DOT HS-804 548

DESIGN FOR A NATIONAL EXPOSURE DATA SYSTEM (NEDS): RECOMMENDED FEATURES AND PROPOSED PILOT METHODOLOGICAL STUDIES

Arthur C. Wolfe

Highway Safety Research Institute
The University of Michigan
Ann Arbor, Michigan 48109

Contract No. DOT HS-7-01685
Contract Amt. $62,500

NOVEMBER 1978
FINAL REPORT

Prepared For
U.S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
Washington, D.C. 20590

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS-804 548		

4. Title and Subtitle
DESIGN FOR A NATIONAL EXPOSURE DATA SYSTEM (NEDS) Recommended Features and Proposed Pilot Methodological Studies

5. Report Date
November 1978

6. Performing Organization Code

7. Author(s)
Arthur C. Wolfe

8. Performing Organization Report No.
UM-HSRI-78-79

9. Performing Organization Name and Address
Highway Safety Research Institute
The University of Michgian
Ann Arbor, Michigan 48109

10. Work Unit No.

11. Contract or Grant No.
DOT-HS-7-01685

12. Sponsoring Agency Name and Address
National Center for Statistics & Analysis
National Highway Traffic Safety Admin.
Department of Transportation
Washington, D.C. 20590

13. Type of Report and Period Covered
Final Report
8/77-9/78

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

In conjunction with the National Accident Sampling System (NASS) which is being established by NHTSA to collect data on a nationally representative sample of accidents there is a need for corresponding data on exposure to the risk of accident so that reliable accident rates can be determined. The Highway Safety Research Institute was awarded a contract to design a National Exposure Data System (NEDS) and to plan a pilot test of this design.

After extensive review of previous exposure research studies and evaluation of the various design alternatives available, a number of features of the recommended design were established. It should be a household interview survey in which selected drivers are asked to provide information about all driving trips made on one or more predesignated days, and it should take place in the same primary sampling areas used for NASS. Not enough information was found in past studies to permit recommending the single most cost-effective household data collection procedures, and it is proposed that a pilot methodological study be carried out over 12 months to provide the essential data base for this decision.

17. Key Words		18. Distribution Statement
Exposure Risk of Accident Driving Patterns Roadside Surveys	Vehicle Use Household Surveys	This document is available to the U.S. public through the National Technical Information Service, Springfield,VA 22161

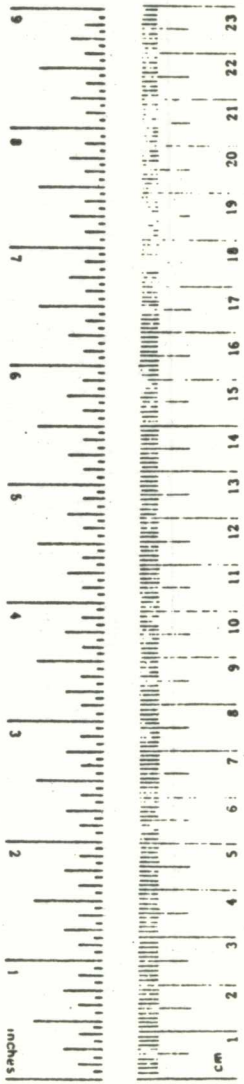
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	114	

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

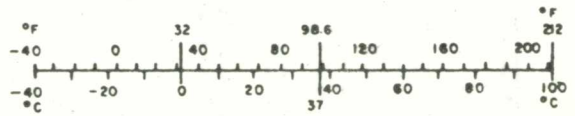
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



ACKNOWLEDGEMENTS

The author is indebted to a number of people for assistance in the completion of this report. These include colleagues at the Highway Safety Research Institute, particularly James O'Day, Richard J. Kaplan, Phyllis Gimotty, Phyllis Thorburn, Kenneth L. Campbell, Kathleen B. Weber, and James E. Haney; associates at the University of Michigan Institute for Social Research, particularly Charles F. Cannell, Robert M. Groves, and John C. Scott; and innumerable researchers in the United States and Canada who provided information on their past or present methods of collecting exposure data from motorists. The valued continuing assistance and counsel of Glenn Parsons, Contract Technical Monitor for the NEDS project in the National Highway Traffic Safety Administration, is also greatly appreciated. Finally Virginia Dexter's cheerful and efficient secretarial assistance in the computer typing of this report and throughout the NEDS design project is gratefully acknowledged. The author of course retains primary responsibility for the substance of this report and its recommendations.

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EXECUTIVE SUMMARY

The National Highway Traffic Safety Administration in the U.S. Department of Transportation is in the process of establishing a National Accident Sampling System (NASS) to collect nationally representative data on motor vehicle accidents. When fully implemented NASS will involve 35-60 permanent accident investigation teams located in a controlled probability sample of geographic areas throughout the United States. In order to determine and compare accident rates for various types of driver, vehicle, roadway, and environmental categories of concern it is necessary to obtain reliable measures of exposure in the same analysis categories as the accident data. With reliable national estimates of the number of miles travelled in some category (e.g., aged 16-20) as the denominator and of the number of accidents in that category as the numerator, it will be possible to determine a reliable accident rate for that category. These accident rate data will then permit great improvements in the ability to compare the magnitudes of various highway safety problems which in turn will hopefully lead to improved planning and evaluation of countermeasure programs.

The Highway Safety Research Institute was awarded a contract to determine the most cost-effective design for an on-going National Exposure Data System (NEDS) to collect national exposure data as a complement to the continuous NASS accident data collection program. This contract called for a literature review of past exposure research methods; preliminary evaluation of various NEDS design alternatives; determination of recommended designs at three annual cost levels ($1,500,000; $1,000,000; and $500,000); and a detailed plan for pilot testing the recommended design. The following report takes up these four tasks in order. However, it was determined that there was insufficient data available from past exposure studies to permit final recommendations regarding all aspects of the NEDS design. Consequently, in place of pilot testing a single design it is proposed that the pilot

test phase include further methodological research on the most cost-effective method of collecting reliable travel data in a household interview and on the relative trade-offs between interviewing one or all drivers in sample households. Before embarking on such an expensive long-term exposure survey program it seems essential that this methodological research be carried out to determine the most cost-effective data collection procedures.

The basic recommended NEDS design calls for the establishment of a continuous program of collecting driver trip information for one or more days in a sample of households in the same primary sampling areas used for the NASS accident data collection. For each selected driver, information would be obtained on his/her age, sex, relationship to household head, driving experience, accident experience for three months, estimated annual mileage, physical handicaps and license restrictions, and type of driver education. For each trip driven on the predesignated Travel Day(s), information would be obtained on trip origin, destination, purpose, distance, and duration; vehicle make, model, year, body type, occupant protection devices, current odometer reading, and month of purchase if purchased new; driver seat belt use; age, sex, seating location, and relationship to driver of each passenger; distance on four basic road types; and road moisture conditions. Among these recommended data elements the only ones not currently collected in the NASS protocol are recent accident experience, driver relationship to household head, driver physical handicaps, month of new vehicle purchase, and passenger relationship to driver.

It is recommended that the Census Bureau's Demographic Surveys Division be supported to carry out the NEDS survey, just as it carries out many other national surveys for the federal government, such as the Current Population Survey and the Health Interview Survey. No other survey organization has the ability to obtain as high response rates from the American public as does the Census Bureau,and it is doubtful that any other organization could provide and supervise interviewers in all of the NASS primary sampling areas as effectively as could the Census Bureau.

Before estimating the total sample sizes which could be obtained at the three suggested cost levels, it will be necessary to complete the

proposed methodological research on data collection methods. This proposed methodological research has two stages, a Validation Study and a Comparative Study. The Validation Study is concerned with how much people underreport trips made on a previous day during a simple-recall household interview. Using samples based on the observation of vehicles in parking lots, three data collection methods will be validated in terms of the percentage of observed vehicle trips actually reported in the subsequent household interviews. The three methods are: (V1) a simple-recall in-person interview, such as used by the Census Bureau in its 1977-78 Nationwide Personal Transportation Survey; (V2) a simple-recall in-person interview with a detailed probing technique devised with the help of the Interviewing Methodology Section of the University of Michigan Institute for Social Research; and (V3) a simple-recall telephone interview also using the probing technique.

The proposed Comparative Study will then go on to compare the results of eight potential data collection methods carried out in eight similar household samples. These methods are: (C1) simple-recall in-person interview, (C2) simple-recall random digit dialing telephone interview, (C3) mailing of a one-day trip log form followed by an in-person interview, (C4) an in-person visit to leave a trip log form followed by an in-person interview, (C5) an in-person visit to leave a trip-log form followed by a telephone interview, (C6) a random digit dialing telephone interview followed by mailing a trip log form and another telephone interview, (C7) an in-person visit to place a 7-day travel diary followed by an in-person interview with no respondent compensation, and (C8) an in-person visit to place a 7-day travel diary followed by an in-person interview with $20 respondent compensation. In addition, the method of tracing trips on maps to obtain more detailed road characteristics data will be tested as part of some of the above procedures.

A third proposed study during the pilot phase involves analysis of the 1977-78 Nationwide Personal Transportation Survey data to determine the tradeoffs in terms of cost, data quality, and statistical precision of interviewing one driver per selected household versus all drivers per selected household.

The results of these studies will be evaluated in relation to cost, completeness of trip reporting, response rates, coverage of the relevant population, accuracy of trip distance data, and completeness of reporting other trip variables. These findings will then be used to finalize the recommended data collection procedures in the complete NEDS design and to determine the recommended sample size for each of the three cost levels. This further comparative methodological research is considered essential before the government commits itself to a long-term NEDS program using a particular data collection method. This pilot-test phase research would require twelve months and about $290,000.

1. INTRODUCTION

One of the most significant recent developments in the field of highway safety research was the decision of the National Highway Traffic Safety Administration (NHTSA) in the U.S. Department of Transportation to establish a National Accident Sampling System (NASS). The United States is the first nation to initiate implementation of an on-going system for the collection of detailed information on a controlled probability sample of traffic accidents. When fully established NASS is expected to deploy 35-60 full-time accident investigation teams in a controlled probability sample of geographic areas to collect data on about 20 000 accidents annually. Ten pilot NASS teams were set up in 1977, and it is hoped that the entire NASS program will be operational by 1981 or 1982.

Early in the initial design stage for NASS, it was concluded that exposure data, in addition to accident data, should be collected in order to provide more comprehensive and detailed information to support the Federal highway safety program effort. Accident data alone would provide greatly needed national estimates on the magnitude of the accident problem (i.e., how many accidents, injuries, and fatalities occurred as a function of various driver, vehicle, and roadway/ environmental factors). However, if some measure were also made available which recorded the extent of exposure in these same driver, vehicle, and roadway categories, then the basis would be available for the calculation of accident rates (i.e., accidents per unit measure of exposure). If this exposure measure were common across all accident categories, one could compare and analyze these rates to determine which exposure condition, or combination of conditions, was associated with

greater accident risks or with higher injury severities. In this way, more definitive data and analytical support would be provided for the development and evaluation of countermeasures. Assuming both accident and exposure data were collected on a continuing basis, a better foundation would also be available for understanding the changes which occur in the accident population over time. These include, for example, accidents and injuries as a function of exposure, such as changes in vehicle mix (smaller cars, more motorcycles and mopeds, larger trucks, etc.); changes, either up or down, in national speed limits; changes in the availability, type, and usages of occupant restraint systems; etc.

In order to proceed toward the establishment of an on-going system of collecting motor vehicle exposure data NHTSA contracted with the University of Michigan Highway Safety Research Institute (HSRI) to determine the most cost-effective design of a National Exposure Data System (NEDS). Almost all previous research studies had found vehicle miles traveled (VMT) to be the most practicable measuring unit for quantifying exposure to the risk of a motor vehicle accident (see especially Carroll, 1973), and the contract called for the use of VMT as the basic measure of exposure to be obtained in as many relevant categories of driver, vehicle, and environmental variables useful in accident analysis as feasible. The contract called for developing NEDS designs at three annual cost levels of effort: $500,000; $1,000,000; and $1,500,000.

The primary purpose of NEDS will be to provide motor vehicle exposure data as a complement to the NASS accident data, so that accident rates can be constructed using NASS data in the numerator and NEDS data in the denominator. The NEDS data will also be useful in providing an exposure base for comparison with other types of accident data collections such as the Fatal Accident Reporting System (FARS). In addition to its value in aiding safety programs, it is expected that reliable national VMT data will be useful to the planning and evaluation programs of other government agencies, particularly the Federal Highway Administration but also such organizations as the Environmental Protection Agency and the Department of Energy.

The contract called for the completion of four tasks in planning

for NEDS: a literature review, a preliminary analysis of system design alternatives, a final detailed system design, and a plan for a pilot test of this design. The subsequent report contains separate sections devoted to each of these tasks. However, it should be noted that the literature review and the preliminary analysis of potential design alternatives did not provide enough information to determine all aspects of the most cost effective design for NEDS. Therefore, instead of planning for a pilot test of a single overall design, Section 5 presents recommendations for including in the pilot test phase a number of small validation and comparative studies whose results will be needed before finalizing all aspects of the recommended NEDS design.

The remainder of this report consists of five sections. Section 2 presents the results of an extensive review of the methods used in various past motor vehicle exposure studies. Then Section 3 discusses the advantages and disadvantages of the various alternatives available in regard to seven aspects of a NEDS design: data elements, sampling areas, sampling elements and sources, data collection methods, timing, survey administration, and sample size and costs. Section 4 presents some recommended features of the NEDS design, while Section 5 concludes by outlining three specific methodological studies needed before determining all the components of the most cost-effective NEDS design. Finally Section 6 contains an extensive list of references, published and unpublished.

Appendices include examples of possible questionnaires for a two-interview household survey, for a roadside interview, and for a mail follow-up to a license plate observation survey. A final appendix discusses various possible analytical uses of the NEDS data.

2. REVIEW OF PREVIOUS EXPOSURE RESEARCH METHODS

Not surprisingly, considering the important role of the automobile in American life and in governmental expenditures on roads and streets, there is a long history in America of surveys of the motoring public concerning patterns of driving behavior. These can be divided into three types: general surveys, trip-by-trip recall surveys, and trip-in-process surveys. Each of these types will be reviewed below.

2.1 General Surveys

These surveys ask respondents to make general estimates about how much driving they have done during specific time periods, and they may also ask respondents to estimate percentages of this driving done under various weather or light conditions, on different types of road, etc. The most extensive of these surveys is the national exposure survey carried out by HSRI under NHTSA sponsorship in 1970 (Carroll, et al., 1971). This involved interviews with 7145 driver's license renewal applicants in 37 offices in 18 of the 24 states which then required a personal appearance for license renewal. Respondents were asked to estimate their driving mileage during the previous 7 days and during the previous 30 days and also to apportion this mileage among various road types and other driving conditions. Information was also obtained about the type of vehicle driven most and about some personal characteristics. Similar large-scale general studies in license renewal offices have been conducted in California (Burg, 1973) and North Carolina (Stewart, 1973), and Pelz and Schuman (1971) carried out a general home in-person survey on driving behavior among 3000 motorists in Detroit suburban households.

In Australia the Bureau of Statistics (1977) has carried out a series of mail surveys (1963, 1971, 1976) to samples of vehicles owners (53,000 in 1976) asking about annual mileage and general usage characteristics, but response rates and follow-up procedures are not mentioned in the report. In North Carolina White (1976) reports a 63% return of a general mileage and usage questionnaire mailed to a 1974 sample of vehicle owners. This survey utilized one follow-up mailing to non-respondents after 3 weeks.

Undoubtedly many other social surveys have asked similar general questions concerning driving behavior. Unfortunately, the few studies available which compare driver estimates with actual odometer readings suggest considerable unreliability in many individual estimates (Carroll, et al., 1971; House and Waller, 1971; White, 1976). For example, White compared annual mileages determined from North Carolina vehicle inspection receipts with owner estimates from a mail survey. The actual mean was 9523 miles compared to 9946 miles as the mean of the estimates, a difference of less than 5%. However, the standard deviation of the difference was 5363 miles, indicating that the estimates of one third of the owners were different from the actual mileages by more than 50%.

One would also expect great unreliability in percentage estimates by night and day, different road types, etc. These separate estimates for different variables also present a problem in analysis because one cannot properly put them together for more discrete classifications (e.g., percentage of miles driven on freeways at night). For these reasons the general approach has been rejected in planning for NEDS in favor of some means of obtaining specific trip information for aggregation into mileage totals in various categories for various time periods.

2.2 Trip-by-Trip Recall Surveys

The vast majority of surveys of this type found in the literature have been origin-destination surveys sponsored by urban and regional planning authorities. They have generally involved selecting a sample of dwelling units and contacting the dwelling unit in person to obtain

information about all trips made by all household members over a certain age on a specific recent day (the Travel Day). Procedures for these surveys were published in a manual by the Bureau of Public Roads in 1944 and revised in 1946 and 1954 (Manual of Procedures for Home Interview Traffic Studies). Barkley (1951) says the first such survey was carried out by the Ohio Department of Highways in Toledo in 1942, and that by 1945 55 cities had conducted such studies. More recently a new Federal Highway Administration (FHWA) manual (1975) lists 301 household travel surveys conducted in 228 urban areas from 1944 to 1975. In another survey planning document prepared for the FHWA DiRenzo lists five such regional or statewide household origin-destination surveys (1976).

Most of these surveys have used a rather microscopic definition of "trip" as one-way travel from one place to another place with a distinct purpose or set of purposes and with no change in mode of travel or (if driving) in the number of passengers. Thus stopping to buy cigarettes or to drop off a passenger is usually defined as terminating one "trip" and initiating a new one -- although respondents often have difficulty describing their trips in such discrete terms. Many of these surveys have not asked for respondents' estimates of the distance of each trip, since the origin and destination locations themselves are usually sufficient for the inter-zonal trip classification analysis carried out by urban transportation planners. However, three pairs of surveys which included trip distance information (Sioux City, Reading, and Detroit) were analyzed by Bellomo, Dial, and Voorhees (1970) in their demonstration of a trend toward increased average trip lengths in American driving.

There have also been a few national in-person interview studies which have been concerned with trip-by-trip recall of travel behavior on a particular Travel Day. For example, under FHWA sponsorship the University of Michigan Institute for Social Research conducted a panel study of metropolitan households in 1963 and 1965 which focused on the journey to work but which also obtained information on all household trips for the previous day (Lansing and Hendricks, 1967). Similar nationwide studies were carried out by Chilton Research Services and by National Analysts in 1968 under the sponsorship of the National

Cooperative Highway Research Program (McMillan and Assael, 1968, 1969), and by Cambridge Systematics in 1978 (with Westat, Inc. as survey subcontractor) under National Science Foundation sponsorship (Sherman, 1978).

In 1969-70 under FHWA sponsorship the Census Bureau carried out the first Nationwide Personal Transportation Survey using Travel Day recall as the heart of its household interview, and FHWA published eleven reports from this study in the 1972-74 period. The Census Bureau has also carried out a series of National Travel Surveys (1963, 1967, 1972) using mail questionnaire procedures to find out about trips over 100 miles one-way taken by members of a sample of households. In 1977-78 a second Nationwide Personal Transportation Survey was merged with the National Travel Survey using in-person interview methods to obtain both long trip and Travel Day trip information for more than 20,000 American households spread over a twelve-month period. The trip information collected includes origin, destination, beginning time, purpose, means, companions, distance, duration, vehicle used, and mapping of trips crossing a rural-urban boundary. Households selected for this survey were visited as soon after the predesignated Travel Day as possible up to four days later, and callbacks were made for over-14 household members who were not available at the initial contact. The overall response rate for eligible respondents was about 83%. The average number of trips reported per household for persons aged over 4 years was 5.9 in the first quarter (April-June 1977) and 4.9 in the second quarter (excluding professional driver trips and walking and bicycle trips by persons under 15).

An in-person Travel Day recall survey was also implemented by HSRI in Michigan driver license renewal offices throughout 1976 (Lee and Wolfe). A sample of 7721 renewal applicants were interviewed by license office personnel and asked about all trips driven on one of the three previous days. Of course such a survey procedure can not include recently licensed drivers, nor can it be used satisfactorily in states which permit license renewal by mail.

A longer simple-recall trip survey was carried out in Greater London in 1954 (Dawson and Wardrop, 1962). In household interviews

respondents were asked to recall all of their trips in the previous seven days. However, the difficulties of obtaining accurate recall of trips without the assistance of memory aids over such a long period is demonstrated by the fact that the average number of casual (non-regular) trips reported was more than twice as large on the last reporting day as on the first reporting day.

2.2.1 Aided Trip Recall Surveys In the hope of obtaining more complete recall of all household trips on the designated Travel Day, a number of surveys have used a two-contact procedure to provide respondents with a trip record form prior to the Travel Day. As used in California, this two-contact procedure involves a contact interview in which general household information is obtained and the necessary number of trip record forms are left, followed by a trip data interview as soon as possible after the Travel Day (Fresno-Clovis Area Transportation Study, 1973; Ochoa, 1976; San Diego County Comprehensive Planning Organization, 1977). Obviously two interviews will generally be more expensive than one interview, but California users of this method seem to feel that this approach pays off in providing more complete and accurate trip information. Usually the interviewer is able to establish a definite time for the second interview at the contact interview, and the second interview is also simpler to conduct with the aid of the trip record form which most of the respondents do use.

Such trip record forms are also sometimes sent to selected households by mail prior to the designated Travel Day (Falk and Halpin, 1966; North Carolina State Highway Commission, 1968?). A variant on the two-contact method known as the Voluntary Return method has been used in several Ohio cities. This involves a field worker dropping off a household trip "self-enumeration" form prior to the Travel Day and picking it up again afterwards. In Cleveland in 1963 144,000 Travel Day reports were obtained by this method (an 83% response rate) at a total survey cost of $4.33 per report. However, Reed (1967) felt that better data could have been obtained if the field workers had spent more time with the respondents going over the forms at pick-up time.

The British have pioneered in conducting aided recall trip surveys over a longer period of time, seven days. The Office of Population

Censuses and Surveys has conducted twelve-month National Travel Surveys, in 1965-66, 1972-73, 1975-76, and in 1978-79. As in California, two interviews are required, a placement interview to place the seven-day trip diary with each household member aged three and over (parents take responsibility for reporting the trips of 3-10 year-olds) and a recall interview to pick up the diaries and to record the trip information. Professional driver trips are excluded, and walking trips of less than one mile and time of day information are included only on the seventh day. Sample households have a predesignated day of the week as the start date, but interviewers are given considerable flexibility as to when the placement interview is conducted. Thus reminder contacts just before and during the survey week are also often made. Response rates in both the 1965-66 and 1972-73 surveys were about 80% of selected households, and in 1972-73 complete information was obtained from 87% of the individuals aged three and over in these cooperating households. (U.K. Department of the Environment, 1976; Rigby, 1977; Das, 1978).

In the United States Worrall (1967) experimented with a 28-day travel diary in an origin-destination household survey in Skokie, Illinois. All household occupants were to record the origin, destination, time, purpose, and companions for all trips for 28 days. A number of reminder contacts were made during the reporting period, but still only 30 of the 104 sample households maintained the diary for the full 28 days. Built in to this survey was an experiment using three levels of compensation in trading stamps for survey participation. Among 29 households in which no payment was offered only 9 agreed to participate and only 2 lasted the 28 days. Among 35 households in which a medium payment was offered 19 agreed to participate but only 7 lasted 28 days. Among the 40 households offered a high payment 31 agreed to participate and 21 cooperated for the whole period (52.5%). The numbers in each group are rather small, but the differences are so dramatic that this study gives strong support to the value of offering compensation to participants in a lengthy diary study -- at least in a middle class suburban area. Worrall (1968) used these data to analyze household trip production by day, and he determined that a 3-day travel diary would provide much more stable estimates of household daily travel than the single Travel Day reports usually collected in origin-destination

surveys. Also in the U.S. Boek (1957) mentions asking respondents to a household interview in Schenectady to keep daily records of miles driven over a period of four weeks with weekly contacts to obtain the data, but she does not report any analysis of these data.

In Canada a more limited seven-day travel diary is now in use in Transport Canada's first National Driving Survey conducted by Canadian Facts, Inc. for the Road and Motor Vehicle Safety Branch (Rochon, Swain, and O'Hara, 1978). In contrast to the British surveys this survey involves driving trips only, and in most households only one driver is selected to participate (there is a procedure to oversample drivers in the 16-24 age group). The survey began in May 1978 and will run for twelve months with an expectation that 9000 drivers will participate out of a sample stratified to represent all months and all provinces and from two to five urbanicity groups. At the contact interview the interviewer obtains information about license type, driver education, driving experience, estimated annual mileage, accident experience for 12 months, types of vehicles used, and personal characteristics. Then the respondent is given a red binder with a separate page to be filled out for each trip made over a predesignated seven-day period. Trip information sought includes beginning and ending odometer readings and times, origin, destination, purpose (6 categories), numbers of passengers in 5 age categories, road types used (4 categories), road moisture conditions, and vehicle used. The interviewer contacts the respondent after three days to answer questions and to encourage continued participation, and he/she returns after seven days to review and pick up the diary. The respondent is given the binder to keep. Trips in large trucks and in small motorcycles are not included, and professional driver trips of the same type may be summarized on a single trip form.

In a pilot diary survey of 509 households in four Ontario cities 10% were found to have no licensed driver, 13% refused to provide listing information, and 14% were not contacted after 3 calls. Of the 351 selected drivers, 81% were interviewed and 72% accepted placement of the diary. However, only 61% of the 351 actually returned the diary, including 5% who reported no trips. The degree of completeness of the

other returned diaries is not mentioned. Thus overall it appears that about 45% of the potentially eligible respondents actually completed the trip diaries. This was deemed satisfactory for going ahead with the national study, although it is hoped that improved contact methods including an introductory letter will result in an improved national response rate. The pilot survey found that asking respondents to estimate the percentage of a trip's miles in each of the four road types and each of the four road moisture conditions did not work well, and the response categories for these variables were changed to "all", "most", and "some" for the national study.

The U.S. Census Bureau has not used any memory aids in its two nationwide personal transportation surveys, although it does routinely send a general respondent letter by mail to sample households. However, in the long-trip portion of the 1977-78 National Travel Survey, which involved recontacts with sample households over the course of a year to find out about all households trips over 75 miles in one-way length, a monthly calendar form was used for recording each trip and its associated transportation and lodging costs (Cannon, 1977). An evaluation of the efficacy of this calendar form will be of interest.

2.2.2 Telephone Trip Recall Surveys. Due to the high personnel costs of home in-person surveys a number of origin-destination surveys have been conducted by telephone. Edens (1963) reports two such surveys in Chatham and Etibicoke, Ontario, in which respondents selected from the telephone directory were called in the evening and asked about afternoon rush hour trips on the same day. Total data collection and coding costs were only $1.00 per interview. A similar survey was reported by Pendakur (1966) in Prince George, British Columbia. There was extensive pre-survey publicity, and the refusal rate was less than 1%. The Delaware Transportation Department (1978) conducted a telephone origin-destination survey in two counties in the summer of 1966. A 10% sample was drawn from the telephone directories, and a 90.2% response rate was achieved after up to 17 calls. Of the missing cases 4.6% were disconnected, and only 2% were outright refusals. This survey indicated the value of persistence in telephone interviewing with 41% completion after one call, 63% after two calls, 73% after 3 calls, 79% after 4

calls, 83% after 5 calls, 85% after 6 calls, and 89% after 10 calls. A similar telephone survey carried out in a number of upstate New York counties obtained a response rate of 63% (DiRenzo, 1976). Also a nationwide telephone survey (presumably using random digit dialing) was carried out by Opinion Research Corporation in 1975 concerning recent automobile trips and attitudes concerning alternative travel behavior (Rappeport and Labaw, 1975).

In Canada, Campbell (1972) used telephone interviews as his primary exposure data source in his interesting comparison of accident and violation rates for 759 drivers aged 16-25 and 733 drivers aged 42-51 in Vancouver. Also in Canada, Recon Research Consultants (1964?) carried out three large telephone surveys in rural areas for the Ontario Department of Highways. In one area they obtained an 85.3% usable response rate from a telephone directory sample with only 0.6% refusals (only 0.1% in the households which received an introductory letter and information booklet). The interviewers used up to six calls, but were able to obtain 57.8% completion on the first call, 74.8% on the second call, and 81.6% on the third call.

The above-mentioned studies did not make use of any trip memory aids, but some telephone surveys have found mailing such a trip log form in advance of the interview to be helpful. Such a survey in Salem, Oregon., where a 93% response rate was obtained, is reported by Clark and Morin (1966). This procedure was also used in Spokane in 1965 (Falk and Halpin, 1966) and in Asheville in 1967 (North Carolina State Highway Commission, 1968?). In Rhode Island a statewide telephone origin-destination survey was carried out in 1971 (Allinson, Inc., 1972?). The basic sample of dwelling units was selected from electric company records and a respondent letter with a trip log form for a particular date was mailed out. Phone numbers were obtained for 72% of these dwelling units with telephone company assistance. Field interviewers were also used to contact dwelling units without telephone numbers and dwelling units where no telephone contact was achieved after 4 calls in 3 days. Information on response rates is not reported, but apparently it was considered a cost-effective data collection method. McMillan (1967) also presents a strong case for the usefulness of the telephone

method using a central facility in terms of cost, quality control, and ease of sampling.

2.2.3 Mail Trip Surveys. Collecting data by mail should be even cheaper than collecting it by telephone, and a number of travel surveys have also used this technique. Kell (1952) mentions origin-destination surveys by mail in Charleston (W.Va.), Mahoning Valley (Ohio), and Evansville (Ind.) with response rates of 54.6%, 46.9%, and 33% respectively. The Federal Highway Administration (1975) includes postcard surveys in Los Angeles, Mansfield (Ohio), Fort Wayne, and South Bend in its compilation of origin-destination surveys. In Cincinnati 227,859 vehicle owners were sent mailback postcards and asked to record all of their vehicle movements on Sept. 21, 1954, and a 36.1% response rate was obtained (Ohio Department of Highways, 1958.)

In Australia Morison (1962) reports a heavily publicized postal survey in Canberra which achieved a 50% response rate, and Foldvary (1963,1969) reports an 18-month postal survey throughout Queensland which obtained a 36.5% return rate. In the latter study questionnaires were sent to a sample of 100 vehicle registrants per day along with their reregistration notice. Trip information for that vehicle was to be provided for a particular day of the week, but a specific date was not requested because of the uncertainties of mail delivery. Trip information collected included driver age and sex, distance, time, purpose, and occupancy. During a four-month period the return rate was increased to 86% by the use of one or two reminder letters, but it was found too expensive to continue this. Foldvary has made use of Queensland accident data for 1961 to carry out an extensive analysis of accident rates in Queensland (1975, 1976, 1977, 1978).

Another large-scale mail survey was carried out in the Stockholm area in 1965 among 22,575 registered residents aged 16 and over (Bygren, 1974). Respondents were asked to record the kilometers driven during each of 42 4-hour periods during one week in May. Up to two reminder letters were sent, and remaining respondents were asked again about a week in June, again with up to two reminder letters. Initial response rates are not given, but overall response rates are 85% for Stockholm, 81% for suburban areas, and 90% for rural areas. In-person interviews

were carried out with 196 of a sample of 262 nonrespondents, and it was found that these nonrespondents averaged considerably higher mileages than did the easy respondents.

Carroll et al. (1971) recommended a mail survey as the most cost-effective means of collecting national exposure information, and in 1973 and 1974 NHTSA sponsored pilot mail trip-log surveys in Michigan (Carroll, 1974, 1975). Ten randomly-selected drivers per day were sent trip-log forms to be completed on a designated future date (8 days after mailing). Trip information sought included vehicle type, beginning and ending odometer readings, and estimated day/night miles and miles on four road types. No identification information was requested, and no follow-up procedures were used. The response rate was 30% in 1973 and 31% in 1974. A large mail survey to vehicle owners by the Kentucky Department of Transportation in 1972 also obtained a 30% response rate on the first wave which included a questionnaire mailed third class 8 days before the designated Travel Day and a reminder letter sent to the entire sample just after the Travel Day (Bennett, 1975). The response rate was brought up to 40% with a second mailing with a new Travel Day.

In Shawnee County, Kan., a mail survey to 17,000 vehicle owners asking just about trips over 20 miles on Sunday, August 25, 1968 brought a 53% response rate after 43 days with no follow-ups (McCann and Maring, 1967). Only 18% reported taking one or more trips of that length. The questionnaires were addressed by computer using the automated vehicle registration file, and the total cost was $.32 per returned questionnaire. An even more successful mail survey, one concerned with truck movements in one day, was carried out by the FHWA in Missouri, New York, and Wisconsin (Kent, 1971). A 78% response with up to two follow-ups was obtained.

2.2.4 Trip Recall Validity Studies. In spite of the vast number of surveys requesting trip recall information, only two studies have been found in the literature review which attempt to validate individual trip recall against an external trip record. In Great Britain Smith and Wood (1977) asked 122 of their colleagues in the Transport and Road Research Laboratory to recall all of their business trips over 35 miles in length in the previous eight months. All of these respondents had

filed at least one travel claim in the previous six months, and these claims were used as the validation criterion. Without memory aids the overall recall rate for the eight months was only 66% of the recorded trips, although this varied from 83% for trips in the most recent month to 45% for trips taken eight months previously. When respondents were allowed to use any available diary and calendar records, the overall recall rate improved to 92%. Seventy percent of the recalled trips were recollected to within two weeks of the actual date, and, as would be expected, the accuracy of the date decreased as the length of time since the trip increased. Longer trips and trips by air were more likely to be recalled.

The second study was carried out in the fall of 1954 in two residential zones in Cincinnati, and it used actual license plate observation at the boundaries of the two zones to validate household reports of trips crossing the zone boundaries (Murray, 1957). In each zone all vehicles entering and leaving the zone had their license plates recorded for 24-hour periods on two different days (24 stations for one zone and 18 stations for the other zone). For one of these days vehicle owners were sent a postcard questionnaire on which to record all vehicle destinations for the Travel Day. For the other day an interview to obtain similar information was sought from a sample of households in each zone. Comparing the postcard reports with observations of the same vehicles it was found that the two methods provided identical data for 62.5% of the 483 reported vehicles, while 10.5% reported more trips than were observed and 27% reported fewer trips than were observed. For 361 vehicles whose trips were reported in a home interview 55% had the same number of observed and reported crossings, while 15% of the household respondents reported more crossings than were observed and 30% reported fewer crossings than were observed. The home interviews took place one or two days after the observed trips, but no analysis of accuracy in relation to these two time periods is reported. In the postcard survey 25% of the 88 vehicles reported as having made no trips were actually observed, and in the home interview survey 30% of the 72 vehicles reported as having made no trips were actually observed.

Thus, this study, sponsored by the Ohio Department of Highways and

the U.S. Bureau of Public Roads, strongly suggests that there may be substantial underreporting of trips in in-person surveys using simple-recall procedures and in mail surveys even when a trip record form is received prior to the Travel Day. This study seems to indicate a considerable amount of overreporting of trips also, but this is more difficult to evaluate because no mention is made of the degree of completeness of the license plate observations. One would not expect 100% accuracy in the recording of license plate numbers, so it is probable that at least some of the "overreported" trips were real trips which were not properly recorded by the observers.

There was also a quasi-validity study of long-trip recall carried out by the Census Bureau as part of the 1972 National Travel Survey (Koons, 1974). This was basically a mail survey with telephone follow-ups, and it asked sample households to report all trips over 100 miles during a 3-month period. In-person reinterviews were sought with a subsample of 873 responding households (60% had responded by mail, 15% by mail with supplementary telephone calls, and 25% by telephone only), and 795 were successfully reinterviewed. After the reinterview the interviewer attempted to reconcile any discrepancies from the original trip report with the respondent's help. In all, 93 trips listed on the original reports were not listed in the reinterview one month later, while 217 trips were listed for the first time in the reinterview. After reconciliation the original reports contained 19% fewer trips, 12% fewer person miles, and 6% fewer person nights than the reinterview reports. Clearly, the mail-telephone method was providing less complete information than the in-person interview method even a month later, but the completeness of trip reports by the in-person interview method still is not known.

Another validity aspect of exposure studies which do not collect odometer readings concerns the accuracy of respondent estimates of trip mileage. Since these estimates provide the basic numbers of the various exposure classifications it is important that they be as accurate as possible. No studies have been found which attempt to validate these estimates on a trip-by-trip basis, although, as mentioned earlier, White (1976) and House and Waller (1971) have demonstrated that there are

substantial errors in vehicle owners' estimates of annual and monthly mileages. Cannon (1977) mentions that in a pilot test of the 1977-78 National Travel Survey a clerk used the respondents' route descriptions to trace 143 trips on maps. It required about five minutes to trace each trip and to measure it with an opisometer. However, he does not give any comparison of the traced mileages with the respondents' estimates. In the 1977-78 Nationwide Personal Transportation Survey respondents who reported crossing an urban-rural division on a Travel Day trip were asked to actually trace the route on a local map. These trip distances have been measured with an opisometer, and when the NPTS tape becomes available in 1979 some useful information on the accuracy of respondent trip distance estimates will be available.

2.2.5 Comparative Trip Recall Studies. In addition to these few validity studies there have been a number of studies which have attempted to systematicaly compare the results and costs of different data collection methods -- mail with in-person interview, telephone interview with in-person interview, mail with telephone interview with in-person interview, and license office in-person interview with home in-person interview. The only one of these that involved using two methods with the same sample is the previously discussed survey in Cincinnati (Murray, 1957). Respondents to the city-wide postcard survey in two areas of the city were interviewed in-person a few weeks later about travel on the same day of the week as the postcard Travel Day. The interviews were either one or two days after the designated Travel Day. In the postcard survey an average of 4.82 trips per vehicle was reported for Tuesday, Sept. 21, 1954, while the home interview survey obtained reports of an average of 3.75 trips in the same vehicles on a Tuesday a few weeks later. This strongly suggests a substantial underreporting bias in the in-person interview method -- at least for the minority of respondents who had been willing to cooperate in the postcard survey. Analysis of the types of trips reported in the two surveys show that the postcard survey averaged only slightly more trips in and out of the zones of residence compared to the in-person survey, but it averaged much higher on intermediate trips made between other zones of Hamilton County compared to the in-person survey. Presumably the interviewers did not do an adequate job of probing about

intermediate trips, a deficiency which could at least partially be overcome.

Kell (1952) reports an even larger discrepancy between mail and in-person methods in two independent samples in Logansport, Ind., in 1951. The postal reports averaged 6.7 trips per vehicle, while the home interview reports averaged 4.7 trips per vehicle. The in-person interviews took place generally on the same evening as the designated Travel Day and asked respondents about trips already taken that day and about trips anticipated later that evening, which might account for some of the discrepancy. Also the fact that there was only a 51% response rate in the postal survey (40% from the initial mailing and 11% from telephone and in-person follow-ups) compared to a 95.5% response rate in the in-person sample might account for much of the discrepancy. But this study also supports the idea of a underreporting bias in in-person interview trip recall.

In 1967 the Bureau of the Census (1970) conducted a careful methodological study of Travel Day survey procedures using two independent household samples in the New Haven area. The mail sample (N=2503) was mailed a questionnaire three days before the designated Travel Day and a reminder card two days later, and the initial response rate was only 28.5%. This was eventually brought up to 79.0% -- 10.3% from a second mailing, 29.1% from telephone follow-ups, and 11.1% from in-person follow-ups. A similar 80.6% response rate was obtained from the in-person interview sample (N=397). The mail sample reported a slightly higher number of motor vehicle trips per household, 6.06, compared to the in-person sample, 5.74. This difference was not statistically significant at a 95% level of confidence, but like the Murray and Kell studies it suggests that a mail survey (with telephone and in-person follow-ups as needed to obtain an adequate response rate) may produce more complete trip recall data than an in-person survey. Since the mail sample reports were estimated to cost only one third as much as the in-person sample reports to collect, it would appear that mail data collection methods are worth serious consideration for the NEDS program.

In contrast to these results are the findings of a pretest study in

preparation for the 1977-78 National Travel Survey (Cannon, 1977). Two large independent samples were asked to report all household trips over 75 miles in the first quarter of 1976. Only one third of the mail sample responded to the initial mailing on March 31 and subsequent mailings on April 7 and April 14. However, telephone and in-person follow-ups extending into June eventually brought the response rate up to 94% of the occupied addresses. The in-person sample was contacted in April, and a 95% response rate was obtained. In analyzing the data it was found that the in-person sample reported 22% more trips than did the mail sample, mostly relatively short automobile trips. These findings may be affected by the longer recall period for many of the follow-up mail sample respondents, but they do suggest a serious underreporting, at least of trips over 75 miles, in the mail survey method.

Turning to a comparison of telephone and in-person methods, the results are also rather mixed. In Kalamazoo in 1966 Alan M. Voorhees and Associates (1969) obtained comparable response rates in independent 5% telephone and in-person samples, 92.7% for the telephone sample (one fifth by in-person contact) and 89.4% for the in-person sample. In spite of these high response rates the average household size reported for the telephone sample was only 2.62 compared to 3.20 for the in-person sample. The average number of total trips reported per person was also considerably less in the telephone sample (2.40) than in the in-person sample (3.07). The report does not mention how the samples were obtained or whether any respondent letters or memory aids were sent in advance of the interviewer contacts.

In a similar study conducted in Spokane in 1965 (Falk and Halpin, 1966) the results were somewhat different. The two samples were based on electric company records, and respondent letters with notice of the Travel Day and with trip record forms were mailed to respondents in both samples. Response rates were not very satisfactory, 70.3% for the telephone sample and 73.2% for the in-person sample. Comparing the telephone sample (N=3736) just with the portion of the in-person sample which also had telephones available (N=2890), the telephone sample averaged slightly smaller in household size but it averaged more total trips per person (2.59 to 2.41). Thus the telephone interviewing method

did not seem to lead to trip underreporting in Spokane. A similar study by the California Department of Transportation in Marysville and Yuba City in 1971 (Ochoa, 1976) obtained much higher response rates (98.8% for the telephone method and 98.3% for the in-person method). In contrast to both Kalamazoo and Spokane it obtained slightly larger average households in the telephone sample (3.2) than in the in-person sample of households with telephones (2.9), but the difference in trips per person was inconsequential (3.3 to 3.4). The sample was selected by a complete field listing of the area. The in-person sample was contacted by an interviewer who left a trip record form prior to the Travel Day, while the telephone sample was mailed a trip record form and contacted by telephone prior to the Travel Day.

In 1967 the North Carolina State Highway Commission (1968?) experimented with a similar comparative survey in Asheville. After a field listing of all households a 1/8 sample was alternately assigned to a telephone sample and to an in-person sample. A 94.4% response rate was obtained for the telephone sample with telephones; an 82.8% response rate was obtained for the telephone sample without telephones (by in-person interview); and a 96.1% response rate was obtained for the regular in-person sample. All sample households were mailed a respondent letter and trip record forms prior to the interviewer contacts. Household size information is not reported, but the average number of trips per household was 7.17 for the total telephone sample and 7.36 for the regular in-person sample. The report adds an interesting comparison of results excluding the first week of interviews. For interviews by telephone the average number of reported trips per household changed from 5.41 the first week to 8.13 for the succeeding weeks. For in-person interviews this average also went up but not as much -- from 6.51 in the first week to 7.62 in succeeding weeks. This suggests that there may have been greater underreporting by both methods in the first week of interviewing and that as the telephone interviewers became more adept at conducting interviews without face-to-face contact they may have achieved more complete trip recall than did the in-person interviewers. But of course there may be other differences in the succeeding week samples that account for these differences.

The final study found which compared just telephone and in-person methods was conducted by the West Virginia Department of Highways (1970) in Princeton and Bluefield in the late 1960s. The sample was selected after a complete field listing, and each selected household was mailed a respondent letter, although apparently a trip record form was included only in the telephone sample. Response rates and survey results are not given, but the report concludes that both methods provided satisfactory information -- with average trips per household slightly higher by the telephone method.

There was also one study found which compared all three data collection methods. In 1963 Recon Research Consultants (1964?) conducted a pilot study in a rural area of Ontario using the local telephone directory for the telephone and mail sampling frame and both the telephone and postal directories for the telephone sampling frame. Response rates obtained were 90.5% for a telephone sample of 208, 81.5% for an in-person sample of 250, and 27.7% (21.6% sufficiently complete) for a postal sample of 1043 using two reminder cards. The analysis presented did not distinguish in-person respondents without telephones from those with telephones, so direct comparison of the results may be misleading. It shows average household sizes of 3.5 in the telephone sample, 3.3 in the in-person sample, and 3.2 in the mail sample. As would be expected, the telephone and mail samples had larger numbers of licensed drivers and motor vehicles per household. The number of trips reported per vehicle in the telephone and in-person samples were quite similar (3.69 and 3.74 respectively), but were considerably less in the mail sample (3.23). Recon concluded that all three methods could produce usable origin-destination data for transportation planning purposes, but that the telephone method was most cost-effective since it cost just a little more than the mail method and only three quarters as much as the in-person method and since large proportions of non-telephone households lacked licensed drivers and motor vehicles anyhow. Subsequently, the Ontario Department of Highways contracted with Recon to conduct a number of telephone origin-destination surveys in 1963 and 1964.

A final comparative study found in the literature review took place

in Battle Creek in 1961 (Mayer and Wallace, 1962). This study compared the results of in-person Travel Day reports obtained in two different settings, the license renewal office and the home. In the office sample renewal applicants were asked about all household trips on the previous day. Since only weekdays were of interest Monday applicants were interviewed later at home. The overall refusal rate was only 0.8% in the license office compared to 7.4% in the home, but the average number of household trips reported was slightly less in the office sample (6.76) than in the home sample (7.17). The office survey costs were about two thirds of the home survey costs, so the authors conclude that the license office in-person interview is a cost-effective method for collecting origin-destination data even though the respondent necessarily has to be a proxy source for all household members' trips, and recently licensed drivers are never available as respondents.

Basically these various comparative methodological studies demonstrate that mail surveys require considerable follow-up effort to obtain satisfactory response rates, that nevertheless mail surveys are considerably cheaper than home in-person surveys, that telephone surveys are also considerably cheaper than home in-person surveys, and that all three methods can produce roughly comparable information about household Travel Day trips. Of course the completeness of trip recall by any of these methods is not known, but the Cincinnati observation study (Murray, 1957) suggests that there is probably substantial underreporting of trips in any simple-recall method.

2.3 Trip-in-Process Surveys.

The simplest and by far the most prevalent type of travel exposure survey is the traffic counting survey. Every day the movements of thousands of vehicles are recorded by state and local highway and traffic engineering departments by means of traffic counting devices deployed on various road segments. For example, the Transportation Surveys Section of the Michigan Department of Highways and Transportation (1977) operates 108 permanent traffic recording stations and conducts about 16,000 traffic counts annually with portable

counters(Keesler, 1977). In Michigan and in every other state these kinds of data are used to estimate annual totals of miles traveled by various road types. However, no state utilizes a controlled probability design for the placement of the traffic counting devices on all types of roads within the state, so the degree of accuracy of the various traffic volume estimates cannot be ascertained, as it can in Great Britain where periodically representative samples of all roads have been used for national traffic volume studies (Tanner et al., 1962; Timbers, 1968). Bodle (1973) discusses two approaches to sampling of local roads for a traffic counting survey and briefly describes their pilot implementation in Colorado and Idaho, but no other discussion of statewide sampling for traffic count surveys was found in the literature review.

Highway departments also sometimes supplement these mechanical traffic counting surveys with manual (human) surveys to classify passing vehicles into particular types, or to count turning movements, etc. An example of the use of such manual classification counts in the construction of accident rates is the recent study of recreational vehicle accidents in Kentucky (Hutchinson and Sayre, 1977). Over an 18-month period special accident reports were filled out on Kentucky accidents involving ten classes of recreational vehicles. In order to obtain adequate exposure information for calculating accident rates by vehicle class, special manual classification surveys were conducted periodically on eight Kentucky road segments.

More sophisticated mechanical counting instruments are also being developed which can measure vehicle speed, weight, and the number of axles on the same vehicle. However, there obviously is no substitute for visual observation as a means of obtaining detailed vehicle classifications such as were needed in the Kentucky study. Time-lapse cinematography does offer a potential for reducing the human time involved in vehicle classification counts, especially if the camera can be operated in unattended mode, but the human eye is still required to view and code the filmed data (W. Baker and Williams, 1972; Dougan et al., 1973). Wilkes (1972) describes the use of the Orbis III camera combined with dual speed sensing strips in the pavement to obtain photographic records of speeders in Arlington, Texas. Murphy (1973)

describes the use of a time-lapse camera with a digital clock to record traffic movements on a low-volume forest service road. Only once a week maintenance and film replacement were required, although there were a number of problems of false triggering of the infra-red sensor by shadows, with vandalism, etc.

Another approach to gathering trip-in-process data by mechanical means involves the installation of special instruments in a motor vehicle to record such data items as time, speed, mileage, brake applications, etc. General Motors has inserted such instruments in customer cars to operate unattended for up to four months with the purpose of obtaining better information about typical vehicle usage patterns (M. Baker, 1974; J. Peterson, 1974; Johnson et al., 1975). The Environmental Protection Administration has also been supporting the development of similar instrumentation to place in private cars in order to obtain better information for its fuel economy cycles (Thompson, 1978). The instrument under development by MB Associates would include a button for the driver to push when changing between rural and urban environments.

Obviously a major problem with such instruments as far as collecting general exposure information is the paucity of data in the driver and environmental areas. As one solution to this problem General Motors has used a "chase car" technique in which a professional driver in an instrumented vehicle follows a randomly selected vehicle for one trip (or until it is obvious that the other driver is being disturbed by the following). He attempts to duplicate the driving behavior of the vehicle being followed and also notes in a tape recorder information on the other driver and on road type and other environmental characteristics (Johnson et al., 1974). Boek (1957) also describes a following technique for the determination of the frequency of unsafe driving actions. The license numbers of the selected vehicles were used to obtain information on the owners' driver records in order to compare accident and violation data with the observed driving behavior.

2.3.1 Roadside Interview Surveys. Another time-honored approach to collecting exposure information in transportation studies is the roadside origin-destination interview. In transportation planning such

a survey is often referred to as an "external" survey (in contrast to the home interview "internal" survey), and it usually involves placing interviewers at roadside stations on main roads around the perifery of the study area (the cordon line). For example, in the 1954 Cincinnati study discussed previously (Ohio Department of Highways, 1958?) 29 stations were operated on the Hamilton County line on roads which exceeded 1000 vehicles per day in traffic volume. Such interviews are typically quite short, involving mainly a driver report of the origin, destination, and purpose of the trip and perhaps where the vehicle is garaged. Vehicle type and state of registration and the number of occupants can be obtained by observation. Lovejoy (1960) reports that the New York Port Authority carried out 93,000 such interviews at toll plazas in 1958. Interviewers were able to average 40 interviews per hour during survey periods established on a continuous sampling basis. In Kentucky Bennett and Taqui (1974) report the use of 72 external cordon stations on the state border between 1964 and 1971. These included 56% of the state boundary crossings covering 95% of the traffic -- excluding the Ohio River bridges in the Louisville and Cincinnati areas where the heavy volumes were considered to make interviewing too hazardous. Hajek (1977) provides some interesting data from an Ontario roadside survey in a discussion of optimal sampling rates at roadside stations.

Obviously roadside interviews can most conveniently be carried out at places where traffic normally has to stop anyway,such as toll plazas, and it is particularly difficult and dangerous to conduct such a survey on a high-speed limited access freeway carrying heavy volumes. Nevertheless, Wiklund and Forsells (1972) report that a successful roadside interviewing survey was carried out on the E-4 motorway outside of Stockholm for four days (including some darkness hours) in 1971. Fifteen thousand interviews were obtained with the traffic and safety assistance of ten police officers, about a 35% sample of the passing traffic. There was only a 1% refusal rate from the selected motorists. They feel the procedures used would work on freeways with up to 30,000 daily traffic volume. In the pilot study interviewing had to be discontinued for 10 minutes at 6:30 p.m. because of a large traffic back-up, but no such problem occurred in the main study.

The San Antonio police have also conducted weekend evening roadside interview and breathtesting surveys on the freeways in that city (Hawkins, 1976), and the Michigan Department of Highways and Transportation has conducted roadside interviews on rural freeways up to 15,000 vehicles in daily traffic volume (Beard, 1978). However, in the national roadside breathtesting survey (Wolfe, 1974) and in most of the scores of local nighttime roadside breathtesting surveys conducted by the NHTSA-sponsored alcohol safety action projects (Lehman et al., 1975) stopping vehicles on freeways was deemed too dangerous. The Interstate Commerce Commission (1977) conducted a nationwide roadside survey of trucks with three or more axles at 1653 sample points on interstate freeways in 1976. It used mostly existing weigh stations and rest areas but also made use of some road shoulder areas along the open highway. The recent FHWA manual (1975) on urban origin-destination surveys includes a technical paper on roadside interviewing at high volume stations (Exhibit 6-4).

A large-scale roadside survey in eleven states was carried out by the Bureau of Public Roads in 1958 (Solomon, 1964). This involved interviews with over 290,000 drivers on 35 main rural road segments (no freeways). In addition to the interview data the traveling speed of the selected vehicles was recorded by radar on a stretch of highway prior to the stopping point. In the resulting analysis these exposure data were compared with data from 10,000 accidents on the same road sections over 3-4 years.

Due to the problems of delay and traffic back-up in even a short roadside interview on busy roads, a number of origin-destination studies have used the procedure of stopping cars just long enough to give the driver a mailback postcard. In a Michigan survey in the Cadillac and Petoskey areas during the summer of 1977 over 27,000 cars were stopped, and about 40% of the postcards were eventually returned (L. Brown, 1978). The New York Port Authority was able to obtain only 17-18% returns in its postal surveys at toll plazas and these were abandoned, (Lovejoy, 1978). In the 1971 Puget Sound Regional Transportation Study comparisons were made between roadside interview and roadside postcard surveys at the same locations. Only about 35% of the postcards were

returned, and the distributions of trip purpose in the two data sets were significantly different, with the postcard method overrepresenting "home" and "work" trips and underrepresenting other trips (P. Brown, 1978). While this technique clearly has some advantages in terms of reduced personnel costs and reduced disturbance to the motoring public, it seems unlikely that sufficiently high response rates could be obtained to provide adequate exposure data for NEDS purposes.

2.3.2 Roadside License Plate Surveys. The recording of the license plate numbers of vehicles passing certain roadside locations has been carried out by a variety of methods for a number of different purposes. One common use of this technique is for determining the average speed of vehicles from one point to a second point along a road by recording all vehicles passing each point and the time of passage (with well-synchronized watches). Sosslau and Houts (1975) describe a pilot study comparing two methods of recording license numbers for such a speed survey, speaking into a voice tape recording and typing on a touch-tone cassette connected to a machine-readable tape. The latter method was more expensive in terms of equipment and more error prone, but they still recommend it for a large study because of its efficiency time-wise by permitting immediate computer matching of the recorded numbers from the two locations. In a large seat belt observation survey in the Detroit area Lincorp observers recorded license numbers by paper and pencil, and these numbers were used to trace the residence locations of the vehicle owners as a means to a socio-economic analysis of seat belt use (Motorists Information, Inc., 1978). Paulley et al. (1977) describe the recording of vehicle registration numbers by time-lapse photography at a number of points along some British motorways in order to determine trip lengths on the motorways by a matching procedure. They found that from 1-5% of the filmed numbers were impossible to read and that another 10% were miscoded. However, these error rates were still better than those in a pilot test recording the numbers verbally into a tape recorder and then keypunching them. Hardman (1978) describes a similar but more extensive survey on British motorways also using primarily photographic recording. At most of the major sites the cameras were mounted on bridges, and telephoto lenses were used to film the vehicles from the front at a distance of several hundred meters so

as to cover all three lanes adequately. Main legibility problems had to do with dirty plates, sunlight glare, shadows from another vehicle, and occasional difficulty distinguishing such similar letters as "D" and "O". Coding of the film which was shot at one frame per second was a time-consuming process including not only the registration number but also the vehicle type and occupancy rate. Makowski and Sinha (1976) provide a statistical procedure for analyzing just the last three digits in such license plate matching surveys.

It is possible that an observational survey, using either cameras or human eyes or both, could also provide information on the sex and approximate age of the driver, thus covering most of the major variables of interest in an exposure survey. However, one key variable, that having to do with the destination and purpose of the trip, can never be obtained by observation. It requires direct information from the driver. In order to obtain this information a number of license plate surveys have used the license plate numbers to ascertain the name and address of the vehicle owner and to mail him or her a mailback questionnaire about the particular trip on which he or she was observed.

A pilot survey of this sort was sponsored by the Federal Highway Administration at four freeway locations in the Boston area on a January weekend in 1968 (McCann and Maring, 1968). In preliminary testing it was decided that neither human recording into a tape recorder nor human reading of numbers for a second person to transcribe provided sufficiently accurate data, and the data at three sites were recorded by a 16 mm Kodak Cine Special camera with a six inch telephoto lens taking pictures of the vehicle rears. If set to cover both lanes the individual state names could not be distinguished adequately, so separate cameras were needed for each lane. Over 93% of the Massachusetts licenses recorded were successfully matched in the state registration file, and the first mailing took place within three days of the observation. Almost 65% of the Massachusetts questionnaires were returned, with higher rates the closer the day of mailing to the day of observation. It took twelve days to complete the matching of out-of-state licenses in the files of seven nearby states, but still a 60% return was obtained from the out-of-state mailing. A small percentage

of the returns were not usable. No follow-up mailings were attempted.

A full-fledged origin-destination external survey using license plate recording with postal follow-ups was carried out at 35 stations at the Rhode Island border in 1972 (Allinson, Inc., 1972?). At the high volume sites a closed circuit television system was used with one camera per lane, all recoding on a single video tape recorder. At other stations recording was done by paper and pencil or by voice into a tape recorder. No satisfactory nighttime recording methods were found, and the survey was conducted during the daytime only. Twenty percent of the surveyed vehicles were used for matching, not only in the Rhode Island state files but also in those of New York, Connecticut, and Massachusetts, and 26,551 questionnaires were mailed out. The return rate of usable responses was only 31%, for an average total cost per return of $15.30.

The Rhode Island survey also did not use any follow-up mailing, but a two-mailing procedure in a similar survey in California did result in a substantially higher return rate (Ochoa, 1978). This was a 1975 travel survey in the Sacramento-Stockton-San Francisco Bay Area Corridor in which a large sample of California license plates were recorded either by camera or by one person with binoculars reading the numbers to a second person who recorded them. The return rate on the first mailing was 51%, and a follow-up mailing to non-respondents brought an additional 23% return. However, only about 66% were usable, mainly due to insufficiently precise origin or destination information. Other similar surveys on high-volume roads have been conducted in 1974, 1975, and 1976 on the main road between Montreal and Ottawa (Smith, 1978), and in 1977 and 1978 on some urban freeways in the Toronto area where stopping traffic for a normal roadside interview was deemed impractical (Gleason et al., 1978). Response rates for the latter surveys have been about 40% without any follow-ups.

The Federal Highway Administration sponsored a second license plate survey in 1968, this time in Kansas and with a built-in comparison to results from a roadside interview survey (McCann and Maring, 1969). The roadside interviews were carried out on I-70 for four days in mid-August, and the filming of license plates was done at the same site two

weeks later. Only Kansas cars were included, and a 69% return from the single mailing was obtained (63% was the usable response rate). A comparison of the trip lengths and purposes indicated that there was little bias in the postal data compared to the interview data, although there was a somewhat smaller proportion of older vehicles in the postal returns. Data collection costs are also reported as similar for the two types of surveys (about $.42 per case), although presumably the camera technique was safer.

None of the license plate surveys discussed above were carried out during hours of darkness, a limitation which would be fatal to a truly representative national exposure data collection scheme which would have to represent nighttime driving as well as daytime driving. For the Rhode Island survey Allinson Inc. looked into three approaches to nighttime license plate recording, but they found the so-called "moonlight" television camera was not suitable, and that both high-level (14 feet) and low-level (2 feet) spotlight and floodlight illumination presented safety hazards to motorists (Danielson et al., 1974). Dougan et al. (1973) reported looking into synchronized stroboscopic lighting for 3-second filming of traffic incidences at some impact attenuation devices in Connecticut. However, they decided that costs were prohibitive for their purposes. Developments in this area are continuing, and with FHWA support the Naval Surface Weapons Laboratory has been developing a prototype camera system capable of photographing license plates and vehicle occupants at night for police enforcement purposes, using infra-red lighting or a red strobe light with filters (W. Baker, 1978).

Another technical innovation which could possibly serve as a substitute for a license plate survey sometime in the future should be mentioned. This is the electronic transponder which can be attached under a vehicle and can emit a unique vehicle identification code which can be picked up by a roadside interrogator (Foote, 1974). The main use for such automatic vehicle identification (AVI) devices at present is to simplify billing procedures for buses and fleets of cars at toll booths, but if such AVI devices came to be universally installed on motor vehicles at sometime in the future such a system could greatly simplify

and improve the accuracy of the process of identification of motor vehicles passing selected roadside locations.

3. PRELIMINARY DESIGN CONSIDERATIONS

In seeking to determine the most cost-effective design for a national motor vehicle exposure data system, it seems useful to begin by looking separately at the different components of a survey design and analyzing the advantages and disadvantages of the various alternatives available for each component. Thus this section contains separate discussions of data elements, primary sampling areas, sampling elements and sources, data collection methods, timing, survey administration, and sample size and survey cost. Obviously these various aspects of a survey plan may be closely interrelated and it may sometimes be difficult to discuss them in isolation, but due to the myriad of at least slightly different complete designs available this seems the most manageable analytical approach.

3.1 Data Elements

The basic purpose of the National Exposure Data System is to obtain information on the amount of motor vehicle travel in various categories considered useful for the planning and evaluation of highway safety countermeasures and/or of other programs concerned with motor vehicle usage. Thus the key dependent variable which must be collected in any NEDS design is vehicle miles traveled (VMT). This data element could be collected either through a procedure which sampled completed trips and asked drivers for records or estimates of the miles traveled, or through a procedure of sampling trips in process on a known-probability sample of road segments. In either approach, if the sampling was properly carried out, the resulting data could be used to estimate national VMT

totals within confidence limits. A second dependent variable which might be useful for some analytic purposes is vehicle duration of travel, although this could probably only be obtained in a past-trip study. The ratio between miles and duration of travel might be of particular analytic interest.

Turning to the independent variables, there are probably hundreds of potential interest to someone in some of the sections of NHTSA, FHWA, EPA, the Department of Energy, etc. The problem is to determine the data elements of most general interest and of most value to NASS which can most feasibly be collected by NEDS. As a basis for determining the most useful independent data elements there is the analysis of the HSRI 1970 national exposure study by Carroll (1971), the discussions at the Symposium on Driving Exposure (Carroll, 1973), and the decisions by the planners of NASS as to which data elements to include in the NASS accident investigations. The Symposium recommended seven basic independent variables: driver age and sex; vehicle make, model, and year; road type (including a rural-urban distinction); and light condition (day/night). Two other predictor variables found to be of considerable value in explaining the variance in exposure in the HSRI national sample of license office renewal applicants are driving on the job and road condition (wet,dry). Although it may not be particularly useful for accident rate analysis, broadening the driving-on-the-job variable to include other trip purposes (commuting, shopping, social, recreational, vacation, etc.) seems desirable for a general understanding of American driving patterns, for estimating the elasticity of demand for fuel, etc. In addition information on the number of occupants is essential for an analysis of person exposure to the risk of accident rather than just driver or vehicle exposure. Thus the above ten variables are considered the basic independent variables for the analysis of exposure data, and they should be collected in any kind of a national exposure survey. All of them are included in the current Canadian National Driving Survey (Rochon, et al., 1978). It should be noted that certain other contextual variables of interest, such as day of week, season, region, and urbanicity, will be built into the sample design and thus will automatically be available for analysis.

Fortunately, all of the above variables are also included among the data elements currently being collected in the NASS pilot study. The NASS data set also includes a number of other variables of potential value in an exposure survey. Other general driver data elements collected in NASS include estimated annual mileage, months of driving experience, type of driver education, type of license, license restrictions, height, weight, and violations record. Other trip specific driver variables include seat belt use, alcohol condition, and frequency of making the same trip. Certainly the roles of driver education and exposure, of use of seat belts, and of alcohol consumption are all controversial issues in the analysis of accident frequency and severity, and it would be desirable to include these in the NEDS program. However, it seems unlikely that reliable alcohol use data could be collected in a past-trip survey, and reported seat belt use also would probably be somewhat unreliable in such a survey.

Among other general vehicle variables in NASS are body type (2-door, 4-door, station wagon, etc.), curb weight, state of registration, availability of protective devices (including child restraints), general type of use (private, business, taxi, etc.), and current odometer reading. Other trip specific vehicle variables in NASS are age of passengers by seat location, sex of passengers by seat location, type of towed unit (if any), type and weight of cargo (if any), and use for school or emergency transportation. It should be noted that general vehicle type and vehicle size variables could be derived from the basic vehicle make, model, and model year data, but more precise classifications could be made if the body type and curb weight variables were also collected. These size and type variables are becoming of increasing interest in accident analysis with the increasing heterogeneity in the vehicle mix on American roads. The availability of various types of occupant protection devices will also be of increasing interest as the automotive industry moves toward meeting the new passive restraint standard. Information on age and sex of passengers by seat position could also be useful for a more detailed person exposure analysis and for understanding the relative vulnerabilities of different seating locations.

The NASS program also collects a large number of environmental data elements regarding the particular accident location, which it would be almost impossible to collect in a past-trip exposure survey, but which could be collected in a trip-in-process survey at a sample of roadside locations. These include detailed road classification, type of roadway section, road surface material, road surface condition, number of travel lanes, roadway division, access control, number of travel directions, number of shoulders, road profile, road alignment, speed limit, narrow bridge area, construction area, previous accident area, roadway immersion area, school zone, and intersection traffic controls. Other variables of potential interest in such a roadside survey which are not presently collected in NASS include presence of roadside obstacles, presence of parked vehicles, traffic density, average traffic speed, road lane width (quite a controversial issue at FHWA), types of warning signs and pavement markings, and location and direction of the sun's rays.

Other general driver data not presently collected in NASS but of potential analytic value include such data elements as physical disabilities, marital status, education, employment status, occupational group, income level, residence type and ownership, relationship to vehicle owner, usual driving speed in relation to others, and accident record. It is important to the NASS program that periodic surveys be conducted concerning reported and non-reported accidents, so that information on the proportion of all accidents available in the NASS sample frame may be assessed and may be used in adjusting national accident estimates based on the NASS data. Thus it might be quite cost-effective to collect this accident experience data as part of an exposure survey rather than in an independent survey. The Canadian National Driving Survey is collecting data on accident experience during the previous twelve months from its sample of drivers, although the National Center for Health Statistics (1972) has found that a much shorter period is optimum for accident recall.

There are also some additional vehicle data elements not now collected in NASS which come to mind as potential variables of interest. These include number of cylinders, engine displacement, power steering,

power brakes, tinted windshield, vehicle color, after-market modifications, whether the vehicle was purchased new or used, and month and date of purchase for new cars. This last variable could be used in conjunction with the current odometer reading to estimate annual vehicle mileage. Of course in a household survey of drivers and their trips it would often be difficult to obtain a lot of vehicle data elements because one would have to repeat these questions for each different vehicle driven on the Travel Day(s). Conversely, in a survey of vehicle owners it would often be a problem to obtain a lot of driver data elements because of the necessity of repeating the questions for each different driver of the vehicle on the Travel Day(s). In a roadside survey there would be only one driver and one vehicle on one trip to ask about, but if the data were collected by roadside interview there would be considerable pressure to keep the interview short. However, if the driver and vehicle data were collected by telephone or mail follow-up it might be possible to include quite a large number of non-basic driver and vehicle data elements. Of course a large number of environmental data elements could easily be included in a roadside survey since most of these would remain constant for all trips sampled during the survey period.

3.2 Primary Sampling Areas

The fact that NEDS is not an independent program of exposure data collection, but rather has as its primary purpose the production of denominator data for the calculation of accident rates using NASS data in the numerator, has a very important influence on the choice of types of NEDS primary sampling areas. If NEDS were an independent program and if telephone or mail data collection methods were deemed adequate, serious consideration might be given to not having any sampling areas but to using a national random sample of drivers or vehicles from state registration files or from telephone random digit dialing methods.

Even if in-person or roadside data collection methods were considered essential, thus making some kind of geographically clustered sample an economic necessity, it would be statistically desirable to conduct an independent NEDS in as large a number of primary sampling

units (PSUs) as possible in order to reduce as much as possible the clustering effect on the size of the variances of the various data elements. Thus a sample design utilizing the hundreds of PSUs of the Census Population Survey, or even the scores of PSUs in the sample design of the University of Michigan Institute for Social Research, would clearly be preferable to the 36-60 PSUs expected to be established in the NASS program if NEDS were independent of NASS.

However, since the primary goal of NEDS is to produce exposure data which together with the NASS accident data will produce as precise estimates as possible of national accident rates (accident/exposure ratios), it seems desirable statistically that the NEDS data be collected in the same PSUs as the NASS data, so that the expected positive covariance between accidents and exposure may be taken into account. In calculating the variance of a ratio, or the variance of any statistic, it is the sampling design which provides a way to calculate expected values, variances, and covariances between statistics. Under various sampling designs some statistics are known to be unbiased, or approximately unbiased, estimates of the population mean, the population variances, and the covariances. As can be seen in the formula below, in the case of the ratio of two estimates of population totals the estimate of the variance of that ratio is a function of the sample estimate of the ratio, of the sample variances of the two sample totals, and of the covariance between them. This basic variance formula involves the calculation of three terms separately for each stratum -- the variance of x, the variance of y, and the covariance -- and summing these to obtain the overall variance as follows:

$$\text{Var}\left(\frac{y}{x}\right) = \frac{1}{x^2}\left[\text{Var}(y) + r^2\,\text{Var}(x) - 2r\,\text{Covar}(x,y)\right]$$

where:

r = the overall ratio
y = the numerator of the ratio
x = the denominator of the ratio

If the sample designs for the x and the y variable are chosen completely independently, the covariance is, by design, zero. Even though the two variables of interest may be positively correlated, as one would expect accidents and driving to be, there can be no covariance term to subtract from the sum of the two variance terms when the sample designs are independent. Thus the statistical issue becomes a question of the relative trade-off between the potential decrease in the x variance term from utilizing a NEDS sample design with a large number of strata and PSUs and the potential value of the subtractible covariance term available from collecting the accident and exposure data in the same NASS PSUs. Unfortunately, there is no availale data for estimating the actual effects of either of these choices on the variance of an accident/exposure ratio. Thus one must choose on the basis of one's best judgement. Since it seems reasonable to expect a fairly high covariance between accidents and exposure, it appears that utilizing the NASS PSUs for the exposure data collection is more likely to lead to a minimization of the variance than is utilizing even a very large number of PSUs in an independent NEDS sample, although there is no way to accurately estimate just how large the number of PSUs would have to be in an independent sample to make up for not having a covariance term to subtract. It would also be possible to augment the NASS sample with an additional selection of NEDS PSUs, thus reducing the variance of the exposure data alone, but this would not seem worthwhile because the covariance term could only be calculated for the PSUs in which both accident and exposure data were collected.

It should be noted that a sample design using the same PSUs does not require that accident and exposure data on the same observational units be collected in order to minimize the variance. While accident data could be collected from people and vehicles at accident locations, exposure data could be collected from people and vehicles at other roadside locations, or at residential addresses, etc., as long as they were in the same PSUs.

Another potential value of collecting the exposure data in the NASS PSUs is the possibility of collecting the needed data on reported and non-reported accidents as part of the NEDS survey. These data need to

be collected in the NASS PSUs for most effective use, and it seems that perhaps they could be collected most cost-effectively in conjunction with the NEDS survey.

It is possible that collecting both accident and exposure data in the same PSUs would cause operational problems by overburdening the public officials or citizens of a PSU. Certainly if roadside surveys were to be carried out the cooperation and assistance of the local police would be essential. Whether they would be more or less willing to provide such assistance in PSUs which already have NASS data collection teams is difficult to judge. It probably depends on how good a relationship has been established by the NASS team. However, for household surveys no assistance would be required from local officials, and with a minimum population size of 50,000 in each PSU it seems likely that only a few persons each year would be contacted for both the NASS and the NEDS data collections. It appears that concern for overburdening a PSU should not be a major factor in the decision as to whether or not to use the NASS PSUs for the NEDS program.

3.3 Sampling Elements and Sources

For a roadside survey the sampling element and the general means of sampling it is obvious. It is a driver-vehicle combination sampled while a trip is in process on a road segment selected on a controlled probability basis (i.e., with a known, not necessarily equal, probability based on a common measure of size) from among all the road segments in a sampling area. Thus local road maps and traffic volume data provide the basic sampling source. However, it would be a substantial task to determine the best procedures for developing a sample of road segments. This would probably involve choosing an appropriate standard segment length (or choosing various standard lengths for various road classes), listing all of the eligible road segments within various traffic volume or general use strata, and randomly selecting appropriate numbers of road segments from each stratum. In large PSUs a subsampling of PSUs into secondary selection areas might be carried out using population or road mileage data prior to the listing of eligible road segments, or procedures involving

choosing random squares on a grid might be used for this subsampling.

Even after road segments were chosen and assigned to a particular time period on a particular date, there would remain the issues of how to choose the particular survey site and how to sample particular vehicles from the passing stream of traffic. It should be mentioned that roadside segments should be as short as feasible (perhaps a half mile or less) because in the calculation of vehicle miles traveled (VMT) the assumption would be made that all vehicles passing the particular roadside site were traveling over the entire segment. While this would not necessarily be true, it is hoped that vehicles which traveled on part of the segment but did not pass the roadside location would be roughly balanced by vehicles which traveled past the roadside location but also did not travel the entire segment, so that fairly accurate estimates of overall VMT would be obtained based on known probabilities of selection of vehicles and of road segments. Thus the need for balancing turn-offs and turn-ons would have to be taken into account in choosing particular roadside sites, along with other considerations such as safety and visibility. Of course actual vehicle counts of turning behavior on the selected segments could also be used to improve the accuracy of the VMT estimates.

A related sampling and operational issue concerns the selection of vehicles. While a fixed sampling rate at a given site would clearly be preferable statistically, this would be very difficult to apply operationally in a roadside interview survey. But there is a serious question of potential bias in a sampling procedure based on interviewer convenience (taking the next available vehicle after one interview is finished), even when an overall sampling fraction for the survey period would be recorded.

For a survey of past trips on one or more Travel Days the basic question is whether the sampling element should be a vehicle and its trips or a driver and his/her trips. In many cases it probably would not make much difference, since often a particular vehicle will be driven by just one driver on a given Travel Day, and conversely often a given driver will operate only one vehicle on a given Travel Day. If state registration files were considered feasible as a sampling source

and some kind of trip record form was to be kept, probably the vehicle would be preferable to the driver as the sampling element because it would seem more convenient to keep a trip record form with the vehicle for all of its drivers to fill out than to expect the driver of a number of vehicles to carry such a form with him/her in each vehicle used. On the other hand, for a simple-recall survey it would undoubtedly be easier to ask one driver to recall all of his/her trips and thus a sample of drivers would be preferred.

In regard to state files as a sampling source, a survey in the 50 states concerning the availability of driver and vehicle records for sampling purposes indicates that in a number of states such sampling would be very difficult or impossible (due to technical or legal problems), and it would also often be very expensive. So the use of state records as a sampling source for a national survey does not seem to be a reasonable possibility. Having to deal continuously with many different state bureaucracies in drawing the NEDS sample would also place a substantial administrative burden on the NEDS program staff. Surveying drivers or vehicle owners at state licensing or vehicle registration offices would also not be a reasonable survey approach for a national survey because many states do not require a personal visit for driver and/or vehicle license renewal. Of course even if all states required in-person renewals such samples would suffer from the underrepresentation of the newest and the oldest drivers and vehicles.

Thus the only feasible sampling sources for a past recall survey would seem to be residential locations where drivers live or residential and non-residential locations where vehicles are owned. In the latter case one would have difficulty obtaining an adequate sample of commercial and government vehicles. Since such vehicles would tend to be concentrated in a few locations, a sampling approach which gave an equal probability of selection to each location (whether a sample of addresses or of telephone numbers) would be likely to greatly overrepresent or underrepresent commercial vehicles. If all vehicles at a selected commercial location were included in the sample, this would place a great burden on the few selected owners of many vehicles, the data from which would likely be quite homogeneous and not representative

of the general diversity of commercial vehicle use. On the other hand, if only one or a few vehicles were sampled at selected commercial locations, commercial vehicles would then be substantially underrepresented in the total sample -- unless some way of giving additional chances of selection to commercial locations was applied.

Since the vast majority of residential locations have only one or two drivers in the household and very few contain more than four drivers, sampling drivers at their places of residence would seem to be the preferable approach for a past-trip survey. Once contact was made with a household it seems likely that it would be cost-effective to obtain trip information from all the drivers in the household, as has been the procedure with the two Nationwide Personal Transportation Surveys carried out by the Census Bureau. Such a procedure would substantially increase the total size of the driver sample without a commensurate increase in costs, and it would also avoid the necessity of a sometimes awkward and complex selection procedure at the household level and the subsequent use of household weights in the analysis stage. It would also provide some interesting within-household data on driving behavior of different household members in relation to number and kinds of household vehicles. On the other hand, if different drivers in a household tend to make similar types of trips (i.e., to be homogeneous in their trip-making), then statistically the data from the additional drivers may not do much to reduce the variance of survey estimates and may not be worth the added cost and the additional burden to respondents.

It is clear that if all drivers in a selected household are included in the sample each should be interviewed individually if at all possible rather than obtaining trip reports by proxy from another household member. Lansing, et al., (1970) in a household survey in which one random respondent reported all household trips found that wives reported an average of 3.75 trips for their husbands, while husbands reported an average of 4.61 trips for themselves.

3.4 Data Collection Procedures

As discussed in the literature review, there are two basic data collection approaches under consideration, the trip-in-process roadside survey and the past-trip recall household survey. The latter has at least five serious problems for the NEDS program -- a potential underreporting of trips, likely inaccurate estimates of trip distances, the difficulty of obtaining very much trip characteristics data in the roadway and environmental area, the problem of too great a respondent burden for professional drivers who make many trips per day (taxi drivers, postmen, local delivery drivers, etc.), and the fact that drivers who live in a NASS sampling area are not the only persons who drive and have accidents in that area. Thus the roadside survey method of sampling trips in process has a great deal of appeal. All of the roadway and environmental data elements of interest would automatically be available as part of the sampling design or by survey personnel observation, and if the sampling procedure were properly carried out there would be no problem of trip underreporting or of poor trip distance estimates or of a mismatch between persons eligible for the exposure sample and persons eligible for the accident sample. Also such a survey would reduce the burden on the local professional driver since he/she would only have one trip sampled like all the other respondents. In addition, roadside interview surveys are likely to provide higher response rates than any other personal data collection method, although there might sometimes be problems with potentially eligible motorists changing their travel routes unnaturally to avoid survey sites which they observe in operation or hear about from friends or CB radios.

On the other hand, there are also likely to be very serious operational problems with a roadside survey which is carried out on all types of roads at all times of the day and night. Stopping a sample of vehicles in order to conduct interviews could be extremely hazardous and disturbing to traffic flow on limited access and other high volume and/or high speed roads, especially during peak travel periods. At the other extreme costs per interview would tend to be very high for roadside interviewing on low-volume rural roads, especially late at night.

Because of these problems the license plate survey with mail or telephone follow-up to vehicle owners via state vehicle registration files is worth serious consideration as an alternative to roadside interviewing, at least at hazardous and/or high volume locations and at inefficient low volume locations. Advances in photographic techniques appear to make such surveys feasible at night as well as during the day. Also the increasing computerization of state motor vehicle registration files could make possible quite rapid follow-up of observed drivers in many states where one half to three quarters of an observed sample might be followed up by telephone within 24 hours, while most of the remainder could be contacted by mail within 72 hours. Hopefully such rapid follow-up, much of it by personal contact via the telephone, plus multi-wave mailings to vehicle owners without listed telephones could produce higher response rates than those in the license plate follow-up studies reported in the literature review.

In spite of the appeal of a roadside survey approach which combines interviewing at middle volume sites with license plate follow-ups at high and low volume sites, it does not seem to be a practical approach for a nationwide NEDS survey because there are a number of states in which current interpretations of privacy laws would prevent releasing the names and addresses of vehicle owners for such a survey purpose. There is also a "1984 Big Brother" element to carrying out a license plate survey which might generate vocal negative reactions from some drivers after being informed that their motor vehicle had been observed by a government-sponsored survey at a certain time on a certain road, and there is a serious question in the current climate of concern about privacy issues as to whether approval could be obtained from the Office of Management and Budget for federal sponsorship of such a survey. There would also be substantial operational problems in organizing such a survey -- in developing the sample of roadside segments, in obtaining reliable photographic equipment which could operate automatically and effectively in all kinds of weather and light conditions, in determining appropriate methods of vandal-proof and thief-proof deployment of such equipment, in choosing safe interviewer sites, in obtaining local police cooperation at interviewer sites, in hiring interviewing and other personnel willing to work at all times of day and days of the week, etc.

While these operational problems might prove too great, the idea of conducting a roadside survey by observation alone without attempting any roadside or follow-up interviewing seems worth serious further consideration. All of the basic data elements except trip purpose could be obtained at least in rudimentary form, and even driving on the job could generally be inferred from the vehicle in use although other trip purposes would be impossible to guess accurately. Obviously some errors in sex and age category of the driver, in the numbers of occupants, and in the vehicle make, model, and year would be inevitable, and perhaps it would only be practical to use a gross vehicle type categorization in such a survey. The chief value of a roadside observation study is that it could be used to obtain detailed environmental and roadway data which would not be available in a past-trip survey and at the same time could provide rough data on the basic driver and vehicle characteristics of interest. These data would probably be more reliable if the selected passing vehicles were captured on film for later classification on the variables of interest rather than depending solely on human observation at the time. Perhaps it would also still be worthwhile to obtain license plate numbers in order to permit obtaining precise vehicle type information from registration files in cooperative states.

However, if more accurate and/or more detailed data on driver and vehicle characteristics are desired, it seems necessary to utilize a past-trip survey procedure of obtaining information directly from drivers selected at their places of residence. While the literature review indicated that the majority of such surveys have been simple-recall surveys concerning some recent Travel Day(s), primarily by in-person interview but a few by telephone interview, a number of aided recall approaches have been tried out which involve use of a trip form given to a respondent prior to the designated Travel Day(s). These methods include a single mail questionnaire, a multi-wave mail questionnaire with telephone and in-person follow-ups, a mailing followed by an in-person trip-report interview, a mailing followed by a telephone trip-report interview, an in-person placement interview followed by an in-person trip-report interview, and a telephone placement interview with a mailing followed by a telephone trip-report interview. In addition, an in-person interview followed by a telephone

trip-report interview seems worth considering.

At issue in choosing among these various household survey methods is relative cost, relative expected response rate, and relative completeness and accuracy of the trip reports. In regard to cost the single mail survey is the cheapest approach, and telephone interviewing is generally cheaper than in-person interviewing. It seems likely that comparable satisfactory response rates can be obtained by both telephone and in-person interviewing if sufficient numbers of callbacks are used, but it is doubtful that even a multi-wave mail survey could obtain a satisfactory response rate without expensive telephone and in-person follow-ups. Of course such follow-up procedures for a mail survey also cause difficulty with the sample design because for accurate trip recall it is necessary to substitute a new Travel Day for the original Travel Day.

The various types of two-contact procedures using trip record forms are also expected to cost more than a simple-recall interview, but such an approach is essential if accurate trip distance data is to be obtained by means of actual odometer readings, and one expects that more complete reporting of all trips on the Travel Day would also be encouraged by contacting respondents prior to the Travel Day and giving them a record form. The few comparative studies available indicate that there is probably not much difference between telephone and in-person interviewing in stimulating trip recall but that mail questionnaires may elicit more complete trip recall than do simple-recall in-person interviews. The one comparative validation study available (Murray 1957) found slightly higher trip reporting by mail than by simple-recall in-person interview but substantial underreporting by both methods.

Drawing a sample by random digit telephone dialing is likely to be substantially cheaper than traditional residential listing methods, and it also has the statistical advantage of permitting random sampling throughout a PSU rather than clustering by blocks. It has the disadvantage of not permitting representation of that small proportion of households which do not have a telephone available, but it is thought that at least a large proportion of such households also do not have any active licensed drivers. Even when an in-person placement interview is

used it is likely that a telephone trip-report interview would be cheaper than an in-person trip-report interview, although it may be that in-person reviewing of the trip record form would lead to more complete and accurate data and would be worth the additional cost. Clearly an in-person trip-report interview would be required for any procedure involving the actual mapping of trips in order to obtain more detailed data on road type and more accurate data on trip distance. The high cost of a procedure involving two in-person interviews might also be considered cost-effective if it enabled collection of trip data for a number of Travel Days as in the Canadian seven-day diary survey.

In any past-trip survey it seems impractical to expect local professional drivers to complete a separate trip record for every movement of their vehicles from one address to another. Therefore a procedure asking such drivers to summarize all of their trips of a similar type seems appropriate, as was used in the 1977-78 NPTS and in the 1978-79 Canadian National Driving Survey. Alternatively, it might be possible to work out a method in which local professional drivers reported in detail on just a sample of their day's trips.

3.5 Timing

Since amount and patterns of driving vary considerably over the different seasons of the year in different parts of the United States, it is clearly desirable that an exposure survey be carried out over a full 12-month period. This is particularly true since the NASS accident data will be collected continuously over twelve months, but it is also desirable in the analysis of the exposure data alone that it be representative of all the seasons of the year. The 1978-79 Canadian National Driving Survey used stratification in regard to monthly gasoline sales as a means of reducing the number of drivers sampled in the winter months, but that appears to be a statistical mistake. It isn't that the number of potential drivers declines in the winter months, it is just that the average amount of driving per driver declines during the winter. Thus the sampling scheme should call for roughly equal numbers of driver respondents each month, and the sum totals of driving by each month's respondents should then reflect the

national fluctuations in driving mileage by month.

In a household survey it would be important to also provide equal representation to each day of the week, and it would be preferable statistically to spread the Travel Days for a month's respondents evenly among all the days of the month, rather than just among the first 15 days of the month as in the 1977-78 Nationwide Personal Transportation Survey, although such a spreading of Travel Days does probably increase administrative and operational costs. To most closely conform with trip-making behavior a Travel Day should probably be defined as 4:00 a.m. on the designated date to 4:00 a.m. the next day.

In a roadside survey it would not only be important to spread the survey periods among all the days of the year so as to adequately represent each season, month, and day of the week, but also to sample all hours of the day and night. If all road segments were given an equal probability of selection and one fixed sampling rate were applied on all selected road segments, then each hour of the day should be sampled equally. However, that would be quite inefficient, and it is probable that stratification of road segments and of survey time periods in relation to traffic volume would be used in conjunction with differential vehicle sampling rates to increase the operational efficiency of the sample.

It is also clearly desirable for the analysis of accident rates that exposure data be collected in an on-going NEDS program which continues from year to year just as the NASS program will. While it is technically possible to construct accident rates with accident data from one year and exposure data from an earlier year, the results of such a procedure might not be considered credible by some users of the data, especially if there were other indications of substantial changes in American driving behavior since the exposure data were collected. Thus one certainly would not have felt comfortable deriving 1974 accident rates from 1974 accident data and 1973 exposure data.

Of course for general transportation and energy planning purposes it is also clearly desirable that NEDS monitor American driving behavior on a continuing basis rather than periodically. If such a continuing program had been in operation in 1973 and 1974, it would have provided

useful information to many government officials, and in a world in which more sudden changes such as the "energy crisis" of 1974 are quite likely it seems highly desirable to have such a travel monitoring program in continuous operation.

3.6 Survey Administration

There appear to be four choices worth considering for the administrative organization of the NEDS program. NHTSA could: (1) contract with the main federal survey agency, the Census Bureau Demographic Surveys Division, to conduct the NEDS survey, (2) contract with some other national survey organization to conduct the survey; (3) contract with separate local survey organizations in each PSU as in the NASS data collections; or (4) contract with the existing NASS contractors to add the exposure survey activity to their accident data collection activities. In the last two approaches it would probably also be necessary to contract the general organization and supervision of the NEDS survey to one or more organizations skilled in survey research.

At issue is which approach is likely to lead to the highest quality data at the least cost and trouble to NHTSA. The single-contractor approaches have the advantage of reduced administrative problems for NHTSA staff as compared with multiple local contracts. However, the NASS PSUs are not likely to coincide completely with any national survey organization's own system of PSUs, so providing interviewing staff in all the NASS PSUs would probably be difficult for a single contractor. Fortunately, the Census Bureau with its hundreds of PSUs (currently over 400 with plans for over 600 in the near future) is expected to already have interviewers employed in most of the NASS PSUs and located in counties fairly close to the remaining NASS PSUs, and the Director of the Demographic Surveys Division has indicated willingness "to administer surveys in any statistically reliable set of geographic areas in the United States". Whether other national survey organizations would be willing to provide interviewer services in all of the NASS PSUs is not known.

The Census Bureau also has an advantage in terms of expected

response rates. No other survey organization, whether national or local, is likely to be able to obtain as high rates of cooperation from the American public as the Census Bureau routinely obtains from its "official" surveys. Also in other data quality aspects the Census Bureau has a high reputation as a result of its extensive experience, supervision system, methodological research, statistical expertise, etc. On the other hand, Census Bureau surveys tend to be quite expensive, and it is quite possible that other national survey organizations would offer to conduct the NEDS survey at a substantially lower cost than that charged by the Census Bureau. How much response rates and other data quality aspects would suffer in the hands of some other national organization is difficult to assess and obviously depends on the particular organization and its survey procedures. However, it is clearly important in a NEDS household travel survey that multi-callback procedures be used to reach not-at-home respondents, because the very people who are not at home a lot are the ones who are likely to travel the most.

Turning to the local approaches, contracting separately with local survey organizations in each NASS PSU seems likely to be a lot of administrative trouble and to be inefficient cost-wise. Since even a maximum NEDS program is likely to involve less than one person-year of interviewing effort per PSU, contracting for each survey separately in each PSU seems likely to result in disproportionately high administrative and overhead charges. Also some more rural PSUs would lack any local survey organizations, and whether such an independent organization could be set up just for NEDS at other than an exorbitant cost seems doubtful.

However, integrating NASS and NEDS data collection efforts by adding survey personnel to the existing NASS teams seems worthy of serious consideration. Although supervision of the local NEDS survey would enlarge the responsibilities of the team administrator, it seems that this could be quite a cost-effective approach because it would lead to only small increases in administrative and overhead costs. The NASS teams already do a lot of household interviewing as part of their accident investigation work, so it would not involve a great change in

the team activities. In fact it might be a feasible and efficient use of personnel to have all team members prepared to work on both the accident investigations and the exposure survey as needed, and such variety in work assignments might actually enhance team morale.

On the other hand, such integration of the NASS and NEDS data collection activities might not work out well in practice. Perhaps there would be a tendency to slight one or the other program resulting in poorer data quality for both. Perhaps some persons who are effective team administrators for NASS would not be able to satisfactorily take on the additional NEDS responsibilities. Certainly close planning and supervision of the local NEDS activities by survey research specialists at NHTSA or in a contracting survey organization would be required. NEDS data quality would probably vary more from PSU to PSU in such a local decentralized approach than in a national single-contractor approach. Also, if an in-person household sample were required, the local teams would have to be taught prescribed procedures for developing sample frames and selection techniques, while existing survey organizations should already have such sampling skills.

Thus for a household survey it is difficult to objectively determine which approach would be the most cost-effective in terms of cost and data quality. For a roadside survey the local integrated approach seems probably best. It seems unlikely that the Census Bureau would want to get involved in this kind of survey, and it is doubtful that other national survey organizations would be interested either. Since the roadside survey periods would be scattered sporadically throughout the year in each PSU, the local NASS team could provide a pool of personnel for sharing the roadside survey task with its odd hours of work. The local team would also have established relationships with the local police, road and traffic authorities, etc., which would greatly facilitate the conduct of the roadside surveys. Of course there would still need to be considerable outside assistance and monitoring in the development of the local sample design and of the operating procedures for the roadside surveys.

3.7 Sample Size and NEDS Costs

The NEDS design contract calls for the development of NEDS plans at three total annual cost levels: $1,500,000; $1,000,000; and $500,000. It is difficult to estimate how many households or drivers could be sampled at each cost level by the different survey approaches. The Census Bureau's 1977-78 NPTS using an in-person simple-recall approach with in-person or telephone follow-ups to absent household members cost over $1,500,000 for a completed sample of about 20,000 households containing about 36,000 drivers. In 1979 dollars the Census Bureau might be able to repeat such a survey in 17,000; 10,000; and 4,000 households respectively at the three cost levels. There are approximately 1.8 drivers per household, so the rough estimates of the numbers of households and drivers which might be sampled, depending on the particular NEDS design and its cost are as follows:

Cost	Households	Drivers
$1,500,000	10,000-20,000	10,000-36,000
$1,000,000	6,000-12,000	6,000-21,600
$500,000	2,500-5,000	2,500-9,000

Examples of the relative precision of sample estimates of a mean value for three different standard deviations, six different total sample sizes, and five different design effects are given in Table 3.1 below. The design effect (Deff) is an indicator of how much a national clustered sample design varies from a national simple random sample of all drivers. The more geographic variation there is in the distribution of a data element and the smaller the number of PSUs the greater the sample design effect on the variance of that element. Stratifying the PSU selection on relevant variables can somewhat counterbalance the effect of clustering sample cases within a relatively small number of geographic areas, but most national samples of PSUs have a design effect greater than 1.0 for most survey variables. The only reference to sample design effects found among all the studies reviewed in Section 2 showed ranges in Deff from 2.45 to 3.69 for six trip purposes, from 1.27

to 3.30 for six destination land uses, and from 2.78 to 3.93 for five travel modes in a 1962 household survey in Buffalo (Creighton, Hamburg, 1971), but no information on the number of clusters and the average cluster size is provided.

Table 3.1
Two-Sigma Confidence Limits+ for a Mean
(Such as Daily Trips per Driver) for Different
Standard Deviations, Sample Sizes, and Design Effects

Total Sample Size	Standard Deviation	Sample Design Effect 1.0	1.5	2.0	3.0	4.0
4,000	2.0	.200	.245	.283	.346	.400
	3.0	.300	.367	.424	.520	.600
	4.0	.400	.490	.566	.693	.800
9,000	2.0	.133	.163	.188	.230	.2567
	3.0	.200	.245	.283	.346	.400
	4.0	.267	.327	.378	.462	.534
16,000	2.0	.100	.122	.141	.173	.200
	3.0	.150	.184	.212	.260	.300
	4.0	.200	.245	.283	.346	.400
25,000	2.0	.080	.098	.113	.139	.160
	3.0	.120	.147	.170	.208	.240
	4.0	.160	.196	.226	.277	.320
36,000	2.0	.067	.082	.095	.116	.134
	3.0	.100	.122	.141	.173	.200
	4.0	.133	.163	.188	.230	.267
49,000	2.0	.057	.070	.081	.099	.114
	3.0	.086	.105	.122	.149	.171
	4.0	.114	.140	.161	.197	.228

+Two-sigma confidence limits (or sampling errors) indicate that there is a 95% probability that the true population mean is within the range defined by the sample mean plus and minus the confidence limit.

How great the design effect of gathering NEDS data in the NASS PSUs will be for particular NEDS data elements is impossible to predict in advance. It seems probable that there is substantial geographic variation in such a variable as the average number of daily trips driven

by licensed drivers, so expected confidence limits at least in the Deff=2.0 column of Table 3.1 do not seem unreasonable. For example, if a survey of 9,000 drivers obtained a mean of 4.0 and a standard deviation of 2.0, using the Deff=2.0 column one obtains a confidence limit of $\pm$.188. This would be interpreted to mean that there is a 95% probability that the true population mean is between 3.812 and 4.188. If the standard deviation was 4.0 instead of 2.0, the confidence range would be twice as great, 3.622-4.378. If the sample size were quadrupled to 36,000 drivers and the standard deviation were still 2.0, the confidence range would be halved to 3.905-4.905. Thus for mean values the greater the dispersion of individual means within the sample the larger the confidence limits on the overall sample mean.

Table 3.1 illustrates the fact that the statistical precision of a mean is directly related to the square root of the sample size and inversely related to the square root of the design effect. Thus, if in the process of increasing the sample size from 9,000 to 36,000 one also increased the design effect from 1.0 to 4.0, the net effect on the statistical precision of a given mean with a given standard deviation would be zero, and it would clearly not be worth the additional data collection and analysis costs. Of course this illustration is somewhat far-fetched, and in general one would expect to be able to obtain greater statistical precision by sampling more drivers.

It is even more difficult to estimate the numbers of trips which could be sampled at various total costs by roadside survey methods because of uncertainties about equipment and other operational costs of such a survey. If the number of daily driving trips per household averages about five, then it would require five times as many roadside respondents as households to obtain data on comparable numbers of trips (assuming a single Travel Day for the household survey). But whether collecting these trip data would cost more or less by roadside survey than by household interview is very difficult to judge at this stage of planning.

4. FEATURES OF THE RECOMMENDED NEDS DESIGN

Based on the considerations discussed in Section 3, HSRI staff have arrived at a number of recommended features of a design for a National Exposure Data System. However, for some aspects of the design there is insufficient information currently available, and a program of essential methodological research is required in order to complete the design recommendations. This program is discussed in detail in Section 5.

4.1 Primary Sampling Areas

Here the choice seems fairly clear. Statistical considerations tend to support the value of implementing NEDS in the same PSUs selected for the National Accident Sampling System. Since the chief purpose of NASS is to develop accident rates with a known variance, it is desirable statistically for the accident and exposure data to be based on the same sample design, so that the covariance terms can be included in the variance calculations. Since positive correlations are expected between exposure and accident variables, it is desirable that a sample design be utilized for NEDS which permits the use of the covariance terms in the calculation of variances and sampling errors, even though other sample designs with larger numbers of PSUs could probably produce more precise exposure data alone. Also the need for conducting periodic household surveys concerning reported and non-reported accidents in the NASS PSUs and the potential cost efficiencies of integrating these surveys with a NEDS household exposure survey provide an additional advantage to using the NASS PSUs for NEDS.

4.2 Sampling Elements and Sources

As discussed in Section 3.4, in many ways a roadside trip-in-process survey of driver-vehicle combinations seems like an ideal mechanism for collecting a maximum number of data elements of interest, especially in the environmental area. Unfortunately, however, it just does not seem practical from safety and privacy considerations to conduct such a survey on all types of roads at all times of day and night, as would be required for a truly representative NEDS program. In spite of some successful roadside interview surveys on some freeways, it does not seem reasonable from a safety and traffic engineering point of view to recommend a roadside interview survey. And the non-accessibility of vehicle registration files in a number of states due to privacy laws precludes recommending a license plate matching survey with telephone/mail follow-ups.

Consequently, it is recommended that a household past-trip survey of licensed drivers contacted at their residences should be the basic mechanism for the NEDS program. Sampling drivers at their residences seems more efficient than sampling vehicles at their owner's locations because drivers are found in quite small clusters in households, while many commercial and governmental vehicles are heavily clustered at a small number of locations, and different samples of locations chosen on an equal-probability basis might come up with quite different sample sizes.

As a source for the licensed drivers sample either listings of residential addresses or of residential telephone numbers may be used, depending on the future decision as to the most cost-effective data collection method. As indicated in Section 3.3, sampling from state driver license files does not seem feasible in all states and thus this sampling source is rejected.

Whether to interview all drivers in a selected household or to randomly select a single driver per household is a decision that requires further information from the 1977-1978 Nationwide Personal Transportation Survey data on the sample design effects of clustering by household. This necessary additional research is discussed in Section 5.3.

4.3 Data Collection Procedures

As indicated above, a household survey of drivers is the recommended survey mechanism. However, there is insufficient information available from past studies to determine the single most cost-effective method to collect the requisite travel data in a household survey. Consequently, a program of further research necessary for this decision is outlined in Section 5.

4.4 Data Elements

As previously discussed, there are a multitude of data elements of potential interest for inclusion in the NEDS survey, but it is obviously not practical to include them all in a household survey. Thus the recommended data elements are as follows:

1. Age, sex, and relationship to household head for each household member.
2. Driver education, years of driving experience, physical handicaps and license restrictions, estimated annual mileage, and accident experience in the previous three months for each responding driver.
3. Make, model, year, body type, month of purchase if purchased new, occupant protection devices, and current odometer reading for each household motor vehicle.
4. For each trip driven on a predesignated Travel Day the origin, destination, and purpose; distance (beginning and ending odometer readings if possible); beginning and ending time; light condition; road moisture condition; vehicle make, model, year, body type, and occupant protection devices; distance by major road type (rural freeway, rural road, urban freeway, urban street); driver seat belt use; age, sex, relationship to driver, and seating location of other occupants.

The above recommended data elements include the basic data elements suggested by the Symposium on Driving Exposure (Carroll, 1973), and all but five of them are included in the present NASS data elements. These five are: relationship of household members and drivers to household head, which seems essential for understanding household vehicle use patterns; physical handicaps, which seems to be an important variable about which exposure information is currently lacking; accident experience in the previous three months, which is data needed by NASS from a sample of households in the NASS PSUs in order to adjust its

accident data for non-reported accidents; month of purchase of new vehicles, which in conjunction with the current odometer reading can provide useful information on average monthly mileage for one-owner vehicles; and passenger relationship to driver, which should be useful for better understanding of vehicle occupancy patterns. It should also be noted that two NASS driver data elements, months of driving experience and annual mileage, refer to the class of the vehicle in the accident, while in a NEDS survey driving experience and annual mileage would probably not be classified by vehicle type.

Obviously one can find good rationales for including other data elements, such as driver socio-economic and size characteristics, vehicle towed unit and cargo variables, etc., and the above recommendations should not be considered frozen. It is hoped that they strike a reasonable balance between the need to obtain as much useful data as possible and the need for a viable questionnaire which does not overburden the respondent or the interviewer. Indeed it may already be asking a bit much to obtain driver seat belt use and passenger age and sex for each reported trip, although ideally one would like to extend those variables to obtaining seat belt use for each passenger also.

4.5 Timing

It is recommended that the NEDS household survey program be made a continuing year-round and year-to-year activity to represent equally all seven days of the week and all twelve months of the year. This is desirable for the accuracy of the accident rates (accident/exposure ratios), since the main NASS data will be collected continuously in the Continuous Sampling System (CSS). It is also desirable from the point of view of trend analysis of American driving behavior. With an on-going NEDS survey already in place it would be possible to measure the impact of such external events as the 1974 oil embargo with much greater precision than was possible at that time.

If, because of financial constraints, one had to choose between, for example, year-long surveys every two years and six-month surveys every year, the year-long survey appears the preferable choice so that seasonal variations in travel behavior would be taken into account.

However, a third alternative, halving the sample size of the year-long survey so that it could be carried out both years, would seem even more desirable if it could be done for the same cost. In fact, in a continuing survey there is nothing sacrosanct about single years, and one could aggregate exposure data over several years for more precise and detailed analysis of certain variables.

4.6 Survey Administration

It is recommended that, if feasible and not too expensive, the NEDS survey program be made an integral part of the Census Bureau's on-going program of sample surveys, such as the Current Population Survey, the Annual Housing Survey, the Health Interview Survey, etc. While the use of other national survey organizations or of existing local NASS contractors are alternatives which still might be worth exploring further, it appears that the Census Bureau has an advantage in terms of expected quality of data and least trouble to NHTSA. No other survey organization is able to obtain as high cooperation rates from the American people as the Census Bureau, and as a continuous federal government survey it seems logical to locate the NEDS survey in the federal agency which has conducted two Nationwide Personal Transportation Surveys, which has the greatest experience in household sampling and in training and supervising interviewers in national household interview surveys, and which has a nationwide survey staff available for interviewing in the NASS PSUs.

4.7 Sample Size and Costs

Recommendations concerning the total sample size collectible at various cost levels must also wait until the completion of the proposed essential further research on the most cost-effective data collection method and on household clustering of drivers.

5. ESSENTIAL FURTHER RESEARCH

Before completing the recommended designs of an on-going NEDS program at three cost levels it is essential that further methodological research be carried out concerning the most cost-effective approach to obtaining high quality trip reports from selected household drivers. Among the criteria for evaluating different data collection methods are: (1) completeness of reporting all trips, (2) accuracy of reporting trip distance (the key dependent variable), (3) the completeness of reporting other trip variables, (4) the degree of satisfactory participation by selected respondents (the response rate), and (5) the unit cost per respondent or household or trip. Among the data collection procedures which need to be evaluated are: (1) prior information as to the designated trip reporting period, (2) use of trip record forms, (3) telephone versus in-person interviewing, (4) length of trip reporting period, (5) use of maps to indicate trip routes, and (6) the use of compensation for participation.

Ideally any methodological research comparing different data collection methods would include a means of validating the completeness of trip reporting by each method. However, only a few methods seem amenable to any kind of trip reporting validation procedure, short of an impossibly expensive program of unobtrusive respondent surveillance on the designated Travel Day. Even vehicle instrumentation, if feasible technically, would not be satisfactory for validating trip recall because undoubtedly the fact of installation of the instrument in the respondent's vehicle would itself influence the respondent's ability and effort to recall all his/her trips -- unless he/she were unaware of this

installation. Thus the following proposed program of research is a two-stage one with two major components: a Validation Study of three data collection procedures and a Comparative Study of eight data collection procedures. The latter study will use mean number of reported trips as a significant evaluation criterion, but it will not include any actual validation procedures for the reported trips. Based on the few validation studies reported in Section 2, it is assumed that trip underreporting is much more likely than trip overreporting and that therefore the procedure obtaining significantly more reported trips than other methods is the most effective.

5.1 The Validation Study

In the absence of any routine records of trips driven, there appears to be only one reasonable way of validating the accuracy of trip recall in an interview. This involves (1) observing the license plate of a vehicle in use at a certain time on a certain day; (2) tracing the owner's name and address from state registration files; (3) contacting his/her household soon after the observed vehicle use (hopefully the next day) in order to obtain trip reports for all household drivers for the day of observed use; and (4) determining if the observed trip was actually recalled in the interview.

There seem to be two choices as to the types of locations where the observed vehicles would be selected, either on the streets in transit or at trip endpoints parked or stopped to pick up or discharge passengers. The latter approach to vehicle selection seems preferable because it permits selection of vehicles in relation to a presumed trip purpose, and thus one could test whether there are differences in trip recall for different types of trips. Among the suggested selection locations are shopping centers, employer parking lots, restaurant parking lots, bar parking lots, school and recreation center parking lots and pick-up points, church parking lots, and movie theater parking lots.

One would expect that among the factors affecting trip recall are length, regularity, unusualness, and salience of the trip purpose. The regular trip to work is rarely likely to be forgotten, nor is the long-distance business or vacation trip, while a trip which is common but not

regularly scheduled, such as a trip to the post office or to the grocery store, may not be recalled easily. There may also be a problem with some sensitive types of trips which the respondent may choose not to report even though he/she recalls them quite readily. Trips to a race track, bar, x-rated movie, massage parlor, lover's lane, Alcoholics Anonymous meeting, etc. come to mind. It would be useful to carry out some pretesting among various groups concerning the sensitivity and salience of different types of trips before deciding exactly which types of trip purposes to include in the Validation Study sample.

It is proposed to conduct the Validation Study in one area of one state over a ten-week period. A total of 1050 observed vehicles would be selected at a rate of 15 per day. Vehicles would be selected in groups of three and randomly assigned to each of the three methods groups. After eliminating untraceable and out-of-the-area vehicles and allowing for normal nonresponse, there should be about 250 households interviewed in each of the three groups. Depending on the magnitude of the non-reporting problem, differences among the three groups of 2-9% in the rate of reporting of the observed trips would be statistically significant at a 95% level of confidence. This is demonstrated in Table 5.1 which indicates the difference in per cent of correctly reported trips which would be necessary for statistical significance, depending on the magnitude of correct reporting in one group.

The three sets of procedures to be compared in the Validation Study are:

V1. Standard in-person home interview as conducted by the Census Bureau in the 1977-1978 Nationwide Personal Transportation Survey, except that there would not be time to send a respondent letter. The telephone could be used to schedule a home visit and to contact members of the household who were not home at the time of the visit.

V2. Special in-person home interview using a detailed probing technique as developed with the help of the Interviewing Methodology Section of the University of Michigan Institute for Social Research (ISR). This would require a somewhat longer interview as respondents were helped to recall all of their activities on the day in question, including of course all travel outside the home. As in V1, there would be no respondent letter and the telephone could be used for scheduling home visits and for follow-ups of absent household drivers.

Table 5.1 Minimum Statistically Significant Group Differences in Correct Reporting of Observed Trips in Relation to Magnitude of Correct Reporting in One Group

Per Cent Correct in First Group	Minimum Statistically Significant Difference in Correct Reporting Between Groups
50%	8.94
60%	8.76
70%	8.20
75%	7.74
80%	7.16
85%	6.38
90%	5.36
92.5%	4.72
95%	3.90
97.5%	2.80
99%	1.78

V3. Special telephone interview using the same detailed probing techniques as Method V2. Only sample households which have a listed telephone number would be included, and V1 and V2 respondents would be asked if they had a listed telephone number in the name of the sampled vehicle's owner in order to permit direct comparison among the three subsamples.

An additional procedure which would be studied in the Validation Study is the use of maps. At the end of the regular interview half of the V1 and V2 samples would be asked to trace all of their reported trips on detailed maps. Any additional trips recalled during the mapping procedures would be indicated accordingly.

The following types of valuable information would be learned from the Validation Study:

1. The general magnitude of trip underreporting using the standard NPTS "simple-recall" method.
2. Whether a special probing technique can significantly decrease the amount of underreporting.
3. Whether the amount of underreporting is significantly different in telephone interviews compared with in-person interviews

using the same questioning techniques.

4. Comparative interview length and costs for the standard in-person interview and the special probing in-person interview.
5. Comparative costs, response rates, and completeness of trip information for a telephone interview and a non-clustered in-person interview.
6. The practicality and additional costs of using a mapping procedure for all trips.
7. The extent to which a mapping procedure aids respondents in recalling previously unmentioned trips.
8. The accuracy of estimates of total trip distance and distance by major road types as checked against the map tracings.
9. The potential usefulness of a mapping procedure in providing more detailed information about road type and other environmental variables of interest.

It should be noted that household respondents would also be asked if any household vehicles were borrowed by any non-household members on the Travel Day. This would avoid classifying a trip as non-reported in the rare case that it might have been made by a non-household member.

5.2 The Comparative Study

As a second stage of methodological work toward the finalization of the NEDS design, it is proposed that a comparative study of eight data collection procedures be carried out. Ideally this study would be carried out in three or four different geographic areas of varying urbanicity in order to increase the generalizability of results. This study would be carried out over a period of ten to twelve weeks, sampling four households per day in each methodological group in order to obtain a total of about 250 participating households in each group (2000 households in all). This sample size would be sufficient to detect at a 95% level of significance group differences of 7-9% in the mean number of reported trips per household, according to Thomas Walsh, Asst. Chief for Consumer Surveys in the Census Bureau's Demographic Surveys Division.

The eight methods to be compared include two "simple-recall" retrospective procedures, four one-day trip log prospective procedures, and two seven-day diary prospective procedures. Specifically they are:

C1. (Standard Simple Recall) In-person home interview preceded by

a general respondent letter as in the 1977-78 NPTS and carried out as soon after the predesignated Travel Day as possible.

C2. (RDD Simple Recall) Random digit dialing telephone interview carried out as soon after the predesignated Travel Day as possible. Obviously no prior respondent letter would be possible.

C3. (Mail-Home Trip Log) Mailing of a respondent letter with one-day trip log forms prior to the predesignated Travel Day, followed by an in-person home interview to collect the trip logs and other household data.

C4. (Home-Home Trip Log) Mailing of a general respondent letter, a home in-person interview prior to the predesignated Travel Day to obtain general household information and to leave the appropriate number of one-day trip log forms for the household drivers, and a home in-person interview as soon as possible after the Travel Day to collect and review the trip logs and to seek information about any non-recorded trips.

C5. (Home-Telephone Trip Log) Same as C4 except that the post Travel Day interview would be conducted by telephone when a telephone number had been obtained in the in-person interview, and the trip logs would be mailed back.

C6. (RDD-Telephone) Random digit dialing telephone interview enough before the predesignated Travel Day to permit mailing of the appropriate number of trip log forms when selected respondents are willing to provide their name and address, followed by a second telephone interview as soon after the Travel Day as possible. The trip log forms would also be mailed back.

C7. (Home-Home Diary without Compensation) Mailing of a general respondent letter, a home in-person interview prior to the predesignated Travel Week to obtain general household information and to leave a seven-day trip diary, and an in-person interview to collect and review the trip diaries. As in the 1978-79 Canadian National Driving Survey, there would also be two or three reminder phone calls during the Travel Week.

C8. (Home-Home Diary with Compensation) Same as C7 except participating households would receive $20 for successfully keeping the trip diaries.

Some of the specifics of these eight methods would not be finalized until the completion of analysis of the first stage Validation Study. For instance the C2 Random Digit Dialing method might be dropped from the Comparative Study if the Validation Study demonstrated that telephone trip recall was significantly inferior to in-person trip recall. On the other hand, telephone sampling and interviewing costs are expected to be considerably cheaper than in-person sampling and

interviewing costs, and the two procedures are worth comparing directly if there is no evidence of serious differences in trip recall by the two interviewing methods.

Also information from the first-stage Validation Study would be used to determine whether the special probing technique should be used in the question design for the Comparative Study, and to determine whether to include trip mapping as part of the one-day in-person interviews (C1, C3, C4). Mapping would not be feasible in telephone interviews, and it seems that it would be too great a respondent burden for the seven-day diary interviews, although mapping might be used for trips only on the last day of the Travel Week.

It is apparent that substantial differences in costs would be expected among these various procedures, ranging from the C2 single telephone interview to the C8 double home visit plus respondent compensation. In general, procedures using double home visits (C4, C7, C8) would be expected to cost more per household than procedures using single home visits (C1, C3, C5) which in turn would cost more than telephone only procedures (C2, C6), but ideally C7 and C8 would provide seven times as much data per household and thus they would be expected to be cheapest on the basis of cost per reported trip.

The purpose of the Comparative Study is to obtain concrete data on the relative trade-offs between costs and data quality. Specifically, it should provide the following types of information essential for finalizing the NEDS design:

1. The extent of unrepresentedness of a random digit dialing sample in terms of missing trip information (from analyzing the proportion of trips and miles reported by respondents without available telephones in the C1, C3-C5, and C7-C8 methods).
2. The extent of no-driver households with and without an available telephone.
3. Comparison of the extent to which respondents will actually complete a one-day trip log requiring odometer readings (C3-C6), in relation to the different methods of presentation and follow-up (mail-home, home-home, home-telephone, telephone-mail-telephone).
4. Comparison of the extent of completion of a seven-day trip diary in relation to providing or not providing compensation (C7 versus C8).

5. Comparison of the extent of completion of a one-day trip log presented and followed up in person with the extent of completion of a seven-day trip diary presented and followed up in person.

6. Comparison of mean number and variance of daily trips reported per household and per driver for the eight methods.

7. Comparison of complete data and partial data response rates for the eight methods.

8. Comparison of the unit costs per household, per driver, and per reported trip for the eight methods.

9. Comparison of the extent of missing data rates on various variables for the eight methods.

5.3 The Household Clustering Study

As mentioned previously, it seems probable that a design involving interviews with all drivers in selected households would be more cost effective than a design involving selecting just one driver per household. The take-all approach also has the advantage of providing additional interesting data on intra-household driving patterns. However, before finalizing this aspect of the NEDS design it would be highly desirable to analyze some past survey data in which the relative effects of the two procedures can be determined.

The logical data set for this purpose is the 1977-1978 Nationwide Personal Transportation Survey recently conducted by the Census Bureau in 20,000 American households. It should be possible to randomly choose a single driver respondent within each household and to compare these trip data from the subsample with the trip data obtained from the total sample of all household drivers. The key comparisons to be made involve the sampling errors, design effects, and rohs of variables of interest such as mean number of trips, proportions of miles driven by different sex and age groups, proportions of miles driven for different purposes, proportions of miles driven in different vehicle types, and proportions of miles driven with different vehicle occupancy patterns. To the extent that there is a large roh from clustering drivers by households, the sampling error would be reduced in the single driver subsample, but the sampling error would also be increased by the square root of the percentage decrease in the total number of drivers in the single-driver subsample compared to the total household sample. While it seems

doubtful that the clustering effect would be large enough to counterbalance the sample size effect, it is important to test this relationship empirically in a large data set like that of NPTS.

Another factor which should be taken into account in deciding about a single driver per household versus all drivers in each household is the degree of difficulty anticipated in listing all drivers and following a prescribed selection procedure. Such a process certainly increases the complexity of the interviewer's task, and it has to take place early in the initial household contact at a time when the respondent may be rather suspicious about the interview. Thus such a selection procedure may lead to a decreased response rate, and of course there is also considerable likelihood that the selected respondent will not be at home. On the other hand, the perceived burden of household participation would clearly be less if only one driver was asked to report his/her trips, and with the one-day trip log and especially with the seven-day diary procedures selecting a single driver might lead to an improved rate of satisfactory participation.

A fourth factor to be taken into account in this decision is cost. Obviously, there are increased costs to interviewing all drivers rather than just one driver per household, even if all drivers happen to be present at the time of the successful call and especially if one or more drivers are absent and have to be contacted later. Again, the NPTS experience should be useful in estimating the marginal cost of interviewing all household drivers versus a single driver per household.

5.4 Sample Size and Estimated Costs

Once the three studies outlined above are completed, it will be possible to make a decision about the most cost-effective data collection procedures in the sample households. Using the cost information obtained in these studies it will then be possible to estimate the total sample sizes which can be studied at the three suggested levels of annual NEDS cost: $1,500,000; $1,000,000; and $500,000. Once these sample sizes are determined, it will also be possible to estimate the relative levels of precision for some key exposure variables at the three total sample sizes if they were national

simple random samples. However, the actual expected increases in sampling errors from clustering the NEDS samples in the NASS PSUs would be impossible to estimate accurately in advance of the actual NEDS data collection and analysis.

5.5 Pilot Study Timing and Costs

As mentioned above, the Validation and Comparative Studies are intended to be carried out in sequence with information gained in the Validation Study applied to finalizing the design of the Comparative Study. The suggested data collection period for the Validation Study is ten weeks, although this could be shortened, and a similar data collection period is suggested for the Comparative Study. Ideally about six months would be available for planning, data collection, and analysis of each study, thus requiring twelve months for the total pilot study program. The Household Clustering Study could be carried out within a three-month period anytime after the 1977-78 NPTS data tape becomes available in early 1979.

It is difficult to estimate precisely the total costs for the proposed pilot study. If carried out with HSRI assistance to a high quality survey organization, such as the Census Bureau or the University of Michigan Institute for Social Research, it appears that the Validation Study would cost about $65,000; the Comparative Study would cost about $220,000; and the Household Clustering Study would cost about $5,000. Thus the total estimated cost for the pilot study program is $290,000.

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APPENDIX A

EXAMPLE OF A SPECIMEN INTERVIEW SCHEDULE FOR A TWO-INTERVIEW HOUSEHOLD SURVEY (INCLUDING A SELF-COMPLETED 1-DAY TRIP LOG)

GENERAL INSTRUCTIONS FOR A TWO-INTERVIEW HOUSEHOLD SURVEY

1. Prior to the designated Travel Day conduct an interview with any adult in the sample household and obtain Section I data on household composition and on current drivers and Section II data on household vehicles.

2. If this Initial Respondent is a current driver, complete Section I and Section III about his/her driving and accident experience, and give him/her the Trip Log to be completed on the Travel Day.

3. Interview any other current drivers available at the initial interview about their driving and accident experience and give them their Trip Logs.

4. For any current drivers not present leave Trip Logs with the Initial Respondent and ask him/her to explain them to the other drivers. A personal contact by telephone with these drivers might also be attempted prior to the Travel Day.

5. If the initial interview was more than one day before the Designated Travel Day, a reminder phone call should be made on the day before (if a telephone is available and a number can be obtained in the initial interview).

6. At the initial interview or later by telephone try to find out the best time for the return interview as soon as possible after the Travel Day, hopefully a time when all current drivers would be available.

7. At the return interview collect all available Trip Logs, interview each driver active on the Travel Day about the Section IVB additional trip data, and interview any current drivers not previously contacted about the missing Sections I and III driving and accident experience data.

8. For any active drivers not available at the return interview try to obtain the additional trip data by telephone, or, if necessary, by additional return visits. If this is not possible within four days of the Travel Day, try to obtain all missing data as accurately as possible from the most knowledgeable available household respondent.

9. During the return interview(s) add to Section II detailed data on any non-household vehicles driven on the Travel Day.

SECTIONS:
- I. RESIDENT HOUSEHOLD MEMBERS AND DRIVING EXPERIENCE
- II. MOTORIZED VEHICLES AVAILABLE/USED
- III. THREE-MONTH ACCIDENT RECORD
- IVA. INDIVIDUAL DRIVER TRIP LOG FOR TRAVEL DAY
- IVB. SUPPLEMENTAL INDIVIDUAL DRIVER TRIP DATA

SECTION I. RESIDENT HOUSEHOLD MEMBERS AND DRIVERS GENERAL INFORMATION

(circle Person No. of Initial Respondent)

We are carrying out a survey which has to do with the use of motor vehicles by all the drivers in this household on one Travel Day. First I need to get some general information on the drivers and other household members who live together at this address.

Person #	First Name	Sex	Year of Birth	Relation to HH Head	Physical or Mental Handicaps Affecting Mobility	Ever Drive and Still Drive	Types of Current Licenses (or Year Stopped Driving)	Any Current License Restrictions	Year Learned to Drive	How Learned to Drive	Estimated Miles Driven Last 12 Months	Estimated Miles Long Trips (7+ Days)	No. of Accidents as Driver Last 3 Months	Interview Date (and Source If Not Driver)
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														

Assign a Driver Number in this column for each current driver.

These questions should be completed in an interview with each current driver.

SECTION II. MOTORIZED VEHICLES AVAILABLE AND/OR USED

Now we need to obtain some basic information about each motorized vehicle (including motorcycles and mopeds) currently available for use by household members.

Vehicle Type	Make and Model	Model Year	Type of Front Seat Belts	Type of Rear Seat Belts	Owner	Purch-ased New or Used	Date of Purchase (or Receipt)	Approx-imate Current Odometer Reading	(If Used) Approx. Odometer When Purchased	Months Odometer Was Not Working
1										
2										
3										
4										
5										
6										
7										
8										

(Obtain information on all household vehicles during the initial interview; add information on any other vehicles used on the Travel Day during the return interview).

SECTION III. THREE-MONTH ACCIDENT RECORD

Accident	TRAFFIC UNITS INVOLVED								
	Type	Towed?	Damage$	Actual Repair	No. of Occupants	Number Injured	Worst Injury	Total $ Treatment	
No. ___	Own Veh.								Report to Police? _____
Driver No. ___	2nd								
	3rd								Report to Insurance Company? _____
Approx. Date:	4th								
_____,	5th								
19 __	6th								Vehicle License No. _____
	7th								
Accident No. ___	Own Veh.								Report to Police? _____
Driver No. ___	2nd								
	3rd								Report to Insurance Company? _____
Approx. Date:	4th								
_____,	5th								
19 __	6th								Vehicle License No. _____
	7th								
Accident No. ___	Own Veh.								Report to Police? _____
Driver No. ___	2nd								
	3rd								Report to Insurance Company? _____
Approx. Date:	4th								
_____,	5th								
19 __	6th								Vehicle License No. _____
	7th								

(Obtain as much of the above information as possible for each accident mentioned in Section I.)

SECTION IVA. INDIVIDUAL DRIVER TRIP LOG FOR TRAVEL DAY _____ Driver No. _____

Please record all driving trips completed (or in process) between 4:00 a.m. on the above date and 4:00 a.m. on the following day. As used in this survey a "trip" means any driving from one place to another place where the vehicle is parked for at least a short period or a passenger is dropped off or picked up. Thus a "shopping trip" might include a number of separate trips as defined here, and each of these trips should be recorded separately below.

Trip No.	Beginning Place	Beginning Time	Beginning Odometer	Ending Place	Ending Time	Ending Odometer	Number of Passengers	Vehicle Used
Examples								
1	Home	7:40 am	27,196	Work	7:55 am	27,201	0	1977 Ford Granada
2	Work	12:05 pm	27,201	Post Ofc.	12:10 pm	27,202	1	"
3	Post Ofc.	12:20 pm	27,202	Rest.	12:25 pm	27,203	1	"
1								
2								
3								
4								
5								
6								
7								
8								
9								

SECTION IVB. SUPPLEMENTAL INDIVIDUAL DRIVER TRIP DATA

Driver No. ___ Interview Date _____ Respondent Person No. _____

Trip No.	Trip Purpose	Seat Belt Fastened?	PASSENGERS Seat	Sex	Age	Relation	Light Condition%	Weather Condition%	Road Condition%	Road Type %
1			Right Front Center Front Right Rear Center Rear Left Rear Other: Other:	___ ___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___ ___	_____ _____ _____ _____ _____ _____ _____	Daylight___ Dusk _____ Dark _____ Dawn _____	Clear ____ Cloudy ___ Rainy ____ Snowy ____ Foggy ____	Dry ____ Wet ____ Ice/ Snow ___	City Street _____ City X way _____ Rural Xway _____ Rural Road _____
2			Right Front Center Front Right Rear Center Rear Left Rear Other: Other:	___ ___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___ ___	_____ _____ _____ _____ _____ _____ _____	Daylight___ Dusk _____ Dark _____ Dawn _____	Clear ____ Cloudy ___ Rainy ____ Snowy ____ Foggy ____	Dry ____ Wet ____ Ice/ Snow ___	City Street _____ City X way _____ Rural Xway _____ Rural Road _____
3			Right Front Center Front Right Rear Center Rear Left Rear Other: Other:	___ ___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___ ___	_____ _____ _____ _____ _____ _____ _____	Daylight___ Dusk _____ Dark _____ Dawn _____	Clear ____ Cloudy ___ Rainy ____ Snowy ____ Foggy ____	Dry ____ Wet ____ Ice/ Snow ___	City Street _____ City X way _____ Rural Xway _____ Rural Road _____
4			Right Front Center Front Right Rear Center Rear Left Rear Other: Other:	___ ___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___ ___	_____ _____ _____ _____ _____ _____ _____	Daylight___ Dusk _____ Dark _____ Dawn _____	Clear ____ Cloudy ___ Rainy ____ Snowy ____ Foggy ____	Dry ____ Wet ____ Ice/ Snow ___	City Street _____ City X way _____ Rural Xway _____ Rural Road _____
5			Right Front Center Front Right Rear Center Rear Left Rear Other: Other:	___ ___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___ ___	_____ _____ _____ _____ _____ _____ _____	Daylight___ Dusk _____ Dark _____ Dawn _____	Clear ____ Cloudy ___ Rainy ____ Snowy ____ Foggy ____	Dry ____ Wet ____ Ice/ Snow ___	City Street _____ City X way _____ Rural Xway _____ Rural Road _____

APPENDIX B

EXAMPLE OF A SPECIMEN INTERVIEW SCHEDULE FOR A ROADSIDE INTERVIEW SURVEY

ROADSIDE INTERVIEW QUESTIONNAIRE

We're conducting a short survey concerning road and vehicle usage patterns to help in transportation and highway safety planning.

+ +

1. What is the year, make, model, and bodytype of this vehicle?

   Year________ Make ____________ Model _________ Body ________

2. What kind of seat belt system does this vehicle have?
   FRONT: ____ Lap only (manual) ____ Shoulder only (manual) ____ None
   ____ Lap and shoulder combined (manual) ___ Air bag
   ____ Lap and shoulder separated (manual)
   ____ Automatic shoulder ____ Automatic lap and shoulder combined

   REAR: ____ None ____ Lap (manual) ____ Other: ______________________

3. Was this vehicle purchased new or used? ____ New ____ Used

4. What was the approximate date of purchase? ____________________________

5. What is the current odometer reading? _____________

   5a. (IF PURCHASED USED) What was the approximate odometer reading when it was purchased? _________________________

6. How many months, if any, was the odometer not working since you purchased this vehicle? __________________

7. How many motor vehicles are currently licensed in your household? ____________

+ +

8. Now I have a few questions about the trip you are on now. Where are you coming from? What kind of place,and near what streets is it located?
   ____

9. And where are you going right now? _____________________________________

10. About how far is it between these two places? __________________________

11. About how long is the driving time? ____________________________________

12. And what is the purpose of this trip? __________________________________

+ +

13. Are you the owner (or co-owner) of this vehicle?
    ___ Yes ___ No: Relation to owner ____________________________

14. When did you first learn to drive? _______________________________

* * * continue on next page * * *

15. Did you study driver education? ___ No ___ Yes, public school ___ Yes, commercial school

16. Do you have any physical handicaps which make driving difficult?
___ No. ___ Yes (explain) _____

17. What state is your driver license from? _____

18. Do you have any special license or endorsement for driving special types of vehicles? ____ No ____ Yes, _____

19. Do you have any restrictions on your current driver's license?
___ No ___ Yes (explain) _____

20. About how many miles would you estimate you have driven yourself in the past 12 months?

21. About how many of these miles were on long trips 7 or more days in duration?
_____

22. Have you been in any accidents as driver in the past 3 months which caused any property damage or personal injury at all?

____ No ____ Yes → How many? _____

22a. For improving our understanding of highway safety problems we need to learn more about accidents which are not reported in the police records? Was this accident (were these accidents) reported to the police?

____ Yes ____ No

22b. I don't want to take any more of your time now, but I would like to call you later to learn more about the accident details. Would you mind giving me a telephone number where you can be reached. _____

22c. When would be the best time to call? _____

23. Finally I have a background question on your age (and the ages of your passengers). In what year were you born? (And how old is your right front passenger? And what is her/her relationship to you?) OBSERVE SEX AND SEAT BELT USE OF ALL OCCUPANTS AND ASK AGE AND RELATION TO DRIVER AS NECESSARY.

VEHICLE OCCUPANT	SEX	AGE	RELATION TO DRIVER	SEAT BELT FASTENED
Driver				___ No ___ Yes
Right Front Passenger				___ No ___ Yes
Center Front Passenger				___ No ___ Yes
Right Rear Passenger				___ No ___ Yes
Center Rear Passenger				___ No ___ Yes
Left Rear Passenger				___ No ___ Yes
Other: _____				___ No ___ Yes
Other: _____				___ No ___ Yes

APPENDIX C

EXAMPLE OF A SPECIMEN MAIL FOLLOW-UP QUESTIONNAIRE FOR A ROADSIDE LICENSE PLATE OBSERVATION SURVEY

OBSERVED TRIP QUESTIONNAIRE

This short questionnaire has been sent to you by _____ _____ as part of a survey concerning road and vehicle usage patterns. The data from this survey will provide useful information for improving transportation and highway safety planning.

As part of our traffic study we recorded license plate numbers of various vehicles using various roads. One of these was license no. _____ which is listed in your name as the owner or co-owner of a (year, make, model) _____ in the (state) _____ vehicle registration files. The vehicle was observed on (street) _____ near (street) _____ in (community or county) _____ at approximately (time) _____ on (day, date) _____.

VEHICLE DATA SECTION

1. Is this the correct year, make, and model? ____ Yes ____ No (please correct)

2. What is the body type? ___ 2-door car ___ 4-door car ___ station wagon
___ van ___ pick-up ___ utility vehicle ___ motorhome ___ straight truck
___ truck tractor ___ bus ___ motorcycle ___ moped ___ other: _____

3. What kind of seat belt system does this vehicle have?

FRONT: ___ Lap only (manual) ___ shoulder only (manual) ___ None
___ Lap and shoulder combined (manual) ____ Air bag
___ Lap and shoulder separated (manual)
___ Automatic shoulder ___ Automatic lap and shoulder combined

REAR: ___ None ___ Lap (manual) ___ Other: _____

4. Was this vehicle purchased new or used? ___ New ___ Used

5. What was the approximate date of purchase? _____

6. About what is the current odometer reading? _____

6a. (IF PURCHASED USED) About what was the odometer reading when it was purchased? _____

7. How many months, if any, was the odometer not working since you purchased this vehicle? _____

8. How many motor vehicles are currently licensed in your household? _____

9. Were you yourself (THE OWNER) driving during the observed trip, or was someone else driving? ___ Self
___ Other: Relation to You _____

IF SOMEONE ELSE WAS DRIVING, PLEASE HAVE HIM/HER COMPLETE THE QUESTIONS ON THE REST OF THIS QUESTIONNAIRE. IF THIS DRIVER IS NOT AVAILABLE PLEASE COMPLETE THE QUESTIONNAIRE FOR HIM/HER TO THE BEST OF YOUR ABILITY.

10. Remaining questions completed by: ___ Owner who was the driver
___ Owner who was not the driver
___ Driver who is not the owner

TRIP DATA SECTION

1. Where did the observed trip begin? Type of Place _____

Near _____ (streets) In _____ (community or county)

2. Where did the observed trip end? Type of Place _____

Near _____ (streets) In _____ (community or county)

3. About how many miles long was the trip? _____

4. About how long was the driving time? _____

5. What was the purpose of the trip? _____

_____

OCCUPANT DATA SECTION (Fill in for each occupant on the trip)

VEHICLE OCCUPANT	SEX	AGE	RELATION TO DRIVER	SEAT BELT FASTENED
Driver				___ No ___ Yes
Right Front Passenger				___ No ___ Yes
Center Front Passenger				___ No ___ Yes
Right Rear Passenger				___ No ___ Yes
Center Rear Passenger				___ No ___ Yes
Left Rear Passenger				___ No ___ Yes
Other: _____				___ No ___ Yes
Other: _____				___ No ___ Yes

DRIVER DATA SECTION

1. When did you first learn to drive? _____

2. Did you study driver education? ___ No ___ Yes, public school
___ Yes, commercial school

... CONTINUE NEXT PAGE ...

3. Do you have any physical handicaps which make driving difficult?

___ No ___ Yes (EXPLAIN) _____

4. What state is your driver's license from? _____

5. Do you have any special license or endorsement for driving special types of vehicles? ___ No
___ Yes (EXPLAIN TYPES) _____

6. Do you have any restrictions on your current driver's license?

___ No ___ Yes (EXPLAIN) _____

7. About how many miles would you estimate you have driven yourself in the past 12 months? _____

8. About how many of these miles were driven on long trips 7 or more days in duration (vacation or business)? _____

9. Have you been in any accidents as driver in the past 3 months which caused any property damage or personal injury at all?

___ No ___ Yes

APPENDIX D

SOME SUGGESTIONS FOR ANALYSIS OF THE NEDS DATA

There are clearly a multitude of interesting analyses which will be possible when an on-going NEDS data collection program is established. Two general types of analyses are envisioned. One has to do with analysis of the exposure data alone, and the other has to do with combining the NEDS data with sources of accident data such as the National Accident Sampling System (NASS) and the Fatal Accident Reporting System (FARS) in order to produce accident rates.

Exposure Data Analysis

Between 1972 and 1974 the Federal Highway Administration produced eleven analytical reports from the exposure data collected in the 1969-70 Nationwide Personal Transportation Survey (NPTS). While the current NEDS plan is somewhat more limited in scope than the NPTS, since as planned now NEDS will only involve trips driving in a motor vehicle, the NEDS data should be sufficient to replicate at least seven of these reports. These are: (No. 1) Auto Occupancy, (No. 2) Annual Miles of Automobile Travel, (No. 3) Seasonal Variations of Automobile Trips and Travel, (No. 6) Characteristics of Licensed Drivers, (No. 7) Household Travel in the United States (actually passenger cars only), (No. 10) Purposes of Automobile Trips and Travel, and (No. 11) Automobile Ownership.

Obviously the key dependent variable in an exposure data analysis is vehicle miles traveled (VMT). A beginning analysis would involve aggregating the trip data for all the surveyed Travel Days and multiplying by 365 and by the appropriate sampling and nonresponse weights in order to obtain an estimate of the annual VMT for the nation and confidence limits on this estimate. Similar estimates could be obtained for every category of the various types of independent variables: driver, vehicle, and roadway/environmental, and also showing these category values as percentages of the total VMT would be of substantial analytic interest. For example, the percentages

of the total VMT driven by males, or by persons over 65, or by physically handicapped drivers, or in various vehicle type classes, or in darkness, or in rain, or on freeways, or on weekends, or with various occupancy patterns, or for various purposes, or with seat belts fastened, etc., would be of great interest in themselves.

For comparative purposes the mean mileages within the various categories would probably be of even greater interest for some variables. For example, comparing annual or daily mean driver miles would be particularly interesting for driver sex and age groups; mean vehicle miles would be of interest for vehicle type, vehicle size, and vehicle age; mean trip miles would be of interest for trip purpose, vehicle occupancy patterns, type of residence community; etc.

A second type of dependent variable of interest with many of these independent variables would be the number of trips driven annually or daily and the mean number of trips. Thus one might envision a table for each independent variable set up similarly to the following example which uses driver sex as the independent variable.

MILES AND TRIPS BY SEX OF DRIVER

Sex		N	Est. Nat. N	Annual VMT	%	Mean Ann. VMT	Mean Daily VMT	Annual Trips	%	Mean Ann. Trips	Mean Daily Trips	Mean Trip Length
Male	Value											
	C.L.											
Female	Value											
	C.L.											
Total	Value											
	C.L.											

A third dependent variable of considerable analytical interest for some purposes is motor vehicle passenger miles traveled (PMT). This could easily be derived using the occupancy data collected for each

surveyed trip. As with VMT, PMT would be of interest both in annual totals and percentages and in annual and daily means. Independent variables of particular analytic interest would include vehicle size, trip purpose, trip distance, household size, vehicles owned per household member, vehicles owned per household driver, occupant age, and occupant sex.

The above discussion has concentrated on bivariate analysis with one independent variable per table. But obviously there are a multitude of further multivariate analyses which would be interesting to carry out, limited of course by the need for an adequate sample size in each analysis cell. Among the possible multivariate analyses of VMT, trips, and PMT are driver sex by age group; vehicle age by vehicle size; occupancy pattern by vehicle age and vehicle size; sex and age group by vehicle size and age; all of these by trip purpose; all of these by time of day, by day of week, by season, and by time of day and day of week and season; all of these by light condition, by moisture condition, by road type, and by light condition and moisture condition and road type; seat belt use by sex and age, by sex and age and vehicle type and vehicle age, by trip distance, by trip distance and trip purpose, and by occupancy patterns; etc.

Of course analysis of the NEDS data does not need to be limited to miles and trips as the dependent variables. Some other possible analyses of interest include household vehicle composition in relation to household person composition and size of community, and household driver composition and experience in relation to household person composition and size of community.

A major virtue of an on-going NEDS data collection program is that one can carry out the kinds of analyses described above separately for various unique time periods and can then study trends in exposure patterns over time. The secular trends are of interest in themselves, but such trend analysis becomes particularly relevant when some disruptive event occurs, such as the "energy crisis" of early 1974. The HSRI mail exposure studies carried out in Michigan in 1973 and 1974 (Carroll, 1974, 1975) suggest that there was a decline in driving in 1974 and that this decline was largely accounted for by a decline in males driving on long trips. If an

on-going NEDS program had been in place in 1973 and 1974 a much more definitive analysis of the "energy crisis" effects would have been possible. It also would have permitted more clearly distinguishing the safety effects of changes in exposure from the safety effects of the national 55 mph speed limit introduced in 1974. If independent estimates were available regarding gasoline consumption by vehicle type and trip length, one could also use the NEDS data to estimate gasoline consumption in relation to many of the independent variables discussed previously.

Accident Rate Analysis

Much of the above discussion applies to accident rate analysis as well. The basic procedure for calculating accident rates involves merely dividing the number of accidents in some category by the number of miles driven in the same classification. For example, if the FARS reporting system finds that 10,000 female drivers are killed in a year, and NEDS estimates that females drive 500,000,000,000 miles in a year, then the fatality rate for female drivers is .00000002 or 2 per 100,000,000 miles. Or if NASS estimates that 500,000 female drivers are involved in towaway accidents in a year, the towaway accident rate for female drivers would be .000001 or 100 per 100,000,000 miles. All that is necessary is that the accident exposure data be classifiable into identical combinations of the independent variables and that there be enough sample cases in the resulting cells for each type of data to permit meaningful national estimates of accidents or VMT respectively. Of course along with the accident rates the confidence limits for those rates based on the NASS data should be calculated by means of the variance formula given on Page 38. For rates using FARS data the variance calculation would use the formula below.

$$\text{Var}\ \frac{x}{y} = \frac{x^2}{y^2} \times \frac{Sy^2}{y^2}$$

where: x = population value of x
y = sample value of y
Sy = sample variance of y

This is not the place to try to define all of the accident rates which could be calculated which might be of interest to highway safety planners. Clearly most of the exposure analyses mentioned in the previous section would be of interest. Some other accident rates of possible particular interest include: fatal and other injuries by seating position by vehicle type (using PMT as the exposure measure); fatal and towaway accidents by time of day and daylight weather condition (effect of low sun on clear days); fatal and other injuries by driver seat belt use by vehicle type and belt type and road type; fatal and towaway accidents by weather condition and road moisture condition and light condition by road type; etc.

In addition to calculating such absolute accident rates it would also be useful analytically to develop relative accident rates for various accident and exposure classifications. This would involve dividing the percentage of total accidents in a given class by the percentage of total VMT in that class. For example, if female drivers drive 25% of the national VMT, compose 20% of the drivers involved in towaway accidents, and compose 15% of the drivers killed in accidents, then the relative towaway accident rate for female drivers would be .80 and the relative fatality rate for female drivers would be .60. Since sex is a dichotomous variable, in this example the comparable male driver rates would be 1.07 and 1.13, indicating male over-involvement compared to females in both types of accidents.

It is these kinds of accident/exposure ratios or relative accident rates which would probably be of greatest value to highway safety specialists in planning and evaluating countermeasures. As an example of such use, one might consider the problem of cars running into the rears of trucks at night. For each of the four road types by day and by night one could calculate with NEDS data the percentage of total car and truck VMT which is driven by large trucks, and similarly for each of these classes one could

calculate from the NASS data the percentage of total accidents involving cars running into large trucks. Then by dividing the exposure percentages into the accident percentages one would obtain ratios for comparing the relative likelihood of such accidents by light condition and by road type. If these ratios tended to be higher at night, then proposing a countermeasure to require increased visibility for large trucks at night would seem a logical outcome. If such a countermeasure were implemented, then one would look for reductions in these rates at night compared to the daytime rates as a means of evaluating the effectiveness of the countermeasures.

Statistical Programs

Clearly a powerful and efficient package of statistical programs is essential to carry out the kinds of analyses of NEDS and NASS data discussed above. These programs must be capable of calculating frequencies, percentages, and means with weighted data and also of determining the variances and confidence limits for these estimates and ratios. One such statistical package is the OSIRIS set of programs developed by the University of Michigan Institute for Social Research. The OSIRIS system has been distributed to hundreds of installations with a wide variety of computer configurations both in the United States and overseas. Other such statistical packages are undoubtedly available also.