TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
WA-RD 478.1		

4. TITLE AND SUBTITLE	5. REPORT DATE
Origin and Destination Studies Literature Search Results	October 1999
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Catherine Bradshaw	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. WORK UNIT NO.
Washington State Transportation Center (TRAC) University of Washington, Box 354802 University District Building; 1107 NE 45th Street, Suite 535 Seattle, Washington 98105-4631	11. CONTRACT OR GRANT NO. Agreement T1803, Task 9
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Washington State Department of Transportation Transportation Building, MS 7370 Olympia, Washington 98504-7370	Final research report 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT

This report summarizes the findings of a literature search conducted in support of a Washington State Department of Transportation effort to plan an origin and destination study in the Interstate 5 corridor.

The objective was to support the study project team by providing information useful in determining the appropriate scope, budget, and design of a survey that will most efficiently and effectively meet the project's objectives.

The report documents findings relevant to surveys of passenger automobiles that make inter-city highway trips. It does not address surveys of freight traffic or the use of urban roadway networks.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Origin and destination studies, license plate surveys, travel surveys	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
None	None	34	

Final Research Report
Research Contract T1803, Task 9
I-5 O/D Literature Search

ORIGIN AND DESTINATION STUDIES LITERATURE SEARCH RESULTS

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October 1999

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ORIGIN AND DESTINATION STUDIES LITERATURE SEARCH RESULTS

INTRODUCTION

The Washington State Department of Transportation (WSDOT) intends to survey motorists in the Interstate 5 corridor to identify travel patterns, trip purposes, trip frequency, and traveler demographics. A project team is currently engaged in planning the project and identifying a broad range of stakeholders to participate in determining the scope of the study.

The objective of the literature search documented in this report is to aid this project team by providing information useful in determining the appropriate scope, budget, and design of a survey that will most efficiently and effectively meet the project's objectives. Because of the schedule requirements of the planned origin and destination survey project, the literature search was not intended to be exhaustive.

This report documents findings relevant to surveys of passenger automobiles that make inter-city highway trips. It does not directly address surveys of freight traffic or the use of urban roadway networks.

ORIGIN AND DESTINATION DATA COLLECTION METHODS

The review of literature on this subject indicates that there are two primary methods for collecting origin and destination data from passenger cars that use specific roadways, with variations in accomplishing each of these methods. In general, the terms "Vehicle Intercept Survey" or "External Station Survey" describe surveys that collect information from auto travelers entering or leaving the study area, or crossing key screen lines within a study area. (1) Table 1 provides an overview of the data collection options.

Table 1: Origin and Destination Data Collection Methods and Variations

Method	Variation (Means of Contacting Driver)	Survey Type
Self-administered, mail-back forms	• Hand out mail-back questionnaires to drivers of cars that are already stopped at rest areas, toll booths, border crossings, etc.	Roadside Handout
	• Stop cars for the purpose of handing out the mail-back questionnaire.	Roadside Handout
	• Mail questionnaire to home addresses that have been derived from license plate numbers recorded at the survey sites.	License Plate
Personal interview	• Interview drivers who are already stopped at rest areas, tollbooths, border crossings, etc.	Roadside Interview
	• Stop cars for the purpose of interviewing drivers.	Roadside Interview
	• Telephone interviews with drivers using phone numbers derived from license plate numbers recorded at the survey sites.[1]	License Plate

The U.S. DOT Travel Survey Manual (1), provides the following general characteristics of vehicle intercept surveys types:

License Plate Survey

- License plate numbers are collected from vehicles that are using the roadway. Numbers are matched with vehicle owner addresses. Vehicle owners are sent a questionnaire to complete and mail back.

[1] The literature includes only one reference to a telephone interview study done using telephone numbers generated from license plate numbers. That study, done in Indianapolis, reportedly generated "negative public reaction."(2)

- The only method that does not required stopping traffic and is therefore preferred for high-volume locations. It does not disrupt traffic and is considered safer for both observers and drivers.
- The main challenges are to convert the raw license data into a name and address list in a short period of time and get respondents to reply in a timely fashion. The longer it takes to get the survey to the vehicle owner the more likely the result will suffer from recall problems and non-response.
- The mail-back questionnaire can be more extensive than a roadside interview in terms of number of questions asked, especially socioeconomic and household related questions. However, there is no opportunity to answer questions or explain aspects of the survey.
- Because it is a mail-back survey method, it is likely to have a relatively low response rate, increasing the likelihood of bias in the results.

Roadside Handout Survey

- Some or all traffic is stopped so that mail-back questionnaires can be handed out at the roadside.
- Lower processing costs and provides the opportunity for field workers to screen potential respondents and provide information and clarification.
- The main drawback is that it is disruptive to traffic, and the survey team loses the ability to follow up with non-respondents unless they are also tracking license plate numbers.

- Generally used on medium volume roadways (8,000 to 12,000/day) because it is less expensive than a license plate survey and less disruptive than the roadside interview.
- Because it is a mail-back survey method, it is likely to have a relatively low response rate, increasing the likelihood of bias in the results.

Roadside Interview Survey

- Some (or all) passing vehicles are stopped, and short interviews are conducted with drivers.
- Far more disruptive but provides a higher response rate than other methods (up to five times higher), which means that the survey data are likely to be of substantially higher quality, with less potential for survey bias.
- Used on lower and medium volume roads. Can create traffic delays. Least safe method for interviewers and drivers.
- Data are available much sooner than for the other methods. More expensive than roadside handout surveys because of labor requirements. Interview must be extremely short. Often combined with a handout survey, especially stated preference exercises.

A scan of recent travel surveys done in June of 1996 (2) found that 24 of the 50 metropolitan planning organizations (MPOs) questioned had recently collected data using an external station survey. Of those, 16 intercepted vehicles for handouts or interviews and eight recorded license plates. Of those recording license plates, four did so manually and for "used technology."

ORIGIN AND DESTINATION SURVEY TRENDS

In 1996, Cambridge Systematics Inc. (1) identified the following trends that affect origin and destination studies:

- Increasing analytical demands on the survey data to support more robust statistical analysis. Demand is for increased efficiency and higher quality of surveys.
- Respondent cooperation rates have been declining over the past several years. This trend has been attributed to a proliferation of survey efforts which has resulted in a general feeling of antipathy, particularly when many of these surveys have been used to sell products or services or solicit contributions. In addition, the level of distrust in government activities has increased dramatically over the past 20 to 30 years, and many people may be unwilling to share information with government agencies because of concerns about personal privacy.
- There is growing use of new survey technologies such as geographic information systems (GIS) for geo-coding travel survey data and techniques such as computer assisted telephone interviewing (CATI) and computer assisted personal interviewing (CAPI) that perform on-line error checking and eliminate most coding and data entry tasks. In some interview situations the origins and destinations are geo-coded in real-time during the interviews.

According to a review of recent travel surveys, geo-coding of data and the use of a GIS as the underlying data management foundation for future travel demand systems comprise recent refinements in conducting these kinds of surveys. The report further states that GIS's are likely to become the standard approach to managing, manipulating, and displaying all forms of transportation related information. (2)

SURVEY DESIGN ISSUES

The Travel Survey Manual (1) presents these two questions as key to the design of a cost-effective data collection effort:

1. What information needs to be collected to provide the greatest degree of support to transportation planners and decision-making agencies?
2. What is the study population of interest whose travel patterns need to be understood and for which data need to be collected?

The Guidebook on Statewide Travel Forecasting (3) prepared in 1999 offers guidance on statewide travel forecasts, an emerging trend in the U.S. Of particular interest is a recommendation that a distinction needs to be made between statewide and urban travel demand models to account for the unique nature of inter-city travel. Specifically, data collection is needed over a longer period of the day to account for the fact that many long duration inter-city trips start in the early parts of the day.

The U.S. DOT Travel Survey Manual (1) presents the following two key concepts as guidance on survey design:

1. "Architects Triangle" (Richardson, Ampt and Meyburg)

   The quality and quantity of data and the cost of data collection are traded off among each other. The goal is to produce the optimal mix of these three elements.

   - Quantity is a function of the number of survey respondents and the amount of information gathered per respondent.

- Quality is related to the selected survey method, fieldwork procedures, instrument design, and representativeness of the chosen sample.

2. "Total Survey Design" (Dillman)

There are two principles of "total survey design":

- Each task is interrelated with all the other tasks and design decisions made in one task need to be consistent with the decisions made in the other tasks.
- The overall usefulness of the survey effort is limited by the weakest element of the design. It is ineffective to invest large resources in one element of the survey if the same quality levels cannot be maintained in the other survey elements.

The Travel Survey Manual (1) presents the following "quality checklist":

- Has the sample population been defined correctly (all relevant individuals included, irrelevant individual excluded)?
- Does the sampling frame adequately describe the population? Does the sample adequately represent the population?
- Does the survey questionnaire accomplish the survey team's goals (all questions relevant, unambiguous, free of wording problems, unambiguous answers)?
- Can the survey data be efficiently processed and transformed into useable information (codes unambiguously assigned to each answer and to one and only one analytically meaningful category)?

Questionnaire Design

The Travel Survey Manual (1) recommends making sure that the questions included in the survey questionnaire are consistent with any complementary survey efforts in terms of consistent response categories, level of detail, and concept definitions. Determine ahead of time how different data sources might be combined for the anticipated analyses. Also maintain consistency with current Census data specifications such as income levels, occupation codes, and ethnic status.

The manual recommends keeping the questionnaire very short by defining the essential data elements but cautions against creating a situation in which analysis of the data is harmed. Include the question only if

- it is relevant to the models being developed or refined or to other anticipated analytical efforts
- it is expected to be a valid measure of the modeling variables,
- it can be coded meaningfully
- analysts and respondents agree unambiguously on the meaning of the questions
- the response categories exhaust all meaningful answers
- these categories are meaningful and understandable
- the benefits of having the question in the survey analysis outweigh its costs in terms of survey length, respondent burden and increased potential for non-response
- the information gained from the questions is more useful than the information that would be gained from other questions that will not be on survey

- it does not provoke respondents to be hostile or to question the goals of the survey or agency.

Some interesting lessons were learned from the results of an origin and destination study done in Thurston County in 1997. (4) Analysts reported that, not surprisingly, the majority of respondents used the town name in their mailing address as their place of origin when coming from home. Respondents were also asked to provide their home zip code. As it turned out, the town names reported by the respondents did not match the results generated from geo-coding the zip code responses. For example, 39 percent of the respondents reported living in Olympia, but the zip code information indicated that only 21 percent actually lived within the city and urban growth area of Olympia. By examining information provided about which freeway exit was used, those analyzing the results of the data collected in Thurston County were able to determine that respondents were generalizing the location of their non-home trip end as well.

Another lesson learned came from an origin and destination study done in the Delaware Valley region in 1989. The questionnaire included a question asking drivers about the major highways that they would use to reach their destination from the survey station. This information was used to compare actual paths with those used by the traffic assignment model. Interestingly, analysis of the results indicated that, consistent with the gravity model, the traffic flow was accommodated on the highways with the shortest travel time. (5)

Sampling Approach

According to the Travel Survey Manual (1), an important objective is to reduce both sampling errors and non-sampling errors. Sampling errors are random errors that are introduced into the survey because not every member of the survey population is included in the drawn sample. Sampling errors reflect the potential variability between the estimate of a parameter in the sample and its true value in the population. These errors affect the "precision" of the survey results.

Non-sampling errors are an assortment of problems that can occur during the survey design and data collection stages that may cause survey measures and parameter estimates to be systematically incorrect. Non-sampling errors reflect how well the information is collected and include non-response and response biases that reflect a systematic distortion of survey responses. These errors affect the "accuracy" of the survey results.

Selected guidelines on determining the appropriate sampling approach as presented in the U.S. DOT Travel Survey Manual (1) include the following:

- Select the sampling approach and sample sizes that will enable the development of reliable, accurate transportation demand models without overspending on an expensive data collection effort.
- Existing information about the survey population can be used to develop more efficient samples so survey costs can be reduced and/or accuracy can be enhanced.
- Identification of the variables that are of greater importance to the survey and the corresponding analyses is critical in determining the required sample size. Examine the tradeoffs between sample size for the whole sample and the expected degree of precision for the variable that may be critical to the analysis.
- Traffic volumes can help to define the sample size requirements of the total respondents required for the survey time period.

- Identify the proposed sample rate for each of the selected roadway locations to be surveyed. This is commonly defined as what is required to achieve an accuracy of 15 percent (error) at a confidence of 95 percent, for a 10 percent proportion of all traffic having a particular origin and destination on the surveyed roadway. This provides the expected number of driver responses required at each roadway location. An additional factor is the license plate match rate (the result of recorded plates from out of state or plates that cannot be read or are misrecorded because of a lack of light, glare, obstructions or bad viewing angles, or simple data entry errors).

Table 2 shows recent experience in Washington State with the percentage of vehicles using the roadway during the survey for which address matches were found.

Table 2: Address Match Rates for License Plate Surveys

	1999 Trans-Lake Washington Survey (6)	**1998 Hood Canal Bridge Survey (7)**
Technology	Videotape, off-site automatic optical character recognition	Videotape including night hours, off-site automatic character recognition
Vehicles using roadway during survey	100%	100%
License plates read	51%	52%
Address matches from DOL	36%	28%

Site Selection

Selected guidelines for determining the appropriate survey sites presented in the U.S. DOT Travel Survey Manual (1) include the following:

- Use existing origin and destination trip table information, traffic count station information, and possibly census journey-to-work data to help determine site selection. Even if outdated, these data will give a feeling for the relative importance of different inter-zonal flows.

- Cordon lines should include entire political jurisdictions (towns, cities, census tracts, and special districts) and any planning area boundaries.
- Location should allow for collection of vehicle counts at or near the survey station throughout the survey period, for later expansion of the survey data.

Project Management and Oversight

The Travel Survey Manual (1) also strongly recommends these management and oversight elements to ensure a successful project:

- A proactive, hands-on project manager with day-to-day responsibility for coordinating activities and keeping the data collection effort on track to achieve the study objectives.
- Include any individuals with a strong sense of the impending modeling tasks in the survey design and implementation process because the outputs of the travel survey project will be travel modeling data.
- Implement a peer review panel made up of survey and modeling experts and convene it at the key stages of the survey project to provide advice and guidance to survey managers. In addition to or in place of the peer review panel, have a "consultant coach" assist with survey planning and design work. This person should be included early in the process to help perform preliminary planning tasks and help the agency prepare to contract with one or more other consultants to perform the final survey design work and actual data collection.

SURVEY COST ESTIMATES

The U.S. DOT Travel Survey Manual (1) cautions against relying on past survey experience for estimating the cost of a future survey. The reasons presented include the impacts of inflation, deteriorating cooperation rates, and geographic differences. The manual notes that it is highly unlikely that past efforts will include the same survey design elements and sampling considerations as the survey team's proposed efforts. Also, the availability and cost of survey worker labor differs from city to city, and response rates and cooperation rates are likely to be quite different. Often, reported costs do not include agency staff. In different survey efforts, contractors are responsible for different survey elements so contract costs may not be comparable either.

The manual recommends an approach for predicting the costs of a proposed survey that builds the cost up from specific anticipated labor, facility, and material costs, some of which are fixed and some of which are variable. This unit cost method is described in Appendix A of the manual. Cost components include the following:

- assembly of background data
- survey design and organization
- training labor and materials
- pre-testing and data collection labor
- data collection equipment
- fieldworker travel and per diem
- printing and postage
- coding (data entry and editing labor and equipment)
- programming and analysis labor and equipment

- other materials costs (publicity, documentation, incentives).

MAIL-BACK SURVEY NON-RESPONSE

Response rates are a key concern for self-administered, mail-back questionnaires used in roadside handout and license plate surveys. Non-response may introduce bias into the results of the survey.

A review of travel surveys conducted in California between 1990 and 1996 (8) provides some insight into the variability of response rates. For ten license plate surveys the response rates ranged from 11% to 43.4%.

Results of a study done in Britain (9) indicate that mail-back survey non-response does introduce bias into the travel data. The study compared data derived from self-completion postcard surveys and roadside interviews administered among separate groups in the same traffic stream. The results indicated that self-completion survey response rates differ by trip origin, destination and frequency and by trip purpose and time of day. The author calls into question assumptions about bias and the use of mail-back survey data as representative of the sample.

According to research on non-response in household travel surveys (10), individuals who are less likely to take part in travel surveys are the mentally and physically handicapped, individuals with language barriers, individuals with limited literacy skills, those who are less well-educated, the elderly, and urban dwellers. The research further notes that other non-respondents include couples with young children, single parents, individuals who hold multiple jobs, and other busy or hard to reach individuals such as 18- to 24-year-olds those who lack the community or civic ties (e.g., renters) that often motivate participation in travel surveys.

Simowski, et. al. (10) offered a series of recommendations on how to reduce non-response in travel surveys. Their primary recommendations involve questionnaire design and the use of incentives. Selected recommendations are presented in the following sections.

Questionnaire Design

- Sample members are more likely to complete the questionnaire if the topic is interesting and if the questionnaire is attractive and easy to follow. Whenever possible use expert review and cognitive interviews to improve the quality of items in the questionnaire. Pretest the questionnaire to improve its clarity, and estimate the time required to complete the questionnaire.
- Prepare all written respondent materials at the lowest reading grade level possible. Ask all questions as simply as possible, and make instructions easy to understand.
- Whenever the size of a non-English speaking subgroup is expected to exceed 5 percent of the population under study and the sample is expected to include 150 or more members of the subgroup, translate the survey instruments and materials into the appropriate language.
- About 7% of the adult population reports trouble seeing standard newspaper prints even with corrective lenses, which increases non-response. Use of a type size of 12 points or more for all written respondent materials if the sample is likely to include elderly individuals or persons with visual difficulties.
- According to Simowski (10), findings on the impact of the length of the survey on non-response are not consistent. One study found that adding 20

questions reduced response rates only by an average of 1 percent. Another study found that questionnaires longer than four pages are likely to reduce response rates by 8 percent. Aside from the actual number of and content of the questions, several factors may affect the potential respondent's estimate of the level of effort needed to complete the instrument. These include level of interest in the topic, apparent length of the questionnaire, attractiveness of the design, the flow and ease of following the instructions in the questionnaire, and the logical grouping and sequencing of questions by topic or chronology.

Incentives

Simowski (10) recommends using small prepaid monetary incentives (less than $2) unless participation in the survey is especially burdensome. Most studies report a positive effect of incentives on data quality. Item non-response is usually lower and answers to open ended questions are more complete.

As an example, the Puget Sound Transportation Panel Survey found that a prepaid incentive of $1 yielded a higher response than a promised incentive of $10. No incentive resulted in a 49 percent response, $1 prepaid resulted in a 64 percent response, while a post completion incentive of $10 resulted in only a 60 percent response.

Other Recommendations

Also recommended by Simowski (10) to reduce non-response are the following:

- Establish a telephone hot line that respondents can call almost any time to obtain timely answers to their questions about the survey and its instruments.
- Use first class mail and prepaid return postage to increase response rates relative to bulk mail.

- Follow up with non-respondents multiple times (at least three for a mail survey) to increase response. Vary the appeals in a mail survey by using a special appeal, such as certified mail, on the third follow-up attempt. Whenever possible make the field period long enough to permit multiple contact attempts for each member in the sample. (Note that this can conflict with attempts to maintain privacy for respondents.)

Survey Purpose and Privacy Concerns

The U.S.DOT Travel Survey Manual (1) states that it is highly desirable to publicize the overall survey effort well in advance of the fieldwork. Respondents are more likely to believe that the survey effort is legitimate and important if they have heard that the survey will be taking place. This is especially true of license plate surveys because respondents will receive the survey instrument without any notification. However, the manual cautions that care should be exercised in providing publicity about the specific survey sites in order to avoid changes in travel plans to avoid or be part of the survey.

The manual also suggests taking steps to ensure that respondents are not deceived, that respondents' privacy rights are not abused, and that the standard social research protections for participants are maintained. It identifies these common problems:

- failing to provide the respondent with information about the sponsorship of the study
- failing to provide information about the contracting firm conducting the survey
- misleading respondents about the time needed for the survey
- providing inaccurate information about gift or monetary incentives

- failing to tell about potential follow-up surveys
- using techniques to observe or identify respondents without their knowledge
- failing to take steps to ensure that privacy is maintained throughout the survey analysis
- careless storage and or disposal of returned questionnaires.

To avoid these problems, the manual recommends providing the following:

- the name of the organization carrying out the research
- the sponsor for the study
- an accurate but brief description of the purposes of the research
- an accurate statement of the extent to which confidentiality is protected (bearing in mind that some states may not allow agencies to protect the respondent's confidentiality as much as other states do)
- an assurance that cooperation is voluntary and that no negative consequences will result to those who decide not to participate
- an assurance that the respondent can skip any questions he or she does not wish to answer.

In addition, data and returned questionnaires need to be treated as confidential business information. All people with access to data or a role in their collection should be committed in writing to confidentiality. Links between answers and the respondent's identification should be minimized. Analysis not requiring names and addresses should be performed without it. Completed forms should not be accessible to people outside the project team. Identities should be removed from completed questionnaires. Upon completion of modeling work the project manager is responsible for destroying or securely storing completed instruments.

An example of how privacy can be protected is the study done on the Hood Canal Bridge in 1998 (7). In that study, the survey form was designed so that respondents could assure their anonymity by removing the portion of their questionnaire containing name and address before returning the survey form.

In California (11), strict confidentiality of the registered vehicle owners' names and addresses was maintained by making sure that only the DMV, Caltrans, and the mailing subcontractor were granted access to these data. Furthermore, none of these entities had access to all three pieces of information (vehicle, name, and address).

LICENSE PLATE SURVEY TECHNOLOGY

Review of the literature indicates that there are at least five options for recording license plate numbers so that they can be sent to the Department of Licensing for address matching. Not all of these options are in widespread use. From most traditional to least these methods are

- An observer at a roadside station observes a license plate number, calls it out, and it is entered into a computer by a second fieldworker.
- An observer at a roadside station observes a license plate number and records it on a tape recorder. The audiotape is later manually transcribed and the data entered into a computer.
- Roadside stations with cameras create videotapes, which are later manually transcribed (someone sits and watches the tape and enters the license numbers in a computer).

- Roadside stations with cameras create videotapes or temporary images that are electronically transcribed with optical character recognition technology.
- An observer at a roadside station observes a license plate number, calls it out, and it is automatically entered into a computer with voice recognition technology.
- A driver and an observer travel in the roadway segment more slowly than the general traffic. The observer enters license plate numbers from passing cars into a computer. (Carousel method)

The project team doing the 1991 Boston Region External Cordon Survey selected the license plate method for their survey because they were not allowed to disrupt or delay traffic flow in any manner at any of their 50 survey sites. However, they used a variety of techniques to gather the license plate numbers and benefited from pilot testing these techniques. They found that using a laptop to enter license plate numbers on-site required typing skills beyond those available in the field crew. The audiocassette method tested well, but during the actual survey the transcription rate was lower than expected and the plate matching rate was significantly lower than the notepad or video methods. To reduce the costs of videotape transcription, the survey team transcribed only the first 4 minutes of each 15-minute period, just enough to meet their sample size requirement. (12)

The key issues are the accuracy of both the observation and the recording of the observation, and the timeliness of the availability of the data. The accuracy affects how many license plate numbers will find matches in the Department of Licensing database and how many people will be mailed the survey in error. The timeliness will affect the response rate and accuracy of the responses if the respondents can not recall the trip they are being asked about. Each of the technology options above has relative advantages and disadvantages in terms of accuracy and timeliness.

According to the Travel Survey Manual (1), the most common errors associated with observers or transcribers (video or audio tapes) are reversing of digits or other data entry errors when tapes are difficult to decipher. Although a greater percentage of license plates may be read with video technology, the match rate may be even lower than for manually recorded license plates because the camera can not look around obstacles or outside the field of view of fixed camera locations. Automated plate matching programs have high error rates with similar characters. License plates that are visible to the naked eye may be too dirty or unlighted to read on videotape. Still, the potential savings in labor both for transcription and data entry makes the use of video technology attractive and can more than offset the cost of having to collect a larger sample. In addition, improvements in videotaping equipment technology make the collection of license plate numbers at night more feasible.

According to Transfomations Inc. (13) manual review of videotapes is costly because of the tremendous number of man hours required to transcribe videotapes, typically more than 10 hours to transcribe one hour of videotape ($250 to $500 per hour of tape). This compares to one hour for optical character recognition technology to transcribe one hour of tape. In addition, manual data entry accuracy degrades with time. This method requires an extended length of time to obtain results and is more expensive than automatic processing of the videotapes

Several studies reported the efforts that were made to improve the how quickly license plate numbers could be made available. These include the following:

- During 1995 and 1996, the Metropolitan Washington Council of Governments surveyed travelers in the Washington, D.C., area. Spotters used laptop computers to record license plate numbers. The survey team had agreements with the departments of licensing in the District of Columbia, Virginia, Maryland, West Virginia, and Pennsylvania. These agreements included an agreement to quickly convert the license plates into addresses. A smaller area external station survey completed several years before revealed that when it took longer to distribute the surveys, the response rate was lower. For the 1995/1996 study the response rate was 30%. The survey team felt that quick mail-out of surveys and the use of a real stamp instead of a metered stamp contributed to the success of the survey. (2)
- In Tampa, the Florida DOT used still photography and spotters equipped with binoculars to record license plate numbers crossing 18 cordon locations. A publicity campaign let people know why the survey was being done but not where. FDOT thought it was very important to disseminate the mail-back survey forms as soon as possible; therefore, the license plates numbers were read off the negatives (rather than developed photographs) and converted to addresses by midnight of the day they were observed. FDOT estimated that 75% of the survey forms reached the intended drivers within 48 hours of the observation. The package included a toll-free telephone number to call for

more information and a letter explaining the specifics of the survey. 10,000 survey forms were mailed out with a 44% return rate. (2)

- During the 1998 study on the Hood Canal Bridge, license plates were recorded on 74 videotapes. Each evening the tapes were sent by overnight delivery to a company in Massachusetts. The following day the tapes were processed with an optical character recognition system to generate the license plate number file. This file was sent back to the video contractor by file transfer protocol (FTP) by 2:00 PM that same day. By 3:30 PM that day the license plate file, along with the vehicle location and time information were provided to WSDOT via FTP. WSDOT put the data on a tape that was delivered to the Washington State Department of Licensing (DOL) that night. The resulting address lists were sent back to one of the contractors, where a mail merge file was created and placed on an FTP site at a mailing house by 9:00 AM the next morning, less than 2 days after the vehicle observations. A total of 26,000 unique license plate images were recorded on video. Of these, 19,500 were matched to Washington addresses. The study identified 19,415 potential survey recipients, 28% of total traffic counted during the hours videotaped. 18,000 survey forms were mailed out with a 39% response rate. The high response rate was attributed to the quick mailing and high level of interest in the future of the bridge.

Automatic License Plate Recognition

The 1999 Guidebook on Statewide Travel Forecasting (3) states that complete automation of the license plate reading and transcribing process makes the process very safe, easy to execute and comparatively accurate.

Automatic license plate recognition has been used in the United States since the early 1980s to monitor southern border crossings. The technology has evolved and expanded to support electronic toll collection at highway speeds. (14)

The process required to read a license plate includes acquiring the image, transferring it to memory, finding the license plate in the scene, and reading and recording the plate number. (14)

In a 1999 article, Adaway (15) points out that a 100 percent recognition rate using automatic license plate reading equipment is simply not possible because of damaged or obscured license plates. Some characters are easily confused, particularly the D and the O. He suggests that a good reader will deliver an average recognition rate of 85 to 95% for unobstructed plates in all weathers, day or night, as a result of advancements in camera and character recognition technology. At night, an infrared illuminator is often used to avoid any driver distraction. A paper presented at the World Congress on Intelligent Transport Systems in 1997 (16) indicated that recent improvements in character recognition technology are improving vehicle license plate recognition systems. These systems are now achieving 97% to 99% accuracy rates. Automatic license plate recognition has been more popular in Britain and one author points out that reading uncluttered British license plates is relatively easy in comparison to the variety of license plates found in the United States. (17)

So far study results in the U.S. have not reported such high accuracy rates. A study done for WSDOT in 1995 (13) used automatic license plate reading technology to measure travel times on freeway HOV and general purpose lanes. In that study license plate match rates were in the 25% to 50% range. A 1996 paper (17) reporting results from a test of automatic license plate reading equipment on the Southeast Expressway in Boston indicates that the equipment was able to read about half of the 33,576 license plates read by the human operators (transcribed from videotape), with about one-third of machine read plates correct in every character.

On-site automatic license plate recognition equipment was used for the Tacoma Narrows Bridge study. (18) License plate numbers were collected 24 hours a day during two three-week periods. (19) A total of 508,848 license plate numbers were collected, of which 79% were matched with addresses by the Washington State Department of Licensing. A manual review of the data indicated that, on average, 63% of the license plate reads were accurate. The report notes that the sample used for the manual review was skewed to inclement weather, and the overall accuracy rate was likely higher than 63%. (18) (This data collection effort was used to identify home addresses of those using the bridge for purposes other than an origin and destination study. Questionnaires were not mailed out.)

A study done by the Transport Research Laboratory in England tested four automatic license plate recognition technologies and found that the license plates were read correctly 70% of the time for a sample of 9079 license plates. (20)

Voice Recognition Technology

A 1997 study (21) reported encouraging results from a preliminary test of voice recognition software to collect license plate data. For this method, the traffic observer dictates the license plate data into a microphone. The license plate number data record is automatically created in the computer by the voice recognition software, and the entry is time-stamped. Testing showed accuracy rates in excess of 95 percent. This technology presents the opportunity to reduce personnel requirements for situations that typically require two observers – one to read off the license plate numbers and the other to enter the information into the computer.

Carousel Method (22)

The "carousel method" was designed in 1994 to collect data in a Baltimore origin and destination study done by the Baltimore Metropolitan Council on I-83. In this method trained observers and drivers in survey vehicles travel in the general traffic stream in defined highway segments at speeds of 10 to 15 mph below the prevailing traffic speed. License plate numbers are entered into a laptop computer and downloaded immediately upon completion of the observations.

In 1995, FHWA funded a test of the cost-effectiveness of the carousel data collection methodology. The study demonstrated an 18% cost reduction relative to the roadside methodology. However, the method did not work well in highway segments that were either under-utilized or heavily congested.

The carousel method was determined to be appropriate for road segments where the average general traffic speeds are at or exceed legal speed limits, traffic volumes are at or above 60,000 ADT, there are three or more lanes in each direction, and traffic flows freely with little or no gapping.

In comparison to stationary roadside observers, the carousel method offers greater safety for both survey staff and the general public, with minimal disturbance to normal traffic flows, a high degree of data accuracy (because of improved sight lines), and less cost when four or more highway segments are being surveyed.

OTHER ORIGIN AND DESTINATION STUDIES

Most of the origin and destinations studies referenced in the literature are for urban areas, although there are a few recent examples of statewide studies for which non-urban corridor information was gathered. The following is a list of selected recent origin and destination studies, including any data collection method, cost, and response rate information available. Some urban studies are included for cost and response rate information. Unless otherwise indicated, the reference for the information in this section is a scan of recent travel surveys done in 1996 for the U.S. DOT. (2)

Table 3: Selected Origin and Destination Studies

Location	Sponsor	Date	# of Sites	Method	Cost	Response (Rate)
Atlanta	Atlanta Regional Com-mission	Fall 199 4	3 5	Roadside handouts & roadside interviews	$200,00 0 (con-sultant only)	
Baltimore	Baltimore Regional Council	June 1994		Carousel method to col-lect license plate numbers, mail-back question-naire	$20,000 (consultant), $10,000 (agency)	
Boston (12)	Central Transporta-tion Planning Staff	Spring & Fall 1991	50	Video cameras for license plates, mail-back question-naire	$270,000	29,400 (26%)

Dallas	North Central Texas Council of Governments	March and April of 1994	38	Roadside interviews	$220,000 (consultant), geo-coded by NCTCOG	28,000
Houston	Houston Galveston Area Council		24	Roadside interviews	$192,000 (contract cost)	13,679
Indianapolis	City of Indianapolis	1993		License plate match, telephone survey		700
San Antonio	Bexar County Metropolitan Planning Organization	March-May 1990	18	Roadside interviews		13,500
San Francisco	Metropolitan Transportation Commission	October 1994		Video taped license plates		6800 (17%)
Washington D.C.	Metropolitan Washington Council of Governments	1995 and 1996		Spotters used laptop computers to record license plate numbers.	Data collection $200,000 Data processing $50,000	(30%)
Milwaukee	Southeast Wisconsin Regional Council of Governments			Mail-back questionnaire		40,000 (30%)
Seattle (Trans-Lake Washington) (6)	Washington State Department of Transportation	May 1999	3	Automated license plate recognition		2470 (16%)
Ohio (statewide)	Ohio State Department of Transportation	1995	316 (inter-city)		$1.2 million	
Oregon (23)	Oregon Department of Transportation	1994	39 (inter-city)	Roadside handout and video taping of license plates for mail-back		
California (11)	Caltrans & Amtrak	May & June 1992	2 (inter-city)	Video taping of license plates and mail-back questionnaire		16,500 (23%)
North Carolina (24)	North Carolina Department of Transportation	December 1994	1 (inter-city)	Roadside interviews at rest area using palmtop computers		1750

RELEVANT ORIGIN AND DESTINATION DATA SOURCES

There are few sources of existing origin and destination data useful for the design and/or analysis of a future study in the I-5 corridor. Recent surveys in the Puget Sound region have generated origin and destination data for the Tacoma Narrows Bridge, the Hood Canal Bridge and the I-90 and 520 bridges across Lake Washington. North of Seattle a survey was done in Whatcom County (to determine which roadways Canadian vehicles were using after entering the U.S. at Sumas) and in Skagit County (to identify local trips on the I-5 bridge over the Skagit River).

The following four surveys are potential sources of data relevant to the current I-5 survey effort:

High Speed Ground Transportation Study

The High Speed Ground Transportation Study (25) included an origin and destination study to support a traveler market analysis and demand forecast for high speed ground transportation alternatives in Washington State. Data were collected to support analysis in three markets: Seattle to Portland, Seattle to Vancouver, B.C., and Seattle to Spokane.

In April and May 1992, inter-city auto traffic was intercepted at three locations: I-5 northbound at the Thurston/Pierce county line, I-5 southbound in Skagit county between Bellingham and Burlington, and I-90 eastbound in Kittitas County. Vehicles were diverted into rest areas, and drivers were interviewed for one to two minutes. Drivers were also asked to complete and mail back a stated preference exercise.

Interviews were conducted during eight-hour periods on one mid-week weekday, one weekend weekday, and one weekend day. The sampling rate was adjusted throughout the survey period to assure an adequate supply of vehicles in queue to be interviewed while limiting the amount of delay to travelers. Between 2500 and 3000 useable interviews were collected at each of the I-5 survey sites. Thirty-nine percent (1,615) of the stated preference exercises were returned.

The data available include socio-economic characteristics, origin city and zip code, destination city and zip code, primary trip purpose (business or non-business), home location, trip frequency, and vehicle ownership. Similar information was collected from airline passengers as well. Detailed results of the survey are reportedly archived in the WSDOT Rail Office. The final report from the study does include tables that identify expanded data showing travel volumes between counties for business and non-business purposes for both automobile and airline passengers.

Thurston County Origin and Destination Study

In June of 1997, the Thurston Regional Planning Council coordinated the collection of origin and destination information from drivers entering and leaving the county using I-5 and Highway 101 during the morning and afternoon peak periods. (4) License plate numbers were collected by video cameras at two locations on I-5 and at one location on Highway 101. The cameras on I-5 captured the license plates of vehicles traveling in all lanes in both directions at the northern and southern ends of Thurston County. License plate numbers were collected on a Tuesday (June 17, 1997) and survey questionnaires were sent to the owners of vehicles recorded at the survey locations between 6:30 AM and 9:30 AM and between 4:00 PM and 6:30 PM. Approximately 40,000 questionnaires were mailed out, and 18,000 were returned, a 45% response rate.

Although survey forms were mailed to freight and trucking companies as well as personal auto owners, the response from these companies was insignificant. This is believed to be due to the fact that the survey form did not include the license plate number, making it difficult for trucking companies to know which of their trucks had been spotted.

American Travel Survey

This survey (3), sponsored by the Bureau of Transportation Statistics, includes trips greater than 100 miles. Eighty thousand households participated. Interviews were conducted with these households about every three months by phone. Data available include

- origin
- destination
- stops along the way
- side trips
- principal means of transportation
- access and egress modes to airports, train and bus stations
- information about the travel party
- reason for the trip
- number of nights spent away from home, and
- type of lodging.

Results of the American Travel Survey are available on-line at *www.bts. gov/programs/atb.*

Oregon DOT I-5 Origin and Destination Studies at Salem and Eugene

Oregon DOT is building its second-generation, state-wide travel demand model. For the purposes of this effort, license plates were videotaped at five sites on I-5 in 1994 as part of the Mid-Willamette Valley and Rogue Valley Study. (23) The study included data collection at 39 sites but only 5 of those were on I-5. The I-5 sites were in Eugene and Salem. Only weekday data was collected except at one site in the Salem area, which included Saturday data collection. License plate numbers were recorded between 10:00 AM and 2:00 PM and between 4:00 PM and 6:00 PM. Data collected from mail-back questionnaires included origins and destinations (nearest city or nearest intersection within metropolitan areas), trip purpose at each end, time of trip, number of occupants, frequency of trip, type and age of vehicles, and type of fuel used (for air quality planning). The results of the surveys in Salem and Eugene are presented in Volumes I & II of the study report.

RESOURCES

- Travel Survey Manual—available on-line at *www.bts.gov/tsmanual/toc.html.*
- Travel Model Improvement Program (TMIP)—on-line at *tmip.tamu.edu.* TMIP is a U.S. DOT research program in cooperation with EPA and DOE implemented in response to the requirements of the Clean Air Act Amendments of 1990 and the Intermodal Surface Transportation Efficiency Act of 1991. Its objectives include responding to greater information needs being placed on the forecasting process and to take advantage of changes in data collection technology. (2)

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