Example 1. Reason for limited O.D. surveys is to identify response differences for different levels of transit competitiveness with auto.

TABLE 2

SOME CHANGES IN TRANSPORTATION DESERVING EVALUATION (Cont'd)

Example	Circumstance	Information of Interest	Evaluation Category	Special Considerations
16.	Suburban community with limited bus service institutes a comprehensive demand responsive feeder service to a rail commuter station.	Shifts in mode of arrival choice in response to service changes. Impact on trunk line ridership.	Controlled Situation (Before and after O.D. surveys of station patrons).	Same as Example 1. Mode of arrival shifts would provide the primary quantitative bases for analysis. Mode choice, trip distribution & trip generation shifts should also be identified.
17.	Rapid transit (or busway) operator opens new station with easy access park and ride lot in an area with previously deficient transit parking but some feeder bus service.	Same as Example 16.	Controlled Situation (Before and after O.D. surveys of station patrons at all stations in impact areas).	Same as Examples 1 and 16.
18.	Rapid transit operator with a string of park & ride facilities, some deficient in size & others not deficient & easy to expand, varies parking fee to shift demand.	Shifts in mode of arrival and arrival route choice in response to fee changes. Relative importance of time, auto operating cost, and parking fee.	Same as Example 17.	Same as Example 1. Mode of arrival & route of arrival shifts would provide the primary quantitative basis for analysis. Mode choice, trip distribution & trip generation shifts should also be identified.
19.	A large centrally located employment area institutes a massive carpooling program with locator service, parking fee & location incentives, & publicity.	Impact on trip costs, travel times and convenience. Associated effect on auto occupancy and mode choice.	Controlled Situation (Before and after O.D. surveys of employees).	Particular attention in the survey phase should be paid to the trip linkages involved for auto driver and auto passengers.

TABLE 2

SOME CHANGES IN TRANSPORTATION DESERVING EVALUATION (Cont'd)

Example	Circumstance	Information of Interest	Evaluation Category	Special Considerations
20.	A large centrally located employment area institutes a comprehensive work hours staggering program.	Impact on trip peaking, congestion, carpooling and mode choice.	Controlled Situation (Before and after O.D. surveys of employees, employee & employer attitudinal surveys, traffic & transit passenger counts by short time increments, travel time surveys).	Care should be taken to note changes in transportation service by time increment, specifically transit schedules & any parking space reservation policies.
21.	A toll bridge authority changes the toll.	Relative importance of auto costs in comparison with other travel impedances. Impact on route choice, auto occupancy, & mode choice.	Controlled Situation (Before & after screenline O.D. surveys of auto drivers, passengers and transit passengers).	Deserves evaluation both shortly after implementation and a year later, with notation as to transit service changes.
22.	Extended repairs significantly reduce highway capacity across a natural barrier.	Trade-offs between time selected for travel & other travel impedances & options.	Controlled Situation (During & after screenline O.D. surveys of auto drivers, passengers and transit passengers. Travel time surveys).	Care should be taken to note changes in travel time as well as other options.
23.	Construction causes removal of extensive surface parking lots & curb parking. No substitute parking is provided.	Relative trade-offs of walking distances, parking costs, auto occupancy and other travel impedance factors. Overall impact of removing parking.	Controlled Situation (Before and after O.D. surveys of employees & commercial patrons).	Special attention should be paid to parking arrangements and walk distances in the survey.

TABLE 2

SOME CHANGES IN TRANSPORTATION DESERVING EVALUATION (Cont'd)

Example	Circumstance	Information of Interest	Evaluation Category	Special Considerations
24.	Transit Operator augments a fairly major conventional bus route with demand activated bus feeder and local service.	Relative importance of walk time and distance in comparison with other travel impedances.	Full Scale (Before and after high sample rate O.D. in the service area).	Special attention should be paid to walk distances both before and after.
25.	A major metropolitan rapid transit system is opened.	All aspects of trip generation, distribution and mode choice	Full Scale (O.D. survey of at least selected zones).	Probably justifies a new full scale metropolitan area home interview O.D. survey keyed to the most recent prior survey, and reexamination of all travel models.
26.	An existing rail rapid transit line is extended with concurrent changes in local & feeder bus service.	Impact on mode of arrival & mode choice in particular. Effect of accessibility changes on auto ownership & mode choice.	Full Scale (O.D. survey in selected zones).	Deserves evaluation both shortly after implementation, a year later, & say five years later.
27.	City of 500,000 population opens a CBD people mover connecting major CBD activities, peripheral parking, & radial bus routes.	Impact on attractiveness of CBD, parking location, mode choice, & non-home-based trip characteristics.	Full Scale (Before and after O.D. surveys of CBD employees commercial patrons and residents).	Special attention should be paid to walk trip interrelationships, accessibility impacts, & mixed mode trade-offs such as attractiveness of remote parking vs. park and ride.
28.	Major transit operator lowers fare from 45¢ to 25¢.	Relative importance of fare (monetary cost) in comparison with other travel impedances. Impact on mode choice and trip generation.	Full Scale (Rider questionnaire plus O.D. survey in selected zones).	Same as Example 1. Reason for home interview O.D. surveys is to identify response differences for different levels of transit competitiveness with auto.

TABLE 2

SOME CHANGES IN TRANSPORTATION DESERVING EVALUATION (Cont'd)

Example	Circumstance	Information of Interest	Evaluation Category	Special Considerations
29.	A major urban freeway link is opened.	All aspects of trip generation, distribution and mode choice.	Full Scale (Vehicle survey plus before & after O.D. survey in selected zones. Could be done in an area with freeway now open if regional home interview O.D. was conducted just prior to facility opening.)	Same as Example 26. Survey results should be compared with model forecasts to verify or disprove predictions as to vehicular trip generation, distribution & vehicle miles of travel.
30.	A major urban freeway is metered to bring freeway traffic flow close to optimum conditions for minimum vehicular emissions. Bus preference is provided.	Impact of metering on vehicular route choice, surface street conditions, mode choice and auto emissions.	Full Scale (Before and after O.D. survey in selected zones with route choice questions. Before & after freeway & surface street counts & travel time/auto emission runs.)	Determination of net effect on vehicular emissions considering surface street impacts would be a prime analysis objective.
31.	A reserved lane for carpools & buses is provided in a major urban corridor.	Same as Example 19.	Full Scale (Before and after O.D. survey in selected zones. Screenline O.D. surveys of auto drivers, passengers and transit passengers. Travel time surveys.)	Same as Example 1.
32.	A city of 500,000 implements an auto free CBD street mall with transit improvements & limited peripheral parking.	Relative trade-offs of walking distances, parking costs, transit use & other travel impedance factors. Impact on attractiveness of the CBD.	Same as Example 27.	Same as Example 1.

TABLE 2

SOME CHANGES IN TRANSPORTATION DESERVING EVALUATION (Cont'd)

Example	Circumstance	Information of Interest	Evaluation Category	Special Considerations
33.	A seasonal fuel shortage causes long lines & short hours at filling stations.	All aspects of trip generation, distribution & mode choice under conditions of fuel restriction.	Full Scale (During and after in-depth O.D. survey in selected zones).	Both weekday and weekend travel should be investigated.
34.	A metropolitan area implements an air quality plan involving a carpool program, parking surcharges and a 25% increase in bus service.	All aspects of trip generation, distribution and mode choice. Impact on individual welfare and commercial activity.	Full Scale (O.D. survey in selected zones. Panel interviews before and after).	Same as Example 26.

TABLE 3

ILLUSTRATIVE STABLE TRANSPORTATION SITUATIONS DESERVING EVALUATION

Circumstance	Relationships of Interest	Evaluation Category	Special Considerations
A rapid transit station with no major competitive transit services, located several miles from the CBD in a uniform density residential area.	Gradient of decreasing transit modal split and decreasing CBD orientation of trips, if any, as distance from the station increases. Information on walk trip and other mode of arrival interrelationships.	Full Scale (High sample O.D. survey within station impact area)	Useful for checking the zone level performance of mode choice and distribution models, and for developing fine grained transit impact area analysis techniques.
A relatively high density, mixed land use area with dwellings, stores & employment, having good pedestrian interconnection & located within an urban area. A control area with residential only land use.	Percentage of typical travel needs met internal to the area & percentage met using the walk mode, both as compared to normal.	Full Scale (O.D. survey with full walk trip investigation)	Useful for checking the zone level performance of trip generation & distribution models, & for developing fine grained planned community analysis techniques.
A CBD cross section with a typical mix of public and private parking and blocks with no parking.	Information as to who pays what for parking compared to posted rates & percent "free." Data on walk time vs. parking cost tradeoffs. Indicators of auto captivity.	Full Scale (Full O.D. survey of all trips by employees. Survey of commercial patrons.)	Useful for expanding knowledge of how to estimate parking costs for use in travel models, and how to treat possible auto captivity.

SOME SPECIFIC DATA GATHERING SUGGESTIONS

A significant number of papers and manuals cover the specific design of various types of travel surveys. Review and abstracting of this literature is beyond the scope of this white paper. There are, however, certain suggestions concerning the data gathering effort that seem worthwhile to highlight.

Background Information Report

There is much to travel data that may not be readily evident and yet can be very important to the analyst who must use it. What is the likelihood that some future researcher, using the 1955 Washington, D.C. home interview survey for time series data, will know that half the area transit riders were lost from transit part way through the survey due to a protracted bus and trolley strike? That is vital information.

It has already been recommended that a background information report be required in connection with each evaluation. This report should document unusual circumstances and provide as well a concise description of regional and study area general conditions. It should also describe in detail the nature of the transportation system supply changes that have been surveyed and evaluated. Figure 2 provides an example outline of such a background report, and serves to indicate the nature of information thought to be most important.

Postcard Type Surveys

Quality control procedures are fairly well established for most types of travel surveys. Adequate sample size and quality control are of course essential if the data are to have any productive use.

Postcard type surveys seem to be an exception in regard to quality control. Such surveys have the potential of providing a large sample at low cost, but will only be useful if the inherent biases of self-administered surveys can be properly controlled and compensated for. Recommended reading in this regard is a paper describing the major potential biases in the 1966 Washington, D.C. bus rider O.D. survey.2/ These biases could have severely undermined the validity of the data had not appropriate statistical controls been adopted. Such statistical controls for postcard type surveys are unfortunately not yet commonplace.

2/ "How to Obtain Transit Travel O-D Data," by Richard H. Pratt, Bureau of Public Roads Circular Memorandum, April 1, 1968, pp. 66-79.

Figure 2. Background Information Report Outline

1. Circumstance under evaluation.
   (Assumed for purpose of illustration to be Example 24 of Table 2.)

2. Location.
   (Urban sector, city, state.)

3. Agency conducting evaluation.
   a. Name, address, phone.
   b. Responsible official.
   c. Principal Investigator

4. Transit operator (if different).
   a. Name, address, phone.
   b. Responsible official.
   c. Principal contact.

5. Dates of service changes.

6. Dates of before and after surveys.

7. Metropolitan area characteristics. (Give dates and sources.)
   a. Population characteristics.
      (1) Central City* population and developed area.
      (2) Transit service area* population and developed area.
      (3) SMSA* population and developed area.
      (4) Average household income for each of above.
      (5) Percentage distribution among major employment classifications for each of above.
      (6) Auto ownership for each of above.
   b. Economic indicators.
      (1) Labor force participation rate per household.
      (2) Before and after cost of living index.
      (3) Before and after unemployment rate.
   c. Transportation/land use characteristics.
      (1) Definition of CBD.*
      (2) Percent of SMSA employment in CBD.
      (3) Percent of SMSA employment in Central City.
      (4) Work and nonwork trip modal split and auto occupancy (Regional, Central City, CBD destination).
      (5) Average work and nonwork trip length (define explicitly).
      (6) Regional and Central City average trip generation rates per Dwelling Unit (define explicitly).
      (7) Freeway system (provide map).
      (8) Transit system (provide map and keyed list of routes with peak and base headways).
      (9) Transit system parameters (average fleet size, daily riders, daily transit rides per capita served).

(10) Provide maps of generalized land use, census tracts and traffic analysis zones.

d. Brief description of metropolitan area trends and special characteristics.

8. Brief description of the impact area* and how it relates to the metropolitan area in terms of the above characteristics.

9. Description of the before and after transit operation servicing the impact area.
   (1) Routes and service areas (provide map).
   (2) Mode of operation.
   (3) Frequency of service (provide schedules and demand responsive vehicle assignments).
   (4) Equipment.
   (5) Fares (describe and provide tariff).
   (6) Promotion.
   (7) Special features.
   (8) Ridership figures and trends (by route, time of day, etc.).

10. Discription of any extraneous factors that may have affected traveler response (strikes, disturbances, land use changes, factory closures, new highway facility changes, fare changes, transit service changes elsewhere in city, etc.).

* Delineate asterisked items on suitable map. All maps should be to the same scale if at all possible.

Cluster Sample Origin Destination Surveys

In discussing the different recommended categories of evaluation, it has been indicated that full scale behavioral evlautions would in all likelihood entail in-depth home interview surveys. These are of course quite expensive, and restricting the surveys to a limited number of traffic zones has accordingly been suggested.

Evaluation of most traveler responses does not require sampling every portion of a study area. It does require obtaining significant samples of travel data for trip interchanges of widely varying characteristics in terms of auto and transit service. It is also necessary that samples be obtained for urban trip makers of varying economic status. and neighborhood characteristics. These objectives are best met by using a cluster sampling technique.

Under such an approach a 10% or better sample is taken from the dwelling units contained within each selected traffic analysis zone. Within each cluster sample trips to all destination are surveyed. Thus each individual cluster sample provides data on travel of widely varied characteristics.

To insure selection of cluster sample survey zones representing in the aggregate a full range of study area conditions, all zones should be classified according to appropriate measures. The actual selection should then be made such as to include at least one zone from each combination of classifications found under study area conditions. Table 4 illustrates such a classification system developed for an evalaution of mode choice and submode choice in a suburban sector.

The only significant weaknesses of cluster sample surveys are related to the fact that they cannot be expanded to represent the total universe of study area travel. Survey results cannot be checked using screenline data and like information, thus requiring more rigorous quality control. They cannot be used to examine certain types of competition effects in the trip distribution mechanism, specifically those now handled by iteration in Gravity Model application. If work trips attracted into the area from dwellings outside the study area are a major factor, consideration should be given to survey augmentation with employee interviews. Otherwise cluster sample surveys should be entirely satisfactory for the development of travel models and relationships.

IMPLEMENTATION OF EVALUATION PROCESS

The evident need for specialization in formulating evaluations of various transportation system changes makes implementation more difficult. It would appear that extensive before and after surveys and evaluation are not something that should be automatically done in every instance that Federal funding is involved, and there will be cases deserving evalaution where there is no Federal funding. The implementaton process will have to be tailored in order to meet the objectives of the evaluation program.

TABLE 4

EXAMPLE CLUSTER SAMPLE CLASSIFICATION SYSTEM

Zonal Measure	Class	Description
Family Income	1	$0 - $5,000 average
	2	$5,001 - $7,500
	3	$7,501 - $10,000
	4	$10,001 up
Density of Development*	1	CBD
	2	Urban
	3	Suburban
	4	Rural
Rail Transit Service	1	Station in or within 1/2 mile of zone
	2	Station within 2 miles of zone
	3	Station within 5 miles of zone
	4	Station beyond 5 miles of zone
Bus Service	1	Trunk bus route within zone
	2	Trunk bus route within 1 mile of zone
	3	Other

* A desirable alternate would be to use transit accessibility ranges.

Requirements and Grants

It would appear that Federal funds need to be made available for the desired evaluations, and budgeted in some manner. Each case would have to stand on its own merit and in effect compete for available funds. A local share in evaluation costs could logically be required when the evaluation is connected with a larger Federal grant and there is a demonstratable local benefit to be gained from the information obtained. The government should have the right to require cooperation when Federal money is involved in a transportation change.

A mechanism is needed for identifying desirable case studies early enough for design and implementation of evaluations without impedance to the basic project. Otherwise the program may get a bad name among action oriented decision makers. A well advertised, voluntary system of case study nomination operating both within and without the U.S. Department of Transportation might well work out best. The program will need someone responsible for its conduct, and this person can with his or her own knowledge insure that at least the most obvious cases deserving evaluation are identified and acted upon.

The case study selection should be guided in part by lists of hypothetical situations determined to need study. Grant administrators could be asked to assist by giving notification upon receipt of projects of certain types. The parties responsible for the evaluation program should be able to approve case studies on their merit, irregardless of other Federal involvement.

Technical Assistance

Even though specialization is needed, extensive assistance can be provided through procedural manuals. Within the three basic areas of specialization suggested in this paper there can be significant standardization, and there can be certain standard items throughout. That which cannot or should not be standardized can be shaped through criteria and guidelines.

At the same time, however, it would appear wise to make provision for active assistance and monitoring. Furthermore, given the diverse interests riding on the results of these evalautions, the Federal monitor should be able and encouraged to draw on the expertise of others.

The program will of course not work if the results are not well disseminated, and if they are not available in readily usable format. The mechanics and precedents for dissemination should already exist.

Consideration should be given to including in the program scope the development and making available of augmented trip files wherever practical. An augmented trip file or calibration file is constructed using origin-destination survey linked trip records as the basic element. Additional information is then appended to each of these records, this information being primarily obtained exogenous to the survey. Much of the additional information is available from transportation networks and calculations which are likely to be more readily available to the agency conducting the before and after evaluation than to the average research agency. Table 5 summarizes the components included in one example of an augmented trip file.

SUMMARY OF RECOMMENDATIONS

The design of before and after survey procedures should be attuned to increasing our useful knowledge of travel behavior. Pertinent uses of travel behavior knowledge include applications in the choice and design of transportation facilities and operations, selection of transportation policies and strategies, analysis of transportation benefits, and prediction of costs.

It is imperative to make full use of existing travel behavior knowledge in developing sound survey and research designs. The survey designs must address the quantifying of both determinants of traveler response and the various manifestations of traveler response. Secondary effects must at a minimum be identified and isolated so that primary effects may be properly modeled. Areas of investigation deserving more attention than has been afforded in past survey designs include enumeration of walk trips that serve as a viable trip choice, and also quantification of parameters important in the weighting of utility measure components.

Field definition and measurement of travel demand variables should be done such as to allow consistency with measurement of variables as they are used in forecasting. Some of the most important survey information is that which will allow exogenous calculation of other data such as network derived travel times.

In order to utilize opportunities for simplifying survey and analysis procedures there must be some specialization. The three recommended categories are surveys of information intended for direct application using simple models or rules of thumb, controlled situation surveys to obtain behavioral data on specific traveler response interrelationships, and full-scale surveys structured to encompass all aspects of behavioral response to major transportation system changes.

Standard survey design technical requirements should include gathering of origin-destination trip data in all instances except in connection with evaluations designed for direct application. The questions asked should not be such as to unreasonably limit subsequent analysis to a specific modeling approach. There should always be full documentation of background information including pertinent metropolitan area and transportation system characteristics, dates and nature of changes, and any special circumstances affecting the survey.

TABLE 5

EXAMPLE SUMMARY OF AUGMENTED TRIP FILE COMPONENTS[3/]

Basic Information From Home Interview Survey Trip Records

1. The origin zone and district of the trip
2. The destination zone and district of the trip
3. The residential zone of the trip maker
4. The mode by which the trip was made
5. The purpose for which the trip was made
6. The household income of the trip maker
7. A factor which showed the number of trips the record represented.

Basic Information From Transportation Networks and Other Calculations

1. Highway and transit travel times
2. Highway distance
3. Transit fare
4. Parking cost at the zone of destination
5. Residential area of the zone of origin
6. Commercial area of the zone of destination

[3/] "Development and Calibration of the Washington Mode Choice Models," prepared for the Metropolitan Washington Council of Governments by R.H. Pratt Associates, Inc., COG Technical Report No. 8, June 1973, Appendix B.

Extensive before and after surveys and evaluation do not appear appropriate for inclusion as a routine accompaniment of Federal project funding. Instead, the case studies should be selected on an individual basis. A mechanism is needed for early identification of desirable case studies, and there should be the flexibility to act even when there is no Federal project funding. Provision of monetary grants and technical assistance to the survey and evaluation program appears necessary if the basic objectives are to be met.

An Outline for An Assessment of Economic Implications of Changes in Transportation System Supply on Traveler Behavior

August 21, 1974

by

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An Assessment of Economic Implications of Changes in Transportation System Supply on Traveler Behavior

I. Introduction

A. Areas of discussion for this outline are the following:

1. Definition of short-term system supply changes from the individual traveler's point of view

2. Definition of long-term system supply changes from the individual traveler's point of view

3. Definition of the necessary decisions to be made for collection of data from before and after system changes

4. Possible analysis techniques for such data

B. This outline is limited to the raising of issues for discussion and to the definition of decisions to be made prior to the collection of data. It does not define the actual choices to be made or the exact questions to be asked. These are to be defined in the procedural manuals.

II. Delineation of short-term supply changes

A. Short-term changes are defined in this paper as those which affect people's actions in the short run. Temporary changes, changes for which an end date is known

1. Short-term is not equivalent to low-capital alternative

2. Short-term changes in this context usually involve a net loss in quality of life to the traveler.

B. Types of short-term system supply changes

1. Transit strikes

2. Facility failures

3. Fuel shortages

4. Detours to allow construction of new facilities

(more)

C. Disasters/short-term changes

1. Cause temporary changes in travel patterns but not permanent changes in such areas as home or job location

2. May cause following changes

   a. Don't make trip

   b. Change destination to avoid problem area

   c. Change mode

   d. Change route choice

III. Delineation of long-term supply changes

A. Long-term changes as defined in this paper are those for which no known end date is present. These changes may be low-capital or high-capital intensive.

1. The only requirement is that the traveler view the situation as permanent and bases travel decisions upon that tenet.

2. These long-term changes usually involve a net gain in quality of life to the traveler.

B. Types of long-term supply changes

1. New or extended transit system

2. New highways | bridges | tunnels

3. Alterations in one-way street configurations

4. Designation of pedestrian only areas

5. Alterations in costs (increase or decrease)

   a. Transit fare changes

   b. Toll structures

C. Long-term supply changes

1. May cause permanent alterations in occupation | home | shopping locations

2. Will cause permanent changes in context and utility structure of individual therefore causing reordering of all priorities, including travel priorities.

(more)

IV. Types of data and means of collection

A. System change if measured over time will include combination of effects of time change and of system change caused by alteration of ceteris paribus conditions (which require that only one factor vary so as to assign influence).

In order to determine the proportion of the change in behavior due to facility change as distinct from change in behavior due to time change, a control group with only a time change is a requirement.

B. For short-term changes

1. Data can usually only be collected after change has occurred.

2. Data collection by following means

a. Location of change interviews

b. Behavior observation

c. In home interviews

3. Data to be collected

a. Types of travel pattern changes caused

b. Perceptions of usual travel context

c. Perceptions of changes' effect on travel patterns

C. For long-term changes

1. Collect data before change, after change, and possibly during change

2. Data collection by following means

a. Constant sample required therefore will need home address sample

(1) Control of not-affected people

(2) Proportion of affected

(more)

b. Interview techniques

(1) In home preferable

(b) Postal with telephone followup possible

c. Need to define required response rates and quality of returns

3. Data to be collected similar to short term

V. Survey instruments

A. Tied to type of data collection and type of system change

B. Possible to define set(s) of socio-economic questions to be useful for all types of system changes.

1. Income by categories

2. Family size and life cycle

3. Ages

4. Dwelling unit type

5. Occupation

C. Define questions for short-term changes

D. Define questions for long-term changes

E. Open-ended questions preferable for effects queries - analyst can never predict entire set of replies, and precodes tend to influence the responses.

F. Questions often must be formulated for specific occasion as it arises with guidance from analysis procedures proposed.

VI. Sampling techniques

A. Dependent upon type of system change

B. Dependent upon type of data collection

C. Dependent upon hypothesized response | refusal rates

D. Dependent upon stratification of population to obtain information from affected

E. Random sampling to obtain respondents required

(more)

VII. Analysis techniques

A. Travel context definition revealed preferences of individuals for travel goods and services

1. Those previous to change in system

2. Those during change

3. Those after change

4. Use to determine interactions of revealed influence sets and actions

5. Use to forecast future travel patterns

B. Utility maximization in travel implies time and/or cost minimization

1. Categorize effect of system change on utility structure and budget constraints

a. Makes journey faster and cheaper

b. Makes journey slower and more expensive

c. Makes either time cost or money cost less

2. Assumption of rational consumer with full knowledge of alternatives available