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THE URBAN TRAVEL DEMAND FORECASTING PROJECT

FINAL REPORT SERIES

VOLUME I

OVERVIEW AND SUMMARY:

URBAN TRAVEL DEMAND FORECASTING PROJECT

by

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OVERVIEW

The Urban Travel Demand Forecasting Project has been carried out to provide transportation engineers and planners with the information necessary to select and use policy-oriented travel demand models developed from observations on behavior of individual households. Emphasis has been placed on refining and testing methods for applying these models and on determining the limits of their validity. An attempt has been made to consider all aspects of a transportation planning effort, from survey and network data collection, through model specification, calibration and validation, to issues of aggregation and policy forecasting, and finally to policy applications on region-wide, corridor and local area issues. Each phase has been investigated at two levels. First one or more specific concrete studies have been performed in each aspect of the project. Second, at each stage an attempt has been made to assess the merits and limits of the concrete methodologies employed, and suggest preferred strategies for planning.

The concrete focus of this project was the introduction of rail rapid transit service (BART) in the San Francisco Bay Area in 1973. The research plan underlying this project was as follows:

- Collect data on a sample of individual commuters in the San Francisco Bay Area before the initiation of Bay Area Rapid Transit (BART) service.

- Predict patronage of BART and three other modes fitted to the pre-BART data.
- Compare the predictions with actual BART patronage, using a second survey taken after BART was in service.
- Assess the usefulness and validity of policy predictions from the models for concrete issues under study at the regional, corridor, or local levels.

An overview of the conclusions of the project can be given by functional area:

Survey Data Collection

- Telephone surveys were found to be cost-effective, and capable of generating data of breadth and quality comparable to that of home interview surveys.
- "On-board" survey frames, combined with appropriate statistical adjustments for calibration from choice-based samples, were found to be cost-effective and straightforward to implement.
- The collection of background and redundant variables proved extremely useful for data cleaning and the formation of compound variables. In particular, reported information on routes, perceived time and cost of both used and non-used modes, wage rates in addition to family income, and schedule delay proved useful.

- Due to high mobility, it proved extremely difficult to maintain a panel structure to the "before and after BART" surveys. This suggests that it is more cost-effective in longitudinal studies of transportation behavior to use successive cross-section rather than panel survey designs.

Network Data Collection

- Zonal-aggregate peak-hour trip time data from transportation networks may measure the actual travel time of an individual with substantial error, due to traffic conditions at scheduled departure and zonal averaging of access times.

- Significant improvement in network travel time calculations compared with disaggregate travel times can be obtained with relatively simple disaggregate transit access calculations.

- Network travel time calculations, with or without access time and schedule corrections, sometimes deviate significantly from actual disaggregate travel times.

Specification, Calibration, and Validation

- A short list of transportation system attributes (e.g., travel times and costs) explain most travel demand behavior. Socioeconomic variables improve overall fits significantly. Inclusion or exclusion of most socioeconomic variables from the models does not greatly affect the importance attributed to travel times and cost.

- Variables which are related to the availability of alternatives, such as auto ownership, are extremely important.

- The multinomial logit functional form for individual mode choice probabilities appears to fit data well and provide reasonable forecasts, even for new modes, despite its theoretical drawbacks due to its simple and rigid parametric structure. Most (but not all) tests of the multinomial logit structure against more complex functional forms accept the logit specification.

- The weighting of time relative to cost is relatively sensitive to the method of constructing the travel time variables. Automobile time appears to be weighted more heavily than transit time, particularly when there is congestion.

- Disaggregate behavioral models calibrated on pre-BART data provided relatively accurate forecasts of BART patronage. Forecasting accuracy was significantly better in models with socioeconomic detail than in models employing only traditional transportation variables. The forecasts were best for BART with bus or auto access, but substantially overpredicted BART with walk access.

- Attitude and perception measurements appear to complement traditional transportation variables such as travel time and cost, in the sense that adding attitude variables to a model containing travel times and costs has little effect on the weights attached to times and costs. The added explanatory power of attitude variables is low.

- The most significant attitude influencing travel behavior is tolerance of traffic stress. Also important was the individual's energy level and enjoyment of activity.

Policy Analysis

- Aggregation from individuals to aggregate flows along a corridor or in a region is non-trivial when disaggregate behavioral models are used, and may be a source of unacceptable error.

- Treatment of zonal demand as if it were generated by homogeneous individuals (the naive method) usually gives unacceptable errors.

- Aggregation by crude classification of disaggregate data into a small number of cells yields reasonable results for sketch planning at an aggregate level, but requires large amounts of data for more detailed planning.

- Monte Carlo or simulation methods are quite flexible, but may require large numbers of evaluations to achieve acceptable accuracy.

- An efficient program (SYNSAM) employing census data has been developed to permit generation of a synthetic sample of households in any future year. This sample can be used to drive policy simulations in policy applications. In concrete application, the method was found to perform satisfactorily except for commute origin-destination patterns, where cross-classified census data is unavailable.

- Validation studies indicate substantial differences in tastes between urban and suburban dwellers, as reflected in weights placed on travel times and costs. There are also differences between cities in taste parameters, although in these comparisons non-comparability of time and cost measures is an alternative explanation.

Regional Policy Analysis

- Analysis of the effects of specific pricing and operations policies on regional-scale urban transportation demand using disaggregate models and synthesized demographic data is shown to be a quick-response, low-cost method.

- Approximation methods based on data classification allows such analyses to be done on mini-computers or hand calculators.

- These multimodal work-trip demand predictions are 1) at least as accurate, 2) much more sensitive to policy issues, and 3) dramatically lower in cost and effort than traditional interzonal or interdistrict aggregate forecasting.

- With conventional computers, but still at well below traditional costs, the outputs can be segmented by moderate numbers of geographic or socio-economic units and transformed into many economic, environmental or energy-type impacts.

- Use of these methods to analyze the usage, revenue, and equity issues of a proposed San Francisco region transit fare policy showed the flexibility and responsiveness necessary to iterate the analyses through an evolving set of policies and impacts.

Corridor Policy Analysis

- A study was carried out of alternative plans for the I-580 corridor.

- Analytic supply models were developed paralleling the analytic disaggregate behavioral demand models. These models avoid the use of costly network coding procedures.

- Supply and demand on the links in the corridor were equlibrated using the Scarf fixed-point algorithm.

- The policy analysis suggests that a designated lane for high occupancy vehicles would be desirable in this corridor, reducing overall travel times. The impacts on mode shares are relatively weak.

Local Area Policy Analysis

- The demand for alternative feeder bus systems in a small suburban community, Walnut Creek, CA., was analyzed using models calibrated from the project surveys combined with a local survey giving characteristics and intentions of potential users.

- Hand methods were used to obtain individual access times at low cost.

- The forecasts from the project models were cross-validated against intentions data. In general, the comparisons indicated substantial discrepancies between model predictions and reported intentions and behaviors.

Conclusions

Overall, this project found that it is feasible to collect sample survey data and calibrate disaggregate behavioral models at very favorable cost levels relative to traditional aggregate methods.

The project was successful in fitting disaggregate models with a much greater degree of policy flexibility than can normally be attained with aggregate models. Our judgement is that in terms of fits to data and forecasting accuracy, the disaggregate models were comparable to aggregate models, but not significantly better. We conclude that to achieve significantly lower errors, it will be necessary to upgrade substantially the quality of transportation time and cost data, the breadth of socio-economic and attitude inventories, and the generality of the model specification. In particular, it seems to be desirable to investigate models which permit autonomous and location-dependent variations in tastes.

Policy analysis using disaggregate behavioral models has been found to be feasible and cost-effective. Several validation tests have been quite successful; however, there are disturbing exceptions. We conclude that the current generation of disaggregate behavioral models should be used for policy purposes with caution and considerable thought. There is a need for substantial additional work on methods for travel demand data collection, model specification and calibration, and forecasting, and a body of validation studies, before a complete foundation is laid for routine use of disaggregate behavioral models in transportation planning.

CHAPTER 1. EXECUTIVE SUMMARY OF VOL. II, SURVEY DATA AND METHODS

The research findings of the Urban Travel Demand Forecasting Project (UTDFP) are based predominantly on data obtained from four personal interview surveys (either face-to-face or by telephone) of San Francisco Bay Area residents. The surveys are:

The Work Travel Study (WTS) - conducted in spring 1972 by the Survey Research Center of the University of California, Berkeley, for the Institute of Urban and Regional Development of the University of California, Berkeley, under subcontract to the San Francisco Bay Area Metropolitan Transportation Commission (MTC). The survey was funded by the US Department of Transportation.

The BART Impact Travel Study 1 - (BITS 1) conducted in winter 1973-74 by the Survey Research Center for the BART Impact Program of MTC. The survey was funded by the U.S. Department of Transportation.

The Attitude Pilot Study (APS) - conducted in spring 1975 by the Survey Research Center and by West Coast Community Surveys for the Urban Travel Demand Forecasting Project of the University of California, Berkeley. The survey was funded by the National Science Foundation.

The BART Impact Travel Study 2 (BITS 2) conducted in fall 1975 by West Coast Community Surveys for the Urban Travel Demand Forecasting Project and the BART Impact Program of MTC. The survey was funded by the National Science Foundation and the U.S. Department of Transportation.

This chapter is a summary of these four surveys and the telephone interview methods used to conduct two of the surveys. First the relationship of the four surveys to this overall research design of the project is discussed. Then the surveys are described individually in a standardized format; references to more detailed survey descriptions are included. Among the referenced materials are the interview questionnaires, annotated to serve as codebooks for the BCD computer tapes on which the survey data was stored. Finally, this chapter contains a summary of an investigation of the feasibility of telephone surveys for research on urban travel demand. The investigation was done before the decision was made to use telephone surveys for some of the project's data collection. The results are reported as a chapter entitled "The Feasibility of Telephone Surveys for Research on Urban Travel Demand" in UTDFP Final Report Volume II. The remainder of volume II is an identical copy of the standardized descrition sheets of the four surveys which are included here.

Relationship of the Surveys to the Overall Research Design

The four surveys conform to a panel research design, focused on the introduction of the San Francisco Bay Area Rapid Transit (BART). This design involved the collection of survey data during both early and later stages of BART's inception period, the same individuals at both stages.

The panel research design was selected for two reasons. First, it allows the models and forecasts devised from "early-BART" data to be tested against "later-BART" data. Second, it allows changes in individual travel circumstances to be related to changes in individual travel behavior, thereby providing a better understanding of causal relationships between circumstances and behavior.

Early-BART data was obtained from two separate surveys: the spring 1972 Work Travel Study (before BART began service), and the winter 1973-74 BART Impact Travel Study-1 (BITS-1) (before BART began service connecting the two sides of the San Francisco Bay). The after-BART data was obtained from a single survey, the fall 1975 BART Impact Travel Study-2 (BITS-2). In this survey, the individuals contacted during the two early-BART surveys were reinterviewed.

An intervening survey, the Attitude Pilot Study, was conducted in spring 1975. It had two primary purposes, both pertaining to the BITS-2 reinterviews: to test a variety of attitudinal survey questions, in order to determine which should be included in the BITS-2 reinterviews; and to test the feasibility of telephone interviewing, the interview method tentatively selected for use in the BITS-2 survey.

Descriptions of Individual Surveys

In the following pages each of the four surveys are described individually, on a survey summary form. Most of the content headings in the survey summary form are self-explanatory, but three require additional definition. Survey agency refers to the organization responsible (in most cases) for sample selection, final design of the interview questionnaire, field work, and coding of completed interviews. Sample size refers to the number of completed interviews. Response rate refers to the per cent of the eligible sample contacted who completed an interview.

In addition to personal interviews (either face-to-face or by telephone), each of the four surveys included mailback questionnaires. These are described on separate survey summary forms.

Survey Summary

WORK TRAVEL STUDY (WTS)

DATE: Spring 1972[1]

FUNDING AGENCY: US Department of Transportation

RESEARCH AGENCY: Institute of Urban and Regional Development, University of California, Berkeley, subcontracted by the Metropolitan Transportation Commission of the San Francisco Bay Area.[2]

SURVEY AGENCY: Survey Research Center, University of California, Berkeley.

INTERVIEW METHOD: Home interview

SAMPLE SIZE (no. of completed interviews): 213

SAMPLE DESIGN: The sample consisted of "potential transit commuters" from the San Francisco East Bay Area who lived within feasible range of BART service in the East Bay, and worked in centrally located employment areas of the region (Oakland, Berkeley, San Francisco, Daly City, and Emeryville).

SAMPLE SELECTION PROCEDURE: Approximately equal numbers of respondents were selected from each of four geographical strata: (a) BART contiguous tracts of core cities, (b) other tracts of core cities, (c) BART contiguous tracts of surrounding areas, and (d) other tracts of the surrounding suburban areas.

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[1] When this survey was conducted BART had not yet begun operation.

[2] The principal authors were Daniel McFadden and Michael Johnson, staff members of the Urban Travel Demand Forecasting Project.

Within each stratum, households were selected with a multistage probability sampling method (selecting, in order, census tracts, blocks within selected tracts, and houses within selected blocks) such that each house in a stratum had equal probability of selection. At each household selected, screening questions were used to identify eligible respondents, i.e., those who worked in the cities designated in the sample design.

Only one person was interviewed per household; if a household contained more than one eligible person, a random procedure was used to select a respondent.

INTERVIEW CONTENT: The interview attempted to determine work travel patterns. Questions were asked about the usual travel mode; alternate travel modes, specifying frequencies and circumstances; details of work trips by car and bus; and trip timing variables. Other questions were designed to measure attitudes towards driving, auto ownership and transit use, and to determine household auto ownership and use; transportation considerations in residential locations; familiarity with BART; and intentions regarding use of BART. For each member of the household, questions were asked about employment or school status, method of traveling to work or school, ability to drive, and various standard demographic variables.

INTERVIEW DURATION: Approximately one hour.

RESPONSE RATE: 86%

COSTS PER COMPLETED INTERVIEW (excluding UTDFP staff time): $104.75

(This figure includes the costs of the Work Travel Study Trip Diary, which were not separately totaled.)

<u>REFERENCES</u>:

Johnson, M. A., and D. McFadden, "Field Materials for the 1972 Work Travel Study Survey," Special Report, Institute of Transportation Studies, University of California, Berkeley, 1976.

McFadden, Daniel et.al., "Travel Demand Forecasting Study," BART I, Part III, Final Report to the Metropolitan Transportation Commission, Institute of Urban and Regional Development, University of California, Berkeley, 1973.

Survey Summary

WORK TRAVEL STUDY TRIP DIARY

DATE: Spring 1972

FUNDING AGENCY: US Department of Transportation

RESEARCH AGENCY: Institute of Urban and Regional Development, University of California, Berkeley.

SURVEY AGENCY: Survey Research Center, University of California, Berkeley.

INTERVIEW METHOD: Following the home interviews, questionnaires were handed to respondents and explained. Respondents and other eligible household members were asked to complete and mail back the questionnaires to the Survey Research Center. A five dollar payment was promised when all trip diary questionnaires for the household were returned.

INTERVIEW CONTENT: The questionnaire requested a coded description of every trip made on the first weekday following the interview. This description included the trip purpose, origin and destination location, time started and ended, method of travel, the number of blocks walked at start of trip, and the number of blocks walked at the end of the trip. For car trips, the description included the number of people in the car, the method of parking at the trip end, and the cost of parking. For transit trips, the description included the number of transfers and the availability of a car for the trip.

SAMPLE SIZE (no. of completed interviews): 319

SAMPLE DESIGN: The sample consisted of all persons sixteen years of age or older from each household sampled in the Work Travel Study.

RESPONSE RATE: 67%

COSTS PER COMPLETED INTERVIEW (excluding UTDFP staff time): Figure not available. (The costs of the trip diary were not totaled separately from those of the Work Travel Study home interviews.)

REFERENCES:

Johnson, M.A., and D. McFadden, "Field materials for the 1972 Work Travel Study Survey," Special Report, Institute of Transportation Studies, University of California, Berkeley, 1976.

McFadden, Daniel et.al., "Travel Demand Forecasting Study," BART I, Part III, Final Report to the Metropolitan Transportation Commission, Institute of Urban and Regional Development, University of California, Berkeley, 1975.

Survey Summary

BART IMPACT TRAVEL STUDY-1 (BITS-1)

DATE: Winter 1973-74[1]

FUNDING AGENCY: US Department of Transportation

RESEARCH AGENCY: BART Impact Program, San Francisco Bay Area Metropolitan Transportation Commission[2]

SURVEY AGENCY: Survey Research Center, University of California, Berkeley

INTERVIEW METHOD: Home interview

SAMPLE SIZE (no. completed interviews): 1724

SAMPLE DESIGN: Four study regions were surveyed, two from the eastern side of San Francisco Bay (the East Bay) and two from the western side (the San Francisco Peninsula) which includes the city of San Francisco. In each region, two areas were selected, one representing a central city area with bus service and a sizeable minority population, the other representing a predominantly white, automobile-oriented suburb with limited (or no) bus service. Interviewing was limited to adults, eighteen years of age or older (or anyone who had ever been married).

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[1] During this survey, BART offered daytime service in San Francisco and on the opposite side of the San Francisco Bay (the East Bay); transbay service connecting the two portions of the system was not yet available.

[2] A number of people participated in the drafting of the survey questions, under the overall direction of Henry Bain of the Metropolitan Transportation Commission. Questions concerned with work travel were written principally by Michael Johnson in consultation with Daniel McFadden, staff members of the Urban Travel Demand Forecasting Project.

SAMPLE SELECTION PROCEDURE: Households were selected by a stratified two-stage cluster sampling procedure (selecting, in order, study areas, blocks within selected areas, and housing units within selected blocks) such that in each study area each household had an equal probability of being selected. Only one person was interviewed per household; if a household contained more than one adult, a random procedure was used to select a respondent.

INTERVIEW CONTENT: The major focus of the interview was on travel behavior (especially choice of travel mode) regarding work, shopping, and recreational trips within the Bay Area. Concerning work trips, respondents were asked about their usual travel mode; alternate travel modes, specifying frequencies and circumstances; and details of travel by usual and alternate modes. Concerning non-work trips, respondents were asked to recall the frequency of their travel during the previous twelve months to various shopping areas and recreation areas.

The interview questions also determined the employment and driver status of all household members; the number of household motor vehicles; the number of parking spaces at the residence; recent changes in home location; the frequency of bus and BART use; comparative perceptions of travel by car, bus, and BART; considerations in modal choice for work and shopping trips; perceptions of named shopping areas and of travel to those areas; concerns about air pollution and traffic congestion; and the threat of crime at bus and BART stops and when approaching or leaving their cars near home.

INTERVIEW DURATION: Approximately one hour.

RESPONSE RATE: 75%

COSTS PER COMPLETED INTERVIEW (excluding UTDFP staff time): $69.03

(this figure includes the costs of the BART Impact Travel Study-1 trip diary, which were not separately totaled).

REFERENCES:

Nicholls, W.L., III, "Sampling and Field Work Methods of the 1973-74 Bay Area Travel Survey," Survey Research Center, University of California, Berkeley, 1974.

Survey Research Center, "Field Materials and Codebook for the 1973-74 BART Impact Travel Survey (BITS-1)," Special Report, Institute of Transportation Studies, University of California, Berkeley, 1976.

Survey Summary

BART IMPACT TRAVEL STUDY-1 TRIP DIARY

DATE: Winter 1973-74

FUNDING AGENCY: BART Impact Program, Metropolitan Transportation Commission of the San Francisco Bay Area

SURVEY AGENCY: Survey Research Center, University of California, Berkeley

INTERVIEW METHOD: Following the home interviews, questionnaires were handed to respondents and explained. Respondents and other eligible household members (see Sample Design) were asked to complete and mail back the questionnaires to the Survey Research Center. A two dollar payment was promised for each returned questionnaire.

SAMPLE SIZE (no. of completed interviews): 3447

SAMPLE DESIGN: The sample consisted of all persons sixteen years of age and older from each household sampled in the BART Impact Travel Study-1.

INTERVIEW CONTENT: The questionnaire requested a coded description of every trip made on the Tuesday following the home interview. This description included the trip purpose, origin and destination location, time started and ended, method of travel, the number of blocks walked at start of trip, and the number of blocks walked at the end of the trip. For car trips, the description also included the number of people in the car, the method of parking at the trip end, and the cost of parking.

For transit trips, the description also included the number of transfers and the availability of a car for the trip.

RESPONSE RATE: 66%

COSTS PER COMPLETED INTERVIEW (excluding UTDFP staff time): Figure not available. (The costs of the trip diary were not totaled separately from the costs of the BART Impact Travel Study-1 home interviews.)

REFERENCES:

Nicholls, W.L., III, "Sampling and Field Work Methods of the 1973-74 Bay Area Travel Survey," Survey Research Center, University of California, Berkeley, 1974.

Survey Research Center, "Field Materials and Codebook for the 1973-74 BART Impact Travel Survey (BITS-1)," Special Report, Institute of Transportation Studies, University of California, Berkeley, 1976.

Survey Summary

ATTITUDE PILOT STUDY (APS)

<u>DATE</u>: Spring 1975[1]

<u>FUNDING AGENCY</u>: National Science Foundation

<u>RESEARCH AGENCY</u>: Urban Travel Demand Forecasting Project, University of California, Berkeley

<u>SURVEY AGENCY</u>: Survey Research Center, University of California, Berkeley

<u>INTERVIEW METHOD</u>: Telephone interview

<u>SAMPLE SIZE</u> (no. of completed interviews): 258

<u>SAMPLE DESIGN</u>: The sample consisted of "potential transit commuters" in the San Francisco Bay area, who lived near BART lines and worked in Berkeley, Oakland or San Francisco.

<u>SAMPLE SELECTION PROCEDURE</u>: The sample was chosen by random digit dialing. Each telephone number called consisted of a selected three-digit prefix, which determined the household location, followed by four randomly generated digits. Screening questions were used to select respondents employed in the areas designated in the sample design.

<u>INTERVIEW CONTENT</u>: The interview attempted to determine travel attitudes and perceptions related to the choice of car, bus, or BART for traveling to work. Questions were asked about the usual mode of travel to work; the alternate travel modes, specifying

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[1] When this survey was completed BART was operating on all lines of the system during the day on weekdays, but had no evening or weekend service.

frequencies and circumstances; details of work trips by car, bus, and BART; reasons for choosing among car, bus, or BART; ratings and rankings of various attributes of car, bus, and BART for commuting; attitudes towards driving, transit use, planning, and punctuality; awareness and familiarity with transit; hypothetical intentions to change usual commute mode in response to service and fare changes; and standard socio-economic and demographic variables.

INTERVIEW DURATION: Approximately 40 minutes.

RESPONSE RATE: 83%

COSTS PER COMPLETED INTERVIEW (excluding UTDFP staff time): $31.60

REFERENCES:

Johnson, M.A., and D. Gayle McFadgen, "Field Materials for the 1975 Attitude Pilot Study Survey," Working Paper No. 7610, Urban Travel Demand Forecasting Project, Institute of Transportation Studies, University of California, Berkeley, 1976.

Johnson, M.A., "Going to Work by Car, Bus, or BART: Attitudes, Perceptions, and Decisions," Working Paper No. 7518, Urban Travel Demand Forecasting Project, Institute of Transportation Studies, University of California, Berkeley, 1975.

Nicholls, W.L., III, "Sampling and Field Work Methods of the Travel Demand Forecasting Project Pilot Telephone Interview Survey," Survey Research Center, University of California, Berkeley, 1975.

Survey Summary

ATTITUDE PILOT STUDY MAILBACK QUESTIONNAIRE

DATE: Spring 1975

FUNDING AGENCY: National Science Foundation

RESEARCH AGENCY: Urban Travel Demand Forecasting Project, University of California, Berkeley

SURVEY AGENCY: West Coast Community Surveys

INTERVIEW METHOD: Questionnaires were mailed to respondents who were asked to complete them and mail them back.

SAMPLE SIZE (no. completed interviews): 125

SAMPLE DESIGN: Questionnaires were sent to all respondents in the Attitude Pilot Study sample who were willing to provide their names and addresses during the telephone interviews.

INTERVIEW CONTENT: The interview contained a large number of questions designed to measure transportation-related concerns or desires. Eleven attitude dimensions were used: reliability, safety from accidents, safety from crime, privacy, convenience, comfort, resistance to change, productive use of time, order and organization, ecology, and self-sufficiency.

Questions were also asked about the travel preferences of family, friends, and co-workers; the extent of the respondent's concern for the approval of these groups; knowledge of transit service and auto travel in the San Francisco Bay area; and changes in home or work location, hours employed, and method of travel to work.

RESPONSE RATE: 73% of the telephone sample provided their names and addresses; of these, 66% returned the questionnaire which was mailed to them.

COSTS PER COMPLETED INTERVIEW (excluding UTDFP staff time): $8.72

REFERENCES:

Johnson, M.A., and D. Gayle McFadgen, "Field Materials for the 1975 Attitude Pilot Study Survey," Working Paper No. 7610, Urban Travel Demand Forecasting Project, Institute of Transportation Studies, University of California, Berkeley, 1976.

McFadgen, D. Gayle, "Fieldwork Methods and Results for the 1975 Attitude Pilot Study Mailback Questionnaire," Working Paper No. 7612, Urban Travel Demand Forecasting Project, Institute of Transportation Studies, University of California, Berkeley, 1976.

Survey Summary

BART IMPACT TRAVEL STUDY-2 (BITS-2)

DATE: Fall 1975[1]

FUNDING AGENCY: National Science Foundation and US Department of Transportation (joint funding)

RESEARCH AGENCY: Urban Travel Demand Forecasting Project, University of California, Berkeley, and BART Impact Program, Metropolitan Transportation Commission.[2]

SURVEY AGENCY: West Coast Community Surveys

INTERVIEW METHODS: Telephone interview

SAMPLE SIZE (no. completed interviews): 1093

SAMPLE DESIGN: The desired sample included all respondents of the Work Travel Study and BART Impact Travel Study surveys who still resided in the combined set of geographical areas sampled in the original surveys.

In addition, the sample included approximately 150 BART commuters who had not been previously interviewed, and who rode

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[1]This survey was conducted three years after BART began service and one year after BART began transbay service. At this time there was still no evening or weekend service.

[2]This telephone interview questionnaire was drafted by the Urban Travel Demand Forecasting Project; the BART Impact Program of the Metropolitan Transportation Commission was consulted. The MTC granted permission to reinterview respondents initially contacted during its BART Impact Travel Study-1 survey. The MTC also made a substantial financial contribution towards funding this survey (approximately one third of total costs) using money obtained from DOT. Although considerable effort was made to accomodate the desires of MTC regarding the survey content, final discretion on content was retained by the UTDFP.

BART to work during the weekday AM peak period. Approximately equal numbers of respondents were obtained at each of nine selected BART stations. Six of the nine selected stations were chosen because of the high proportions of riders arriving by bus. The remaining three stations were selected randomly from those remaining BART stations which were not in downtown areas of Oakland or San Francisco.

SAMPLE SELECTION PROCEDURE: Procedures used to contact and reinterview respondents included address updating done by the US Post Office, examination of voters' registration records, inspection of Bay Area telephone directories and reverse telephone directories, telephone calls to neighbors, and letters to respondents requesting information about their whereabouts and/or telephone numbers.

To obtain an additional sample of BART riders, travelers were approached at each of the selected stations and asked whether they were going to work and were willing to provide their names, addresses, and telephone numbers in order to be interviewed by phone at a later time. Of the eligible and willing respondents, a sub-sample from each station was selected, chosen so that their arrival times at the station were spread evenly across the AM peak period.

INTERVIEW CONTENT: The interview attempted to determine work travel patterns. Questions were asked about usual travel mode; alternative travel modes, specifying frequencies andcircumstances; and details of work trips by car, bus and BART including trip timing, carpooling, and perception of auto travel costs. Questions were also asked about attitudes towards driving, auto ownership and transit use. Questions were also asked about current auto ownership and use by the respondent's household; transportation considerations in residential locations; frequencies of non-work travel by various modes; frequencies and usual travel modes for shopping for major items at various Bay Area locations; and preferences and anticipated responses to several contemplated changes in BART service. Questions were asked about employment or school status, method of traveling to work or school, driving status, and various standard demographic variables for each member of the household.

INTERVIEW DURATION: Approximately 30 minutes.

RESPONSE RATE: 63% of the previously interviewed respondents were contacted by phone. Of these, 80% completed an interview. Of the additional sample of BART riders, 81% completed an interview.

COSTS PER COMPLETED INTERVIEW (excluding UTDFP staff time): $17.62 ($2.54 of this figure was due to efforts to re-contact respondents).

REFERENCES:

Johnson, M.A., "Field Materials for the 1975 BART Impact Travel Study-2 Survey," Working Paper No. 7608, Urban Travel Demand Forecasting Project, Institute of Transportation Studies, University of California, Berkeley, 1976.

West Coast Community Surveys, "Field Work Methods of the Second Bay Area Travel Study: A Telephone Survey Conducted in October-December, 1975," Working Paper No. 7609, Urban Travel Demand Forecasting Project, Institute of Transportation Studies, University of California, Berkeley, 1976.

Survey Summary

BART IMPACT TRAVEL STUDY-2

MAILBACK QUESTIONNAIRE AND TRIP DIARY

DATE: Fall 1975

FUNDING AGENCY: National Science Foundation

RESEARCH AGENCY: Urban Travel Demand Forecasting Project, University of California, Berkeley

SURVEY AGENCY: West Coast Community Surveys

INTERVIEW METHOD: Questionnaires were mailed to respondents, who were asked to complete them and mail them back. With each questionnaire, two dollars was included as an incentive. Shortly after the questionnaires were mailed, each respondent was called by an interviewer who offered to provide any additional explanation needed to complete the questionnaire.

SAMPLE SIZE (no. completed interviews): 829

SAMPLE DESIGN: Questionnaires were sent to all respondents of the BART Impact Travel Study-2 for whom correct addresses were available. (Respondents were asked during the telephone interviews to correct if necessary the address presumed by the survey agency.)

INTERVIEW CONTENT: Respondents were asked to rate car, bus and BART on each of 10 attributes (the same attributes used in the BART Impact Travel Study-1 survey). Other questions were designed to measure concerns or desires about ecology, security from crime, punctuality, enjoyment of driving, and general attitudes towards transit use.

The questionnaire also included a trip diary designed to allow a coded description of every trip made during the five day period from Friday to Tuesday following the receipt of the questionnaire. The coded trip description included the trip purpose, origin and destination location, time started and ended, method of travel, the number of blocks walked at start of trip, and the number of blocks walked at the end of the trip. For car trips, the description also included the number of people in the car, the method of parking at the trip end, and the cost of parking. For transit trips, the description also included the number of transfers and whether a car was available for the trip.

RESPONSE RATE: Questionnaires were sent to all but six respondents of the BART Impact Travel Study-2. (Those six did not provide names and addresses). 76 percent of the questionnaires sent out were returned completed.

COST PER COMPLETED INTERVIEW (excluding UTDFP staff time): $7.72

REFERENCES:

Johnson, M.A., "Field Materials for the 1975 BART Impact Travel Study-2 Survey," Working Paper No. 7608, Urban Travel Demand Forecasting Project, Institute of Transportation Studies, University of California, Berkeley, 1976.

West Coast Community Surveys, "Field Work Methods of the Second Bay Area Travel Study: A Telephone Survey Conducted in October-December, 1975," Working Paper No. 7609, Urban Travel Demand Forecasting Project, Institute of Transportation Studies, University of California, Berkeley, 1976.

D. An Evaluation of Telephone Interviewing

As indicated previously, two of the surveys done for this research project used telephone interviews. Before these surveys were conducted, an investigation of telephone interviewing was made. The investigation had two parts: a reading of pertinent literature, and consultation with the staff of three survey research organizations that had extensive experience with telephone interviews. Three aspects of telephone interviewing were evaluated: sample selections, data quality, and cost. A frame of reference for the evaluations were provided in most cases by comparing telephone interviews to face-to-face interviews. Overall, the investigation led to the conclusion that telephone interviewing was a highly satisfactory method for the intended data collection.

The major advantage of telephone interviews is their low cost. Typically, phone interviews cost approximately one third as much as comparable face-to-face interviews. Telephone interviews are generally comparable to face-to-face interviews in terms of sampling adequacy and quality of the data obtained.

The most obvious limitation of telephone interviewing--that some households do not own phones--was not a serious problem for several reasons: (1) in 1975 only about ten percent of the households in the San Francisco Bay Region did not have phones. The proportion was even smaller for households with working members, which were the main interest of the Project. (2) Recent research has indicated that properly selected telephone samples are not significantly biased in terms of their demographic characteristics. (3) For the major data collection effort of this Project, it was feasible to identify respondents without phones and contact them with face-to-face interviews, if desired.

Disregarding the problem of households without phones, most telephone surveys have had response rates similar to those of comparable face-to-face surveys.

The quantity of information obtainable with a telephone interview is less than for a face-to-face interview. Phone interviews should last not more than twenty or thirty minutes, unless the topics are of special interest to the respondents. On the other hand, telephone interviews use interview time somewhat more efficiently than do face-to-face interviews.

Several studies have verified that when comparable questions are asked in telephone and face-to-face interviews, the responses do not differ substantially. It is of course impossible to ask questions over the phone which require visual materials. The use of response category cards is also impossible on the phone; however, satisfactory alternative approaches seem to have been developed for most questions for which the cards are typically used.

In some respects telephone interviewing may be superior to face-to-face interviewing. There is likely to be more uniformity in the interviews, since the respondent cannot respond to interviewer appearance, facial cues, etc. Typically, phone interviewing is done from a central office with a skilled supervisor constantly present. This allows continued interviewer training, greater uniformity of interviewing, and control against non-conscientious performance.

CHAPTER 2. EXECUTIVE SUMMARY OF VOL. III,

DISAGGREGATED SUPPLY DATA COMPUTATION PROCEDURES

The zonally-aggregated, peak-hour trip time data used in previous work travel research have left questions unanswered and suggested biases in the understanding of individual demand behavior. Commuters respond to the particular mix of service attributes available to their homes and to their work schedules, not to peak-hour, zonal average service.

Methods were developed and used by the Urban Travel Demand Forecasting Project to prepare alternative mode work-trip times and costs, temporally and spatially disaggregated to the individual circumstances of a sample of commuters. Together with socio-economic data obtained from household surveys of these workers, the trip data allow accurate resolution of the determinants of individual mode-choice behavior.

The trip data were prepared for the same commute-trip sample before and after the implementation of the Bay Area Rapid Transit (BART) System in the San Francisco Bay Area. This allowed independent development of disaggregated travel demand models, and their validation under changed conditions, principally the introduction of a new mode. Several versions of the trip descriptions were produced to test different trip schedule choice hypotheses and the effects of data aggregation. The source data were the temporally and spatially aggregated data from traditional transportation travel time network files, supplemented by field measurements of highway congestion and the transit service schedules.

The prepared data were composed of files of trip travel time, cost components, and reliability measures of each work trip on alternative modes. Different trip data versions were calculated for different work schedules and at different levels of aggregation. Also produced were documented methods and supporting software for computing the different levels of disaggregate data.

Table 1 shows the number of alternative modes for which trip attributes and versions were prepared in the before and after (BART) travel environment. The before-BART period was mid-1972 and the after period was late 1975. This corresponded to the behavioral and socioeconomic data in the associated surveys. Much attention was given to use of the same source data types and trip computation methods for the after-BART period to ensure that the data represented only the change in the transportation environment for the validation of the model forecasts.

Tables 2 and 3 show the time components prepared for each version of the trip descriptions. These components allow the models to determine if travelers have different sensitivities to different parts of service times.

TABLE 1

Transportation Mode Alternatives
Computed for the "Before" and "After" Years*

Before BART Alternatives	After BART Alternatives	Principal Mode	Access Sub-Mode
1	1	Auto alone	------
2	2	Bus (walk access)	------
3	3	Bus	Auto
4	7	Carpool	------
	4	BART (walk access)	------
	5	BART	Bus
	6	BART	Auto

*Walk access and egress was considered from trip ends to the sub-mode if applicable, otherwise straight to the principal mode. Auto was never allowed as an egress sub-mode. Bus was a possible egress sub-mode for any BART trip.

TABLE 2

Travel Time Attributes Computed for Transit Trips

Access travel time

First headway

Line-haul time

Number of transfers

Cumulative transfer headways

Egress travel time

(and for each trip leg, up to 4 maximum):

Headway

Line-haul

TABLE 3

Travel Time Attributes Computed for Auto Trips

Line-haul time

Freeway travel time

Freeway time traveling under 10, 20, 40 and 50 mph

Non-freeway traveling under 10, 20, 40 and 50 mph

TABLE 4

Supply Variable Versions Prepared

Schedule of Trip	Suffix used for Variable	Directions Calculated Highway	Directions Calculated Transit
At official work schedule with extra peak data	T	2	2
At official schedule approximated with network data only	X	2	2
On peak network	P	1	2
On midday network	M	2	2
At 8 am and 5 pm	S	2	0*
On peak network corrected by external data	Q	1	0
On midday network corrected by external data	N	1	0
At official work schedule + 30 minutes	L	2	0
At official work schedule - 30 minutes	E	2	0
With disaggregated access variables	D	**	**
Total home-to-work trip versions computed		9	4
Total trip versions computed		15	8

NOTES

*Equivalent to trips on peak network

**Only 3-8 variables per mode, otherwise equivalent to "T"-variables

The different versions of the trip attributes, computed to represent different degrees of temporal disaggregation accuracy and different trip schedules, are shown in Table 4. For example, versions designated in the table by the P, T, and X codes, respectively, represent three trip descriptions calculated for average travel, at the commuters actual work schedule, and at an approximation for their schedule. The versions coded L and E are for "late" and "early" travel to work to be used in models of trip timing.

In addition, transit fares, auto running costs, parking costs, tolls, measures of the reliability of the modes, and geographic codes identifying the path were prepared for each trip. These were computed for trips to and from work, for the trip schedule versions for auto and bus modes before BART, and auto, bus, and BART alternatives afterward. These computations totaled approximately 4000 variables per case.

Figure 1 charts the flow of data through the computation processes used in the preparation of the individual trip time files. The three inputs to the process were the origin-destination and schedule definitions of the worker's trips, the network travel time files, and supplementary service level data on highway and transit through the peak periods. The principal preparation processes were the network path runs, the extraction of the individual trip components from them, and the development and operation of programs capable of producing various versions of the temporally disaggregated trip times from the network and peak period data.

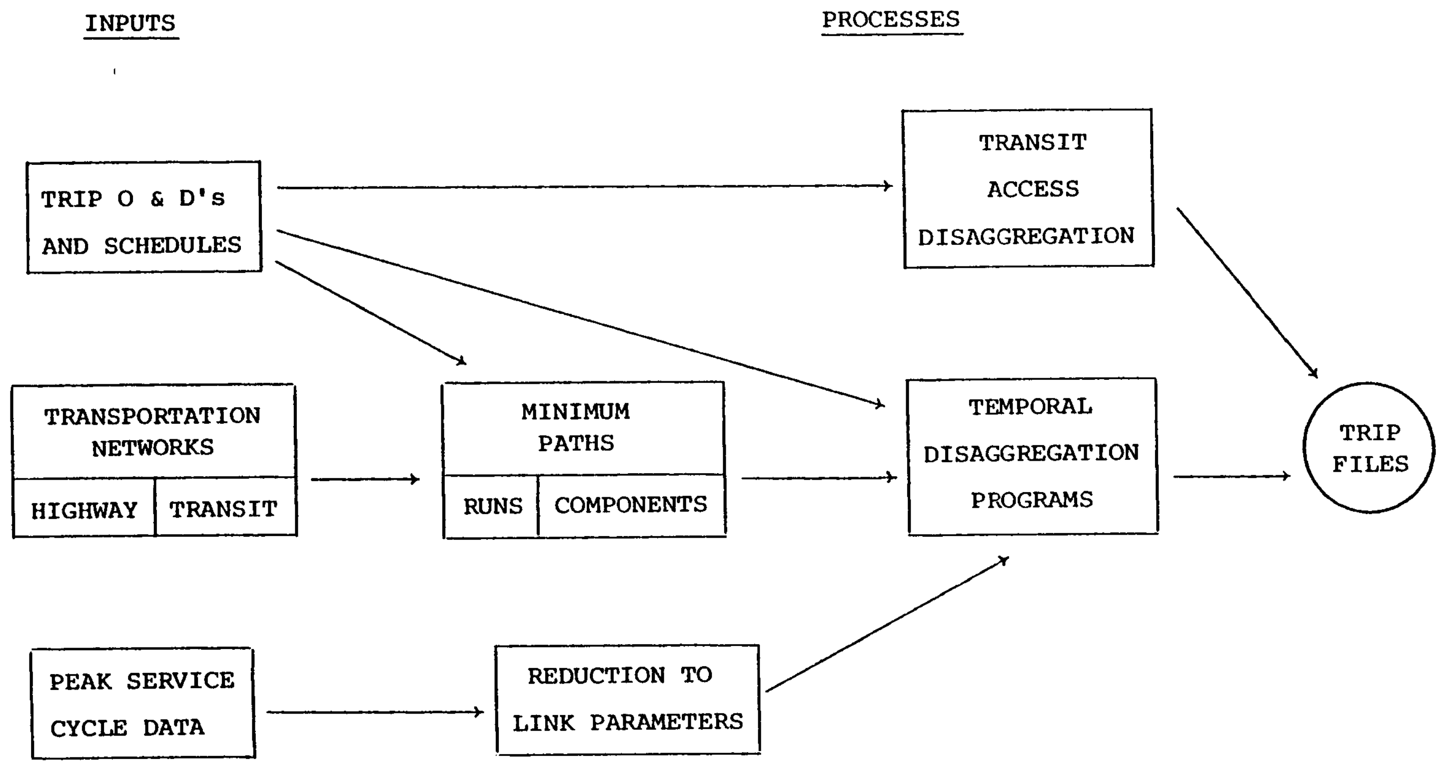

FIGURE 1

Flow of Data and Operations for Producing Disaggregated Trips

Interzonal network paths were run from all trip-ends for the different periods of the day. The components of the desired paths were retrieved and fed, together with functions representing the peak-cycle data, into the temporal disaggregation programs. These programs performed a scaled table look-up from the peak-cycle data, according to the individual trip schedules, to determine travel times in the peak transition period. Voluminous field data on service during commuting hours were reduced to simple functions representing the shape of the peak cycle for each network link—a key input to the temporal disaggregation programs. These temporal disaggregation processes, though similar, were independently designed and run for auto, bus, and rail trips. Spatial disaggregation was done only as a post-path-running correction of the aggregate network access distances. These were measured from the individual trip-end addresses to nearby transit stops. Fully individual tradeoffs between walk-access and headway times were not represented.

Other trip attribute data preparation included collection of field data on parking costs and transit reliability. Programs were developed to associate these data with the individual trip paths previously determined.

Very few assumptions or approximations were used in the objective representation of the attributes of the commute trip alternatives. The mpst important was the assumption that the traditional network path algorithms do represent travelers' routes. A related assumption was that work trips are between only two points (single purpose). Since only one transit network was available, the different bus and rail alternatives were represented by separate minimum path runs, penalizing out the undesired mode.

CHAPTER 3. EXECUTIVE SUMMARY OF VOL. IV

QUAIL 4.0 USER'S MANUAL

QUAIL (for QUAlitative, Intermittant, and Limited Dependent Variable Statistical Program) is a special purpose computer program for analysis of statistical models involving non-continuous dependent variables, and for manipulation and storage of associated arrays of data. QUAIL contains the following statistical procedures:

1. binary logit
2. multinomial (conditional) logit
3. ordinary least squares
4. two-state least squares (instrumental variables)
5. lumpit
6. multinomial probit (experimental)
7. simple univariate and multivariate statistics

The logic procedures may be carried out with linear equality restrictions on parameters. Estimation can be done by maximum likelihood, non-linear least squares, or by weighted exogenous sample maximum likelihood. The program can perform matrix calculations, carry out arithmetic and logical operations on variables, and create and update a data tape. It allows the use of subsamples and booleans (masking variables) to provide flexibility in activating and operating on observations, and provides for automatic handling of missing data.

QUAIL is designed so that most user errors in command statements are detected at an early stage before data is loaded or any results are computed. This feature makes it possible to "debug" QUAIL programs at low cost, and avoids the problem of expensive, unsuccessful runs when working with large data sets.

The basic research done in the development of QUAIL was generously supported in part by grants GS-35890X, SOC72-05551, and SOC75-22657, National Science Foundation, Social Sciences Division; by grants GI-43740 and APR74-20392, National Science Foundation, Research Applied to National Needs Program; and by grants 74-12-8 and 78-4-1, Alfred P. Sloan Foundation, to the University of California, Berkeley.

The User's Manual was originally written by David Brownstone, Gregory M. Duncan, and Daniel McFadden (Working Paper No. 7402, Urban Travel Demand Forecasting Project, Institute of Transportation Studies, University of California, Berkeley, 1974). It was rewritten and extended for QUAIL 3.0 and QUAIL 4.0 by Jerry Berkman. Revisions of this manual were made in January 1975, January 1976, and September 1977. This version supersedes previous manuals which appeared in the years listed above.

QUAIL is written almost entirely in FORTRAN IV. Versions are currently running on IBM 360/370 and CDC 6400-6600-7600 computers. Details on the inner structure of QUAIL and the numerical and statistical methods used in its model estimations are described in the "QUAIL Programmers Manual" Working Paper No. 7904 of this project.

QUAIL is not a maintained program. A list of qualified consultants available on a fee basis can be obtained by writing to the QUAIL Consultant. Information on the availability of the program, ordering procedures, and costs, can be obtained by writing to the QUAIL Consultant in the address given below.

<u>Through 31 August 1979</u>:

David Brownstone
Department of Economics
University of California
Berkeley, CA 94720

<u>After 1 September 1979</u>:

David Brownstone
Department of Economics
Princeton University
Princeton, NJ 08540

It should be noted that QUAIL has been specifically designed for statistical analysis of non-continuous dependent variables, and is not intended for use as a general data transformation and storage utility or as a linear statistical model/regression analysis package. However, it is useful for these purposes.

The QUAIL User's Manual is designed for use by individuals who have some knowledge of programming in FORTRAN or SPSS. Specifically the manual assumes the reader is familiar with SPSS or FORTRAN format statements and arithmetic and logical expressions. A thorough familiarity with basic statistical concepts, including maximum likelihood estimators and their large-sample properties is also required.

Appendix C is the Table of Contents of the User's Manual.

QUAIL was designed by Daniel McFadden and Hugh Wills and was originally implemented by Steven Glanville. Successive versions have been coded by Jerry Berkman, Chris Murano, Carlos Puig, David Brownstone, and Gregory M. Duncan. The multinomial logit procedure in this program was developed by Daniel McFadden, and coded in successive versions by C. Tait Ratcliffe, C. K. Liew H. Varian, H. Wills, and D. Brownstone. The LUMPIT procedure was originally written by Suzanne Scotchmer and modified slightly by Carlos Puig. The PROBIT procedure was coded by Carlos Puig based on a progeam from Cambridge Systematics, Inc. (CSI). PROBIT development was supported by the Electric Power Research Institute (EPRI) and the Computer Usage Corporation (CUC) of Sunnyvale, California. The IBM version of QUAIL was coded by Jerry Berkman, Scott Leubking, Carlos Puig, and David Brownstone. Support for the IBM conversion was supplied by the RAND Corporation, The U.S. Department of Transportation, EPRI, CSI, and the University of California, Berkeley's Computer Center.

CHAPTER 4. EXECUTIVE SUMMARY OF VOL. V

DEMAND MODEL ESTIMATION AND VALIDATION

The overall objective of the Urban Travel Demand Forecasting Project is to provide transportation engineers and planners with the information necessary to select and use policy-oriented disaggregate behavioral travel demand models, and to assess the applicability and limits of special alternative models. Volume V is devoted to the investigations of demand, forming the core of this project.

The research plan underlying this demand research was to:

- Collect data on a sample of individual commuters in the San Francisco Bay Area before the initiation of Bay Area Rapid Transit (BART) service;
- Predict BART patronage from demand models fitted to the pre-BART data, and
- Compare the predictions with actual BART patronage, using a second survey taken after BART was in service.

Attention was concentrated on work mode-choice. A number of parallel questions in demand analysis were addressed:

- What variables influence demand?
- How does the method of measurement of variables affect demand model estimates?
- What functional forms for demand achieve the multiple objectives of validity, practicality, and simplicity? (In particular, is the multinomial logit (NML) model, with its structural property of independence from irrele-

vant alternatives (IIA), a valid forecasting model for a new mode?

- How can socioeconomic and demographic variables be forecast as inputs to transportation policy forecasts?
- How can transportation level-of-service attributes be calculated under alternative policy scenarios without building complete networks?
- To what degree are disaggregate behavioral models transferable from one population to another within, or between, cities?
- How can aggregate travel demands be conveniently calculated from disaggregate behavioral models?
- What is the role of attitudes and perceptions in travel behavior?
- How can disaggregate behavioral models be adapted to equilibration of transportation supply and demand?

The conclusions of the research can be summarized:

- A short list of traditional transportation system attributes (e.g., travel times and costs) explain most travel demand behavior. Socioeconomic variables improve overall fits significantly. Inclusion or exclusion of most socioeconomic variables from the models does not greatly affect the importance attributed to on-vehicle time and costs--thus, policies affecting only these variables may be validly analyzed in models without great socioeconomic detail. Variables which are related to the "availability" of alternatives, such as auto ownership, are extremely important.

- Disaggregate behavioral models fitted to pre-BART data provided relatively accurate forecasts of BART patronage. Forecasting accuracy was significantly better in models with socioeconomic detail than in models employing only traditional transportation variables. The forecasts were best for BART with bus- or walk-access but substantially overpredicted BART-with-walk-access patronage.
- The use of network travel times, compared with travel times calculated directly from trip timing studies, showed considerable dispersion and some systematic biases. Overall fits were not greatly affected, but implied values of time changed substantially depending on the method of variable measurement used.
- The multinomial logit model is found to provide a valid functional form for a variety of transportation applications. Empirical tests are developed for the independence from irrelevant alternatives (IIA) property, and are not rejected for the travel demand behavior observed by the project.
- A pragmatic method for synthesizing census data into a transportation demand data base at any desired date for policy analysis has been developed.
- Analytic supply models, giving transportation level-of-service attributes as parametric functions of policies and

of patronage, provide a relatively inexpensive, policy-sensitive supply counterpart to disaggregate demand models.

- Disaggregate behavioral models fail tests of transferability between urban and suburban residents, indicating either significant taste variations with residential locations or geographical variations in network coding practices. There is also some evidence of non-transferability between cities, most probably attributable to differences in variable measurements.
- A market segmentation based on summary "utility levels" of alternatives is found to be a particularly effective method of obtaining reasonably accurate aggregate forecasts. Random sampling from the population is a second effective method .
- Attitude and perception measurements complement traditional transportation measures as explanations of travel behavior, in the sense that adding attitude variables to a model containing traditional transportation variables has little effect on the importance assigned to the traditional variables. Generally, adding attitude variables to a model does not substantially increase its explanatory power.
- Equilibration of disaggregate demand models and parametric supply models in a corridor has been achieved using a computational procedure for approximating fixed points of a mapping. This method provides a practical alternative to conventional network equilibration methods.

Overall, the demand studies summarized in this volume have demonstrated disaggregate travel demand forecasting to be a practical policy-analysis tool. The limitations of the current generation of these models are spelled out, and suggest that considerable care is needed in their application to new mode forecasting, and in transferring models across populations. Some limitations of the models appear to be amenable to improved variable specification, achievable with further research and improved disaggregate data collection.

CHAPTER 5. EXECUTIVE SUMMARY OF VOL. VI, ATTITUDES, BELIEFS AND TRANSPORTATION BEHAVIOR

Several studies done as part of the UTDFP were based substantially on subjective data, reflecting travelers' beliefs, attitudes, and intentions. The research topics were: (1) the importance of various travel attributes as influences on choices among car, bus, and BART commuting, and (2) attitudes reflecting basic preferences for auto and transit travel.

These studies are described in detail in Volume VI of the UTDFP final report series, which is summarized below.

Definitions

The first chapter of Volume VI presents definitions of beliefs, attitudes, and intentions for use in the remainder of the volume. (These terms, especially "attitude," have been used with much ambiguity by transportation researchers, which has hindered communication and led more than once to inappropriate substantive conclusions.) In addition to defining these terms, the chapter discusses the relationships of the concepts to each other, to objective measures of physical phenomena, to the concept of utility (a concept central to much of the research done on urban travel behavior), and to behavior.

Attribute Importance

The next chapter describes a study of ten different travel attributes and their relative importance as influences on choices among car, bus, and BART for traveling to work in the San Francisco Bay Area. The attributes were: (1) cost, (2) total travel time, (3) dependability, (4) relaxation, (5) safety from accidents, (6) use of time while traveling, (7) flexibility, (8) seat availability, (9) safety from crime, and (10) waiting time.

A sample of 258 commuters were interviewed. Each was asked to rate his satisfaction with car, bus, and BART on each of the ten attributes. Each commuter was also asked how he usually traveled to work. The relative importance of the attributes was inferred by examining the attribute ratings and the relationships, over the study sample, between the ratings and the usual choice of travel mode.

One consideration in evaluating the importance of any attribute was the extent to which average attribute ratings differed for the three travel modes. To investigate this, average ratings of car, bus, and BART were calculated for each attribute.

On the average, the car was rated as much superior to bus and BART on total travel time, dependability, and flexibility. On the other attributes, car commuting was rated as slightly inferior to transit travel, especially so with respect to safety from accidents. The average ratings for bus and BART commuting were generally similar to each other, although BART commuting was rated as slightly better in terms of safety from crime, waiting time, and relaxation.

Seat availability, crime safety, and waiting time were not rated for car travel; assuming, however, as seems reasonable, that car would have been given the highest possible rating on these attributes, the differences in evaluations between car and the two transit modes were substantial.

To evaluate the extent to which the average differences in <u>ratings</u> reflected average differences in <u>utility</u>, and to estimate other components of attribute importance, it was necessary to analyze the relationships, over the study sample, between the attribute ratings and preferences among the rated modes. This was done with maximum likelihood logit analyses. In general, the analyses indicated that the ratings for all of the attributes were strongly related to travel mode choice; however, the relationships were somewhat weaker for the attributes of relaxation, time use, and accident safety.

Attribute importance was measured with a recently devised statistic that combined utility coefficients estimated from the logit analyses with values of the attribute ratings, over the sample. This statistic estimated the extent to which each attribute contributed to differences in utility among the choice alternatives.

In terms of overall importance, considering choices among all three modes, the attributes seemed to cluster into several groups having roughly equal importance statistics. Waiting time, dependability, total time, and crime safety appeared to be the most important attributes. Cost, seat availability, and flexibility appeared to be next in importance, followed by relaxation and accident safety. Time use appeared to be the least important attribute.

Several of the attributes judged to be most important--including crime safety, dependability, and seat availability--are not typically included in quantitative planning procedures, such as travel demand forecasting or cost-benefit analysis. The results of this study suggest that these attributes should be taken more into account in transportation policy decisions.

These conclusions must be qualified by uncertainties regarding the extent to which the observed relationships to behavior for intercorrelated attribute ratings actually reflected the influence of different underlying policy variables. Additional research, along lines suggested in the complete report, is required to clarify these relationships.

In addition to the substantive findings, this study had value as an illustration of research methodology. The definitions of attribute importance and corresponding measurement methods can be applied to research, based either on subjective or objective data, on a wide variety of choice behaviors.

Basic Preferences

The next chapter of Volume VI describes two studies of attitudes related to the basic characteristics of auto and transit travel, that is, characteristics which do not vary substantially for different trips. There are many such characteristics. For example, transit travel involves conforming to a route and schedule and sharing a common space with strangers; auto travel does not. Auto users typically own and drive the vehicle in which they travel; transit users do not.

Attitudes related to such characteristics can be considered to reflect basic preferences for auto and transit travel. The studies described in this report investigated the influence of various attitudes of this sort on people's choices between auto and transit travel for commuting to work. Very little research has previously been done on this subject.

In the first study the attitudes investigated fell into four categories: (1) enjoyment of the experience of driving, (2) tolerance of traffic stress, (3) enjoyment of automobile ownership, and (4) evaluation of bus travel in terms of comfort and freedom from distraction. In the second study more general attitudes were investigated which reflected feelings and tendencies regarding: (1) security from crime, (2) time pressure, (3) privacy, (4) punctuality, (5) ecology issues, and (6) personal energy and activity. Although the attitudes investigated in the second study seemed likely to influence evaluations of auto and transit travel the attitude measures themselves were not primarily oriented to transportation.

Both studies used survey data from the San Francisco Bay Area. The first study examined choices between auto and bus commuting; it was based on a 1972 home interview survey of 213 people. The second study examined choices among auto, bus, and BART commuting; it used data from a 1975 mailback follow-up survey of 125 people who had previously been interviewed by telephone about related transportation topics.

The method of analysis used was essentially the same in both studies. A large number of individual attitude items were combined into a small number of composite attitude variables, reflecting the concepts enumerated above. Each composite variable was made up of highly intercorrelated items, as identified with a factor analysis procedure, that also had similar apparent meanings. A multiple logit analysis was done to determine the relationships, over the sample of people interviewed, between the values of the composite attitude variables and the choices between auto and transit commuting. Also included in the logit analysis were a number of non-attitudinal variables describing the people in the sample and the travel modes available to them, in terms of travel times, costs, and other factors conventionally used to explain travel mode choice.

In the first study the most pertinent result was that the composite attitudinal variable reflecting tolerance of traffic stress had a statistically significant relationship to behavior, comparable in size (as measured with a standardized utility coefficient) to the more important non-attitudinal variables. This suggested that the basic attribute underlying this variable--presumably, the necessity to drive in stressful circumstances--was a relatively important influence on people's preferences between auto and transit commuting. This conclusion was consistent with a finding from the interviews that avoiding the strain of driving was the reason most frequently given for preferring bus to auto commuting, hypothetically, assuming that times and costs were equal.

In the second study the composite attitude measure reflecting energy and enjoyment of activity had a substantial and statistically signigicant relationship to travel mode choice. This result suggested that people who are active and energetic (or at least view themselves that way) are more likely to use transit, while people who tend to avoid effort are more likely to travel by car. This is consistent with the notion that the easiest way to travel in urban areas is to jump in the car and drive off.

For all of the attitude variables in the second study the relationships to travel mode choice were in the expected direction, conforming to the joint hypothesis that transit use is associated with not worrying about personal security, not feeling pressed for time, not minding crowds, tending to schedule activities, being concerned with ecology issues, and feeling active and energetic.

The two studies were concerned primarily with the extent to which variations in the measured attitudes seemed to influence choices between auto and transit travel. Also of interest, however, was the extent to which average attitudes determined mode choices. Unfortuneately, the scaling of the attitude items did not allow a quantitative examination of the extent to which average attitudes contributed to utility differences among the auto and transit modes examined. In the first study, however, it was possible to reach some qualitative and judgemental conclusions.

Average responses tend to be somewhat critical of driving and auto ownership and favorable to bus use. This was inconsistent with the preponderant preference of the sample (about four to one) for auto over transit as a usual method of commuting; the inconsistency suggested that the average attitudes were not an important influence on travel mode choice.

The relationships observed in these two studies suggest that measures of basic preference attitudes may have useful applications in quantitative planning methods, such as travel demand forecasting. Even if it is not feasible to obtain attitude measures for many planning applications, they should be taken into account in the calibration of models used for the applications, in order to accurately estimate coefficients for other variables. Accurate estimation of model coefficients requires that no important influence on behavior be omitted during the calibration.

Because of the small sample size and exploratory nature of the attitude measurement the conclusions of these two studies should be considered tentative, especially conclusions that particular attitude dimensions are <u>not</u> related to travel behavior. Nevertheless, the positive results that were observed and the research issues that were raised suggest that further research on this subject will prove interesting and useful.

CHAPTER 6. EXECUTIVE SUMMARY OF VOL. VII, AGGREGATION METHODS AND TESTS

Transportation policy analysts and forecasters have recognized that models of individual travel behavior give increased accuracy, issue sensitivty and efficiency in quantitive predictions.* However, analysts are always interested in group demand levels or impacts, while such models express individual behavior as a function of individual situations. This has introduced a new problem into the prediction process--the problem of aggregation. The problem is new relative to the practice of predicting aggregate travel demands from the average characteristics of (hopefully) uniform aggregates. The trouble with such "aggregate models" is that the individual situations upon which people's choices are based are often masked by taking group averages. Applied to typically non-linear decision processes, aggregate models result in biases and loss of sensitivity in the predictions.

Disaggregate models are calibrated in terms of individual decision-maker data. The aggregate predictions desired for planning are made from these models using data for the distribution as well as the average of the characteristics of the choice alternatives available to those in the aggregate. This distributional data, in the form of covariances or cross-

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* Such models are discussued in Volume V of the VTDFP Final Report Series

classifications of the data, is the key to attaining the accuracy and sensitivity of predictions from disaggregate models.

Fortunately, this extra aggregation step is off-set by the fact that the basic disaggregate models are much more efficient to calibrate (in data consumption and computation time) than aggregate data models. Data averaging throws away information in the latter. But since planning re-requires repeated forecasts and analyses over different groups, the data requirements and aggregation process are still major burdens. Some analysts have sought to avoid this burden by predicting with disaggregate models using only average data in sub-groups of a population. While this "naive" aggregation practice realizes the calibration efficiency of the base models, the accuracy and policy-issue sensitivity of such predictions may be no better than that of aggregate models. Previous reports have suggested that errors were small by this naive approach for travel predictions between the typical traffic analysis zones (5000-10,000 population units) in urban transportation planning. Small errors have also been reported for predictions over much larger aggregates when these have been divided into classes based on the values of certain explanatory variables exhibited by the members of the aggregate. This practice in prediction is referred to as the classification method of aggregation.

Final Report Vol. VII finds that errors by the naive and simple classification approaches to aggregation are not small for prediction of travel-mode choice, except within small sub-aggregates of a metropolitan region. The major previous report on these errors (by Koppelman) was based on an over-optimistic special case of travel data. Fortunately, the present study reveals an extension to the classification approach which considerably reduces the computations burden of accurate aggregated predictions.

Recognizing that data on individual observations or within-aggregate distributions on choice characteristics is usually not economically feasible to obtain, the report also introduces methods for determining the focus on data collection to minimize prediction error. New and revised sources of data are suggested. Sampling sizes necessary to achieve desired accuracy in predictions are also explored and found to be a major problem in traditional segmented-output forecasting.

Aggregation Error Tests

The data and models used for assessing the magnitude of the aggregation problem and evaluating alternative methods are from the Urban Travel Demand Forecasting Project at the University of California at Berkeley. The data for this study was from a survey of 771 workers drawn from about half of the San Francisco Bay Area. The socio-economic variables are individual or household observations. The choice attribute variables (travel times, costs, etc.) are from highly individualized trip simulations.

Individual choice of mode from the trip to work is expressed in this study by the multinomial logit function for the probability of an individual choosing one alternative among several.

Exact aggregate choice shares are obtained by summing the choice probabilities over the values of the explanatory variables for all the individuals in the prediction group of interest. This is known as the enumeration method. This is a laborious, data consuming method of aggregation. Its burden has motivated the development of different approximate aggregation methods reported previously and those introduced here. Most of these are tested in this report. The aggregate choice shares obtained by enumeration were mentioned as they are the ideal reference values for evaluating the approximate methods. The measure of aggregation error in the tests here is the root-mean-square (RMS) of the percent errors in the choice alternatives.

The extreme approximation -- the naive method -- assumes that the individual choice function represents aggregate shares when using simply the average explanatory variable values for each prediction group. Table 1 shows the error from the naive method applied at three geographic levels of the aggregation of the UTDFP pre-BART sample data. Predictions are all for the total region. The input data were classified into the geographic aggregates shown and the average variable values in these classes used for prediction. Results from this procedure represent either of two forecasting situations: geographic classification for predictions over the full sample, or the average absolute errors when making separate predictions for all the cells at each geographic level. For an RMS error measure these errors are approximately equivalent.

TABLE 1

Aggregation Error at Three

Scales of Geographic Classification

Naive Method

Data Classification Scale

	Region	Cities	Traffic Analysis Zones
Percent RMS Error	40.0%	17.9%	13.8%

The errors in Table 1 are two to four times larger than previously reported for naive error. It is obvious that geographic classification alone is not an adequate aggregation method for the data and model used. Errors also increase with the scale of the prediction aggregate size. This had been expected, but not observed, in previous tests. Since classification/aggregation was done on the basis of residential (origin) district only, these results may be twice what would be expected from trips classified or predicted between origin and destination aggregates.

Table 1 results are larger than the previous aggregation study by Koppelman because they represent trips throughout a metropolitan area, the choice shares were unequal, the model here more fully specified the choices, and the data were highly disaggregated.

Table 2 shows the error on our sample by four available approximate aggregation methods and a new method proposed here. Choice share prediction is again for the total (regional) sample. The naive method and the geographic classification method are the same as for the previous table. The Taylor series method is due to Talvitie. The by-variable-value classification approximates that of Koppelman. The new utility classification method is described later.

TABLE 2

Aggregation Error by Five Methods

Total Share Prediction

	Naive	Taylor Series	Classification by City	Classification by Auto Ownership	Classification by Utility Scale
Percent RMS Error	40.0%	121.0%	17.9%	21.7%	3.1%

All of the methods except the Taylor series reduce error below that of the naive procedure. This exception confirms previous results that the Taylor series approximation is counter-productive due to its poor convergence properties on large variance data. Unfortunately, such data is where the correction is important. Also, geographic classification, as seen above, is inefficient in reducing aggregation error.

The predictions by classes of auto ownership similarly reduce only about half the naive error, leaving unacceptable accuracy at the regional scale of forecasting. Four classes were defined for auto ownership. Koppelman showed auto availability classification to reduce a smaller regional naive error by two-thirds, with a result of three percent. Granting that his variable, cars per driver, will reduce two-thirds of the naive error, such a classifier would still leave an unacceptable error in general regional aggregate travel predictions (for trips to all destinations and with unequal shares). Choice set availability classifiers used on predictions for sub-city or city-interchange level aggregates may yield more acceptable errors (below 1/3 of the 18% city classification figure).

The method of utility classification gives a much greater reduction relative to naive error than the other methods. Only four class cells were used. This method is outlined below and detailed in Vol. VII.

Utility Scale Classification

Although classification by the values of one or two variables gives unacceptable error for large aggregate predictions, the error can be made small by cross-classification between more of the variables in a model. However, if more than a few variables contribute significantly to the variance of the utility of the choices, the number of cross-classification cells must be large to achieve small error.

A more efficient method of classification is possible for the category of models with independence between the choice alternatives such as those of the logit form. Cross-classification between individual variables includes much information which is ignored by the utility scales by which the variables in these models are expressed. The essential information to predict each individual's choice in these models is completely contained in the J scales of the attributes of J alternatives of choice. Cross-classification between the total utilities of the different alternatives picks up the full scale variances and between-scale covariances, thus describing the full distribution of individual choice factors in an aggregate prediction sample. Regardless of scale complexity, this procedure bypasses those individual variable cross-classification trade-offs, which do not effect the scale values. Thus, the procedure requires fewer classes.

Defining relatively homogeneous classes of utility combinations across modes gets at the essence of the classification approach -- the grouping of individuals with uniform choice situations. Since the procedure operates on the utility scales, it is termed the utility scale classification method of aggregation.

Utility class sizes and boundaries cannot be defined in the same way as can individual variable classifications. Utilities are not discrete and intuition gives no guide on the thresholds of utility in mode choice. However, utility values are clearly related to choice function thresholds. For the binary logit models the optimum divisions would differentiate utilities near the maximum non-linearity of the choice function ($\pm$ 1.6 on the utility difference scale). For multiple choice logit model classification, the criteria should concentrate on pairs of alternatives with these same differences of utilities.

Cluster analysis techniques could be employed to achieve general isolation of classes. The tests here show that ad hoc class divisions are adequate and more appropriate considering the above non-linearities and the press of obtaining predictions.

The class cell definition procedure of Vol. VII resulted in a much smaller error than any of the individual variable or geographic classification methods in the tests of Tables 1 or 2 with only two utility classes on a four-alternative model. The other methods used from four to 150 classes. This advantage is to be expected at the regional level where the maximum utility variance of all of the variables is present. It would also be true for predictions for small aggregates unless only a minor sub-set of model variables dominanted the variability of these sub-samples. Such is not the case for within-city aggregates in this study. Vol. VII also shows the aggregation error found as a function of the mumber of utility class cells. Errors are acceptable (2-3%) with only four cells and negligible with eight cells.

Since utility scale classification does not differentiate the joint distributions of utilities between choice alternatives, it does not apply to models which allow dependence between alternatives such as general probit models. Aggregate predictions with these models generally require consideration of the variance-covariance matrix estimates of the unobserved utilities in choice such as obtained in probit model calibrations. Aggregate prediction methods for probit models have been reported by Bouthelier and Daganzo. However, compared to the complexity of these calibrations and predictions, simple utility classes may yield tolerable errors and be much more efficient even in the probit case.

This, as any accurate classification method, requires that individual choice-maker data observations be available to compute the cell mean values.

Hence, the principle advantage of the method is in the efficiency of the predictive calculations, given the data. This is no small advantage since predictions can require exponentiation over many choices for each individual in large samples or they may be desired for numerous policy (input) alternatives.

Indirectly this method may also aid the data collection process. By identifying the minimum amount of information necessary for prediction, it focuses on these requirements. Data on the unique within-alternative distributions of variable values are <u>not</u> necessary for logit models, only the utility scale variances are. It may be possible to directly extract the utility scale distribution information in a sample directly from census cross-tabulations or from minor sub-sets of the model variables. The latter approach is discussed briefly below, the former in the body of the report.

Covariance Matrix Analysis of the Explanatory Variables

Whatever the method of aggregation, the requirement for disaggregate data, against a past experience of aggregate data collection, suggest that data collection has to be focused on the major source of error. Thus, it is necessary to know which variables in a model contribute the greatest part of the covariances of the utilities within any prediction aggregate. Precedent and intuition have shown the relatively greater importance of some variables (such as socio-economic descriptors and transit access variables) in mode choice. The problem is that the variables which are important for classification vary with the geographic scale of the aggregate predictions and, to the extent that there is no universal model of behavior, with the model being used. The limited precedents available may be for the wrong cases. It is unreasonable to expect expert judgment or research-level optimization of aggregation accuracy in practical planning situations.

Effective use of cross-classification methods, where necessary, also depend on the knowledge of the variables contributing the most to utility covariances at the level of aggregation.

A systematic picture of priorities of individual data for each variable can be gained by looking at the covariance matrices of the within-aggregate variation of the explantory variables at the desired level of aggregation. This is most illustrative when the covariance elements are normalized by dividing by the largest of their values in order to give a picture of the ranking of the contributions of each variable to the overall utility variance.

For binary logit choice models the relationship between these covariances and aggregation error is understood under the assumption of a normal distribution of the utility scale of the explanatory variables (see equation 2-6 in Final Report Vol. VII). Thus their normalized matrix provides a convenient way to rank the individual varialbes, and their combinations, in terms of their importance for reducing aggregation error for binary choice. The larger the variance of the difference of utilities between the two modes, the larger the aggregation error. The variables which have individual values which are most important for reducing aggregation are the ones with the largest variance values in the matrix.

Vol. VII shows that a large part of the variance of the utilities, and hance aggregation correction, can be recovered by considering only a few of the variables in the model. For example, three of the eleven variables in the model used in Table 11 of Vol. V -- CARS/DRIVERS, BUSWALK, AND BONVEH (the number of autos per household, walking time to the bus mode, and the time riding on bus mode) -- constitute sixty-four percent of the utility variance. When only their individual values are used for binary prediction, they correct for eighty percent of the aggregation error produced by the naive method.

The covariance matrix, in its implied correlations between the classifier variables(s) and the others, also contains the information for guiding the classification method. The additional power of a classifier due to this effect is given by the sum of the prodcut of covariances and correlation coefficients of all variables correlated to the classifier. With this procedure, one can minimize aggregation error, given limits on the number of classification variables, or minimize the number of classifiers, given tolerable limits on error.

For multiple choice, this analysis requires a relationship between the covariances of the variables in all the alternatives and choice. Such relationships are generally not available. However, a simple approximate guide to the important aggregation variables can be gained in the multinomial case, by observing the covariance matrixes of only major pairs of the alternatives. Vol. VII tests the effectiveness of this approach.

In practical forecasting it is suggested to use this covariance method on a small sample of a population over which policy forecasting data are required to determine the subsequent cost-effective emphasiss of individual data collection in the larger forecasting sample.

Conclusions and Recommendations

This study has added empirical results to the aggregation issue and introduced two new methods for simplifying aggregated predictions. The empirical results show that the error caused by ignoring or approximating the aggregation process is larger than previously reported. These results do not necessarily conflict with the others. The errors shown here are typical of predictions of ubiquitous regional mode-choice with fully-specified models and data, unlike the prior reports. The methods introduced show how the essence of the disaggregate information in a data sample may be identified, abbreviated, and processed for economy of data collection and prediction.

There are six major conclusions from the study. These are listed below, followed by the recommended aggregation method and data sources for the majority of forecasting and policy analysis situations:

1. Aggregation error is larger than shown in previous tests. The naive method applied to region-wide mode-choice can give forty percent RMS error. Aggregate demands, segmented by origin or destination, or classified by model variable values, are also proportionally higher than shown in previous studies.
2. The relative ranking by Koppelman of the accurancy of the existing approximate aggregation methods is confirmed. However, all the errors are larger and grow substantially with the size of the aggregates.
3. The present leading approximate method of aggregation, classification by the values of a single explanatory variable, gives unacceptable errors on large-aggregate predictions. Cross-classification by several variables is inefficient and costly. Pre-

sentations of these methods have shown no systematic criteria for class cell definition.

4. Classification by the value of the total utility scales of the choice alternatives gives at least a five times better accuracy-to-cell count (and thus to data and computation effort) than classes defined on separate variable values. It can reduce naive error by a factor of 72 (to 0.4 percent) with only eight cells.
5. Analysis of the covariance matrix of the utility components of the explanatory variables in a small data sample can point to the subset of variables for which disaggregate data are necessary for desired aggregation accuracy.
6. Sampling error is an unrecognized problem in predictions differentiated by output segment. Present inter-zonal forecasting systems are more deficient in sample size than in degree of data disaggregation. The sample sizes and data disaggregation required for segmented outputs can only be achieved at reasonable costs with statistical or classified data reduction and the more efficient of the aggregation methods.

Although Vol. VII stresses that the variety of prediction contexts in planning cannot be served by a single aggregation method, it does reveal procedures based on utility scale classification that can be adapted to a wide range of prediction and accuracy objectives. This method, a combination of covariance analysis, utility classification and synthetic generation of disaggregate socioeconomic and supply data, is described in UTDFP Vol. VII, supplemented by Vols. VIII and X.

The aggregation issue for individual choice models can now be recognized as the need to identfy homogeneous choice groups in the overall prediction population, as opposed to groups with the like characteristics, trip attributes, or trip-end geography. Choice groups are directly and most efficiently indicated by clusters of the utility scales of the traveler's explanatory variables. Aggregation is an issue only because average choice in a group modelled by a non-linear choice function is not equal to the choice of an individual with the average of the spread of utilities of those in the group. But this non-linearity of choice functions and the variability of groups are not so severe, even for a whole metropolitan population, that its effects cannot be reduced to negligible error with less than eight utility classes.

These observations suggest several fruitful shifts in emphasis on aggregate predictions. Very little data is required to account for aggregation per se. Overall regional choice share predictions can be made on a (different) sample no larger than the small sizes needed for calibration. It is segmentation of the output shares by many geographic, socio-economic or other sectors which require large data bases to statistically identify the proportions of the population in each sector. There is no need to calculate choice shares for each output sector. Once the limited number of homogeneous utility groups for the whole population is identified, their members have uniform choices. Hence, sector shares are merely the sector proportions in the choice group. Classification, variance computation, or choice function evaluation are unnecessary at the sector level.

Planning should either shift away from the emphasis on many-sector outputs or recognize the implied large data generation efforts. If many-sector predictions are necessary, they should stress statistics on the proportions of those in the sectors more than the collection of individual disaggregate explanatory variables. A modest effort on the latter is adequate to satisfy aggregation. Synthesis of disaggregate-socioeconomic and supply data can supply the necessary data to control aggregation error.

Sampling for highly differentiated sectors is revealed as the major data and processing problem in forecasting. Concentration on limited segmentation of predictions can make aggregate prediction with disaggregate models simple compared to most traditional aggregate data modeling. The efficiency of disaggregate modeling that was first seen when it was found that they could be calibrated on a fraction of the data necessary for aggregate calibrations is now seen for the prediction process. The aggregation process does not require planners to "pay-back" for this efficiency at the forecasting stage.

CHAPTER 7. EXECUTIVE SUMMARY OF VOL. VIII

DEMOGRAPHIC DATA FOR POLICY ANALYSIS

Disaggregate behavioral model forecasts of the effects of urban transportation policy require auxiliary forecasts of the variables exogenous to the model system. The exogenous variables typically include residence and work location, and household socioeconomic and demographic characteristics. Consistent aggregation of behavioral models requires that these variables be provided for each homogeneous market segment, or for a representative random sample of households. The forecasting method should take into account shifts in demographic and land use patterns, changing economic conditions, and population growth.

It is in the nature of auxiliary forecasting that one does not have available complete structural or causal models; hence, forecasting must use data analysis and trend projection techniques, combined with available external forecasts. The method should be able to combine the information contained in a variety of different data sources, and have the capacity to upgrade the quality of the forecasts as additional data become available.

SYNSAM is a methodology for generating a synthetic representative sample of households for an urban area for any specified date. Vol. VIII describes the implementation of this procedure for the San Francisco Bay Area, involving the construction of a sample of 12,000 households for the year 1976. In addition to residence and work locations, data for each household comprises a subset of the socioeconomic variables tabulated in the Public Use Sample (PUS) of the 1970 Census. The implementation utilizes 1960 and 1970 Census data plus external projections of population and economic conditions. Since such data are available for all Standard Metropolitan Statistical Areas (SMSA), the procedure is readily transferable to other cities.

We also provide a description of the software that was used to implement the two principal computational steps in the procedure, and which is available as a set of FORTRAN routines. These are sufficiently flexible to allow application to other geographic areas and to different sets of socioeconomic variables. Options include the construction of samples weighted according to residence zone.

A principal feature of the SYNSAM procedure is the use of Iterative Proportional Fitting (IPF) to construct and update the contingency table for zone of residence and for a selected set of household characteristics, starting from the various marginal tabulations available on census tapes and other sources. The program is based on an algorithm due to Haberman. An account of this program, together with notes on its use, is given in Appendix C of Vol. VIII. The other principal step is to actually construct the synthetic sample by random sampling, once the contingency tables for socioeconomic characteristics have been computed. For each household in the sample, the program selects a residence zone; selects a vector of nine household socioeconomic characteristics; assigns an employment zone; selects a matching representative household with the same vector of socioeconomic characteristics from the PUS census file; and selects a worker within this household. Some programming notes are given in Appendix D which may be taken as a "user's guide" in the event that the program is used to synthesize other samples for market segments or for different areas.

Since SYNSAM is intended to be a flexible methodology, capable of accommodating a variety of data sources and estimates, we discuss also alternative methods and possible improvements in some steps of the procedure.

CHAPTER 8. EXECUTIVE SUMMARY OF VOL. IX, REGIONAL POLICY ANALYSIS CASE STUDY

Regional policy analysis refers to coarse-scale, short-range forecasting of the effects of transportation service and pricing policies on multimodal travel in urban areas. Its wide-area emphasis contracts with the other case studies in this project which focus on corridor and suburban travel analysis. Its most direct contrast, however, is with traditional comprehensive urban transportation planning (UTP) by metropolitan planning organizations (MPO's) which attempt long-range, interzonal forecasts of major transportation system changes. It is short-range in the sense of ignoring auto-ownership and location change factors in its efforts.

The key features of this case study are:

- Low effort, quick-response predictions,
- Achievement of policy-issue sensitivity with disaggregate models,
- Prediction of multimodal aggregate demand using synthesized random traveler samples,
- Derivation of several demand-related impacts such as system revenues and energy and environmental impacts,
- Flexible, though coarse, differentiation of demand levels and impacts by any geographic, socioeconomic or other identifiable segment,

- Limitation of analysis to policies affecting modest demand changes such that equilibration with supply capacity constraints can be ignored.

Volume IX builds upon an examination of the planning needs and institutional context for demand-based policy analysis. It employs computer and hand-calculator methods for predicting work travel by three modes. It demonstrates a variety of efficient data generation and preparation methods and applies the methods in an analysis of transit fare, gas price and transit service changes for commuter trips in the San Francisco Bay region. Finally, it tests and evaluates the accuracy and usefulness of these predictions in the policy analysis cycle of an MPO.

In general, Vol. IX concludes that the trend towards coarse-scale, yet detailed issue-sensitive analysis with disaggregate models (Bigelow; Dunbar; Atherton and Ben-Akiva) is appropriate for the stages of metropolitan travel and impact analysis involving many policy alternatives or variants. At this critical stage in the conceptual evolution of policies, regional analysis gives clarity and quick-response to the issues. Hand calculator techniques based on data classification methods are found to give the quickest and coarsest predictions; their extension to random sample enumeration on large though inexpensive ($5.-15./run) computers permits more detailed and flexible impact analysis. In either case, the use of disaggregate models and data allows a great deal of sensitivity to detailed operations or pricing policies regardless of how aggregated the ultimate predictions may be.

Two major contributions to solving the data burden of disaggregate modeling are demonstrated in this case study. The SYNSAM method of generating a random sample of workers from census data (documented in Vol. VIII of this series) is applied here, substituting for expensive surveys.

Second, efficient classification methods of aggregating the data for predictions (from Vol. VII) are applied, eliminating the need for computers in the travel predictions. This sacrifices the detail possible for segmentation of travel and impact effects by sub-group, but very little in accuracy. The hand methods achieve all of the simplicity of aggregate sketch-planning methods, while retaining the accuracy and some of policy detail of disaggregate methods.

The examples assume that interzonal travel time and cost data by the modes being analyzed is available. (Volumes X and XI show methods that promise to reduce this burden of data collection as well).

The case study analyzes the effects on work mode shares of structural changes in the transit and auto modes, including modified fares, service frequencies, tolls, and gas taxes. The computerized methods provide mode share predictions for the nine counties of the region and for a large number of demographic categories, including income and auto ownership. VMT, pollutant emissions and other energy measures are also produced. The hand calculator examples differentiate outputs only by socioeconomic segments, though coarse. Geographic segmentation and overall environmental impacts also could be derived.

The computer-based forecasting method utilizes the UMODEL routine and framework of the Urban Mass Transportation Administration's Urban Transportation Planning System (UTPS) for its implementation. However, the interface to the user is a simple program language tailored to incremental policy analysis, not requiring familiarity with UTPS. (Setting up and maintaining the method in the UTP framework is fully described in Volume IX and related documents. prepared for MTC). Implementation of the hand-calculator method requires no computer skills for demand prediction. However, an elementary statistical analysis computer package is required in setting up the initial classification of the data. The calibration of a demand model is also not addressed in Vol. IX. It is assumed to be available either through prior calibration on a local data set or through transfer (with appropriate tests) from another metropolitan area.

The policies tested on the San Francisco region showed the following kinds of results:

1. Overall response of modal demand to feasible auto or transit pricing polices was small.
2. The highest sensitivities were to changes in transit frequencies: system-wide changes yield the greatest demand/system cost ratio of any policy.
3. Demand changes, even for the relatively insensitive pricing policies, were much more (or less) significant on particular socio-economic groups and transit operators than indicated by the averages for the region.

It appears that many of the equity issues in transportation analysis can be revealed through careful definition of socio-economic sub-groups in the disaggregate analysis. However, this finding also suggests that a broader range of equity issues can be revealed through extension of the computerized versions of these regional analyses methods.

Two principal types of accuracy tests were undertaken in the case study: validation of base-line (existing system/policy) predictions with field observations of demand, and tests of the degree to which the hand/calssification methods reproduced the more exact computer enumeration methods. The former tests evaluated three further parts of the process: the degree to which the synthetic (SYNSAM) traveler data file reproduced actual traveler data, the transferability of the choice model used from the portion of the region (the central half of it) in which it was calibrated to the whole San Francisco Bay Area and the accuracy of the field observations. The tests of the hand calculator predictions merely measured the accuracy of the averaging process and of the underlying data classification scheme.

The baseline validation revealed substantial differences in both regional and sub-regional modal demands from field data. The differences were similar to those typically found in the checking and adjustment stage of large UTP forecasting systems at similar levels of segmentation. The largest contributions to error appeared to be the non-transferability of the models over urban vs. suburban and rural areas. However, significant errors also existed in the sub-region where the model was calibrated suggesting that the SYNSAM data base require further work to accurately reproduce traveler characteristics.*

The tests of the hand caclculator methods showed their regional results to differ comparatively little (less than 3%) from the enumeration methods.

The methods of this study (as all others) are subject to accuracy limitations of sub-group predictions dictated by the conventional statistics of sampling. With objectives similar to the modest data collection costs in this case study (3000 household sample), breakdown of demands should not be attempted for segments of less than about 15% of the region if sub-group accuries of better than 10% are expected. This would be true of any methods trying any detailed breakdown of outputs while limiting data collection costs.

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*A factor mitigating this criticism is that the field data itself was adjusted for conformity with questionable historical records of the MPO maintaining it.

Overall, the case study has shown that very low effort methods can make predictions of the effect of detailed pricing mode choice and transportation service changes on work with at least the same accuracy as traditional aggregate modeling. The issue sensitivity of the new methods greatly exceeds that of aggregate models. Different levels of detail/accuracy/effort are possible to suit the planning situation. A number of environmental and economic impacts may be derived from the basic demand predictions. The major problems remaining in these methods are the availability of better spatially transferable models, and the improvement of synthetic socio-economic sample generation methods. The major extensions possible for these methods are as simple components of larger prediction systems taking into account supply-demand equilibration and joint choice of mode with auto ownership, residential location, and/or other freedoms of longer range behavior.

CHAPTER 9. EXECUTIVE SUMMARY OF VOL. X, POLICY ANALYSIS OF A TRANSPORTATION CORRIDOR

The Urban Transportation Corridor Policy Analysis is one of the three practical applications of disaggregate travel demand models conducted as part of the Urban Travel Demand Forecasting Project. A study of an urban corridor was felt to be particularly timely because of the increased importance of sub-area studies as an intermediate level of planning between region-wide planning and project planning. Specifically, the objectives were:

- To review existing literature of corridor or sub-area transportation planning particularly with respect to the methods developed or used.
- To develop a work-trip demand model that is tailored to the needs of the corridor policy study.
- To develop models for transportation levels of service aimed at reducing the time-consuming and costly network coding procedures.
- To develop a method of equilibration of demand and level-of-service appropriate to disaggregate demand models and disaggregate level-of-service models.

- To examine the cost structure of various transportation modes to help decide provision of efficient urban transportation.

- To integrate the various components of travel demand and supply within one model system.

- And, most importantly, to conduct a policy study of an urban transportation corridor, examining both capital and non-capital intensive policies and assessing the equity implications of the various policies.

The conclusions of the research can be summarized:

- Disaggregate travel demand models together with a (synthesized) sample of households proved to be a very convenient and cost-effective way to predict demand for travel and for analyzing the consequences of alternative plans by market segments (equity).

- Parametric transportation service models can be utilized together with the disaggregate travel demand models, and equilibration of demand and service can be accomplished at low costs. The computational procedure employed in the study was that of approximating fixed points of a mapping. This method provides a practical alternative to conventional network equilibration methods and is particularly useful with equation-based representation of level-of-service.

- The costs of alternative transportation modes are a very complex problem for analysis. The analyses and calculations made show that substantial subsidies and cross-subsidies are made to and within the passenger transportation industry.

- Auto mode in particular has many hidden costs which are not paid directly by the users. Rail transit mode is also a very expensive mode. As a rough comparison one vehicle mile of travel for auto (which is equal to one passenger mile of travel for drive-alone mode) is in the neighborhood of twenty cents, one passenger mile on bus (sixty percent load factor) is approximately five cents, and one passenger mile on BART (sixty percent load factor) about eighty-five cents. The BART figure reduces to fifteen cents if the capital costs of constructing the BART system are calculated as historical rather than replacement costs.

- The policy analysis of alternative plans in the I-580 corridor showed that a designated lane for high occupancy vehicles (HOV) improves the linehaul speeds in most cases even when it means reducing the capacity for single occupant cars.

- The traditional traffic engineering measures — improved feeder service, HOV lanes, etc. — do not substantially alter the current aggregate modal shares. However, the patronage (rather than percentage share) of little used modes (normally transit) can be substantially increased with such measures.
- It is also seen that such popular TSM measures as HOV lanes and express bus service confer benefits mostly to the well-to-do suburbanites and since these policies are geared to reducing travel time without increasing the price of travel, they will also encourage urban sprawl, thus increasing energy consumption and pollution.
- "Full cost" pricing (which does not include time costs) does effect substantial changes in modal shares and vehicle miles traveled, and hence in energy consumption.
- "Full cost" pricing appears to increase the bus fares of suburban dwellers by fifty to one hundred percent while the fares for low income people and urban dwellers (only twenty-two percent of urban dwellers had low incomes) remain approximately at present levels. This means that, currently, the low income people and the urban dwellers pay for the actual costs of most public transportation services they need but the high income and the suburban transit users do not, and are, thus, heavily subsidized. It was concluded that flat fare systems are regressive while distance based fares are not.

Finally, the policy study demonstrated that the model system developed for the transportation corridor policy studies is a flexible planning tool which enables a timely analysis of alternative plans at low cost.

CHAPTER 10. EXECUTIVE SUMMARY OF VOL. XI, FORECASTING TRAVEL DEMAND IN SMALL AREAS USING DISAGGREGATE BEHAVIORAL MODELS: A CASE STUDY

Final report Vol. XI describes a study done to forecast the patronage of a new transit system proposed for a suburban city in the San Francisco Bay Area, using disaggregate behavioral models of transportation choice. The general forecasting methodology was to collect survey and transportation supply data for a sample of the people the transit system was intended to serve, to use individual choice models to forecast the probability that each person in the sample would use the system under a variety of policy alternatives, and to aggregate these individual forecasts to obtain forecasts for the population of potential users, weighting as necessary to correct for disproportionate sampling of different population segments.

The study had several innovative features: (1) An unusually detailed set of transportation alternatives was considered. The models that were used estimated the probabilities of choices among seven different travel modes. (2) Calculation of time and cost data needed as inputs to the forecasting models included hand measurements of walk distances for each person in the sample, and described portions of trips both inside and outside the local area. (3) A method based on iterative proportional fitting was used to correct for unrepresentative sampling of the population of potential bus users. (4) Analyses were done to test and compare the accuracy of the probabilities estimated by different behavioral models, using data available before the bus system was running.

The study was an example of travel demand forecasting for policies which affect small geographical areas. Typically, such forecasting cannot be done satisfactorily using the data bases and forecasting methods maintained by metropolitan planning organizations, which are ordinarily intended to investigate policies having impacts on an entire metropolitan region, or on large transportation corridors within a region, and are on a scale too large to be adequately sensitive to local policy changes.

On the other hand, when policies impact only a small geographical area it is often feasible to collect data and make forecasts on an _ad hoc_ basis, with a level of detail appropriate to the particular policy issues. Disaggregate models of transportation choice are easily adapted to such applications.

This study differs from most previous studies in which individual choice models were used to forecast travel demand in small geographical areas in several important respects:
(1) the number of different transportation alternatives considered; (2) the detail and accuracy of the transportation supply data used as inputs to the forecasting models; (3) the methods used to weight the sample data to obtain aggregate forecasts, and (4) the use of analyses to test and compare the accuracy of the probabilities estimated by different behavioral models, using data available _before_ the bus system was running.

Implementation of the forecasting methodologies was quite successful. The time and expense required for data collection and analysis seemed within reasonable limits for widespread application. Tests of the predictive accuracy of the behavioral models were disappointing, however. The estimated probabilities of using currently available travel modes had little relationship to current behavior, and the estimated probabilities of using the proposed bus system had little relationship to people's intentions to use the system as reported in telephone interviews. The results suggested that behavioral models of the type used in this study can be feasibly applied to travel demand forecasting in small urban areas, but that additional development and testing of the models should be done before they are used as a basis for policy decisions.

APPENDIX A

LIST OF OTHER PUBLISHED PAPERS FROM THE URBAN TRAVEL DEMAND FORECASTING PROJECT

Papers and Books

Johnson, M.A., "A Comparison of Several Methods of Calculating Travel Time Data for Analysis of Urban Travel Demand," Proceedings of the 17th Annual Meeting of the Transportation Research Forum, Vol. XVII, No. 1, 1976.

Johnson, M.A., "Evaluating Attribute Importance in Multiattribute Models," accepted in 1978 for publication in Transportation Research Record, Transportation Research Board, Washington, D.C.

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APPENDIX B

DATA AVAILABLE FOR RESEARCH IN TRAVELER BEHAVIOR AND POLICY ANALYSIS

Systems Laboratory
Institute of Transportation Studies
University of California, Berkeley

The Systems Laboratory is making available nine data files collected by the Urban Travel Demand Forecasting Project. Abstracts and brief format information on each appear in the attached list. The following additional information is also available for each: a one page Data File Description sheet, a one page File Format sheet, codebooks, and papers or reports giving examples of the use of the data. Examples of the one page sheets for one of the files are also attached. All of the files are available on tape in "external" BCD (machine-independent) 6-bit plus parity formats. Binary formats for certain analysis programs on CDC 6000 series machines are also available for some files.

Four of the data files are coded responses from stratified sample household traveler surveys; two before and two after the establishment of the BART rail service in the San Francisco area. These have been used for the analysis of the relation of socioeconomic characteristics, attitudes, and perceptions to the choice of travel mode to work. The fifth file is a five day diary of all trips of one individual/household in the after-BART surveys.

Two other files are extracts of the survey data before and after BART plus separately collected disaggregated travel times and costs of work trips by all modes. This data has been used for calibration of disaggregate models relating auto ownership and work trip mode choice to household data and objective trip attributes.

The last two data files are random samples of individual household and work trip characteristics synthesized from the U.S. census public use sample and tabulations. Only the latter file contains trip attributes (from network simulations). These files have been used for the analysis of regional traveler response to various transportation pricing and service policies. The cost of each data file is $25 for tape reel, copying and mailing. Code books costs are shown in the UTDFP list of working papers.

For further information on these and other data files, contact the Systems Laboratory, Institute of Transportation Studies, University of California, Berkeley, California 94720.

PUBLIC DATA LIBRARY LIST
Urban Travel Demand Forecasting Project
Systems Laboratory
INSTITUTE OF TRANSPORTATION STUDIES

Revised
April, 1979

FILE NAME	ABSTRACT OF CONTENTS	FILE SIZE	AVAILABLE FORMAT(S)	CODEBOOKS(S)	DATE OF COLLECTION
TDFP5XC (TDFP5XQ)	Work trip household-level socioeconomic and supply variables for calibration of disaggregate mode + auto ownership choice models. From McFadden Travel Demand Forecasting Project. Pre-BART period.	991 Workers 148 Variables	1:TAPE/EXT. BCD/7-TRACK/800 BPI 2:TAPE/QUAIL 3.8/CDC/BINARY	A: ITS UTDFP/W.P.#7605 B: ITS/UTDFP/W.P. #7514	May 1972
POSTBAHC	Work trip household socioeconomic and supply variables for calibration and validation of disaggregate mode + auto-ownership choice models, from McFadden Travel Demand Project.	936 Workers 244 Variables	1: TAPE/EXT. BCD/7-TRACK	ITS/UTDFP/W.P.#7901	November 1975
WTS	East-Bay of San Francisco survey of work travel patterns, household, + employment characteristics, auto ownership, mode use + transportation attitudes.	213 Households 400 Variables	1: PICKLE/CDC/U. of C./BERKELEY	Travel Demand Forecasting Project (WTS) Codebook, D. McFadden, IURD, U. of CA, 5/73	May 1972
BITS1 (BATS 73-74)	Survey of four potential BART service areas - travel patterns, household + employment characteristics, auto ownership, mode use, + attitudes - for BART-impact program, metropolitan.	1724 Households 300 Variables	1: TAPE/7-TRACK/BCD/556 PBI.	1973-74 Bay Area Travel Survey General Codebook, Survey Research Center, 6/74 UCB	November 1973
APS	Pilot telephone survey of commuters living and working in BART operating area. Household characteristics, work travel details, attitudes and perceptions on auto, BART and bus use. UTDF project.	258 Households ~400 Variables	1: TAPE/EXT.BCD/7-TRACK/800BPI	ITS/UTDFP/W.P.#7610	April 1975

PUBLIC DATA LIBRARY LIST
(continued)

FILE NAME	ABSTRACT OF CONTENTS	FILE SIZE	AVAILABLE FORMAT(S)	CODEBOOKS(S)	DATE OF COLLECTION
BITS2C	Resurvey of BITSI + WTS samples + supplemental sample in selected BART service areas - work travel patterns, mode use, attitudes, auto-ownership, household + employment characteristics.	1093 Households 200 Variables	1: TAPE/EXT.BCD 7-TRACK	ITS/UTDFP/W.P.# 7608	October 1975
BITS2DIARY	Diary of every trip made by one member/household in a Friday-Tuesday period. Includes trip purpose, end-points, timing, mode, + parking, San Francisco Region sample identical to BITS2.	815 Individuals 24 Variables	1: TAPE/BCD/7-TRACK/1600 BPI 2: SPSS/TAPE/CDC/BINARY	ITS/W.P.7902 S.F. Bay Area, 1975 BART Impact Travel Study-2 Trip Diary by A. Adiv	November 1975
GTSYN2C	Synthetic random sample of individual household and worker characteristics in S.F. Bay Area in 1976 - A sample of household and variables from SYNSAM2 file for travel forecasting, by McFadden	3000 Households 112 Variables	1: TAPE/EXT.BCD/7-TRACK	A: Memo to SYNSAM Users, G. Harvey, UTDF PROJ/ITS 12/28/76 B: UCB-ITS-SR-77-10	1976
HHWKSEGM	Random sample of individual S.F. Bay Region workers and their trip characteristics for transportation policy analysis, done by McFadden Travel Demand Project.	3004 Commuters 40 Variables	1:TAPE/7-TRACK/EXT. BCD	Memo to C. Murano, " SRGP Tape," by G. Harvey, 3/78	1975

APPENDIX C

TABLE OF CONTENTS OF QUAIL 4.0, USER'S MANUAL (FEB. 1979)

by

Jerry Berkman, David Brownstone

and Associates

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