Using Video Technology To Conduct 1991 Boston Region External Cordon Survey

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The 1991 Boston Region External Cordon Survey is described. External cordon surveys are designed to obtain information on trips that cross the external boundary of a study area. The primary use of external survey data is the development and calibration of external trip distribution models. Particular emphasis is given to two innovative aspects of the 1991 Boston survey: (a) the application of small sample design techniques for the efficient design of an appropriate sample in order to gather significant data on variables of interest, and (b) the extensive use of video technology. When conducting roadside interviews or handing out postcards is not possible because of restrictions regarding traffic delays, the study has shown that video can be used successfully to obtain the needed information, using off-the-shelf equipment and specific techniques to minimize costs.

In 1990 the Central Transportation Planning Staff (CTPS), the staff to the metropolitan planning organization (MPO) in the Boston region, initiated the Regional Planning Study (RPS), a multiyear project to update the model set for estimating travel demand in the Boston region. The project included an extensive data collection effort designed to provide the requisite information for model development.

This paper describes the 1991 Boston Region External Cordon Survey, one component of the RPS data collection effort. External cordon surveys are designed to gather information on trips that cross the external boundary of a study area. These include external-external (E/E) trips, which begin and end outside the study area but travel through it; internal-external (I/E) trips, which begin inside the study area but end outside; and external-internal (E/I) trips, which originate outside the study area but end within it. Vehicles crossing the cordon line are the basic sampling unit, for which the following basic travel data are usually collected: trip origin and destination by address or nearest intersection, travel time, trip purpose, vehicle occupancy, and vehicle class.

The primary use of external survey data is the development and calibration of external trip distribution models. Origin-destination (O-D) survey data are used to develop estimates of average trip lengths so that trip-length frequency distributions (TLFDs) can be used for model calibration. This is done because direct estimation of external vehicle trip tables from survey O-D data is problematical: survey data at the required zonal level are statistically insignificant at useful confidence and precision levels. In addition, data from the external survey can also be compared with information from the 1990 census and the 1991 Boston Region Household-Based Survey to analyze the relationship among demographics, economic activities, and travel behavior.

This paper summarizes the available techniques for conducting an external cordon survey and describes the methods used for the study. Particular emphasis is given to two innovative aspects of this survey: the application of small-scale sample design techniques and the extensive use of video technology.

AVAILABLE SURVEY METHODS

External cordon surveys are usually conducted using one of three methods: roadside interview, roadside postcard survey distribution (postcards are to be mailed back), or license plate recording/matching with a survey mailed out to be returned (*1*).

Roadside Interview

Perhaps the most common method for gathering the requisite data is to administer a roadside oral interview at the selected survey stations. This method provides the needed data quickly and allows the interviewer to prompt and probe for complete information. In addition, the response rate is usually higher than for the other methods, reducing nonresponse biases. Because there is no delay in estimating the response rate, an adequate sampling rate can be used to achieve the goals of the sample design. No mailing costs are incurred, so costs tend to be lower than for other methods, although this must be balanced against the probable higher personnel costs.

Several possible disadvantages should be noted. Conduct of the survey may cause traffic delays, particularly during the peak period and at high-volume locations. Management of the survey may be complicated because of the need to involve several organizations, including the police and the highway department. Safety of the surveyors may also be an issue.

Postcard Surveys

Another method is to stop vehicles at the survey station and hand out a postcard to be mailed back after completion by

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the respondent. This procedure is somewhat less likely to disrupt traffic than conducting interviews is, and it requires fewer field personnel. However, the response rate is usually lower, in the range of 20 to 30 percent. The low response rate may result in significant nonresponse bias. Costs may be significantly higher than for a roadside interview, also: a recent study in San Antonio that compared roadside interviews with postcard distribution concluded that the unit cost of valid responses was several times higher for the postcard method than for the roadside interview method (*2*).

License Plate Recording and Survey Mailout

A third method involves recording license plate numbers as vehicles pass, matching plate numbers against registry files to determine home addresses, and mailing a survey form to be returned by mail. The license plates can be recorded by using pencil and notepad, audiotape recorder, laptop or portable computer, or film or video camera. License plate matching is usually done through the use of a computerized matching procedure. The major advantage of the license plate method is that it does not disrupt traffic.

There are several disadvantages to the license plate approach, however. The lag between time of observation and the receipt of the survey by the respondent may lead to low response rates (and significant nonresponse bias) and high recollection errors. The method can be fairly complicated to manage, and costs may be higher than for the other methods. Adverse publicity may be generated because of errors in license plate recording or address matching and the subsequent mailing of surveys to the wrong household. Even if errors are kept to a minimum, the public may perceive it as an invasion of privacy.

The license plate method was selected for the Boston survey for one overriding reason: the authors were not allowed to disrupt or delay traffic flow in any manner, at any location.

Supplemental Information

In addition to the actual survey data, two types of vehicle count information are needed to weight and expand the sample data to represent the entire vehicle population for the study area:

1. Manual vehicle counts at survey stations to obtain information on vehicle classification and vehicle occupancy during the survey.
2. Automatic traffic recorder (ATR) counts to collect average weekday hourly traffic information for both travel directions at each survey station.

SAMPLE DESIGN

The external cordon line of the Boston RPS area is shown in Figure 1. At the cordon line, 102 roadways were identified as possible survey sites. It was estimated that 80 percent of the daily traffic crosses the cordon through the 33 highest-volume stations, 85 percent through 40 stations, and 90 percent through 47 stations. Because of budgetary limitations, and for purposes of efficiency, it was decided that traffic at the 47 stations with an average daily traffic (ADT) greater than about 5,000 should be surveyed, capturing 90 percent of the traffic crossing the cordon. To examine the TLFDs of facilities with low traffic volumes, three stations with ADTs of less than 5,000 were also included. This selection resulted in 50 external stations at which surveys were performed.

Previous surveys of this type have relied on one of two approaches to sampling. The first approach focuses on providing a sufficient sample size for direct estimation of traffic flows at an aggregate (district-to-district) level. The second approach focuses on the statistical requirements of estimating a proportion as it relates to a variable of interest such as trip purpose or vehicle classification (*3*) or as it relates to a particular destination (*4*). Neither approach correlates explicitly with the primary purpose of these kinds of surveys: the estimation of zonal-interchange-level external trip tables.

Unfortunately, direct estimation of trip tables from survey data at a useful statistical level of confidence and precision is problematical: for a large region, with perhaps a thousand traffic zones (and consequently a million possible trip interchanges), it is almost impossible to collect enough data for direct estimation of trip tables (even recognizing that a proportion of trip interchanges will have zero trips). An alternative to the use of survey data for direct trip table estimation is the use of survey data to develop estimates of parameters (particularly TLFD) for calibration of external trip distribution models. The distribution models are then used to estimate zonal-interchange external trip tables. (Of course, statistically significant aggregate interchange trip data are useful for validating the distribution models.)

Therefore, for this survey, trip length was chosen as the variable of interest. Both Smith's (*5*) and Stopher's (*6*) small-sample survey design methods were applied to determine the required sample size for each external station in order to ensure a statistically significant estimate of average trip length, the variable of interest, at a 90 percent confidence level and a ± 5 percent precision level. In essence, small-sample design procedures allow the use of previously collected information about the variance of the variable of interest to efficiently design a sampling procedure to collect updated information about those variables.

The following procedures were used to apply the small-sample design techniques:

1. The survey stations were grouped into different geographic sectors corresponding to the CTPS sectors. Since the study area is in the shape of a semicircle and the major roadways are in a radial pattern, differences in the TLFD among major roadways can be identified. All the external survey stations are included in one of the six sectors: North Shore, North, Northwest, West, Southwest, and South.
2. The proportions of I/E, E/I, and E/E trips to total external trips were extracted from the existing CTPS regional highway trip table, which is based on previous survey data. Estimates of mean trip length and trip length coefficient of variation for each survey station were also obtained from the regional trip table. An estimate of the number of completed and valid surveys was then calculated for each survey station by applying Smith's and Stopher's sample design procedures.

It should be noted that the estimates of trip length and trip length coefficient of variation developed from existing infor-

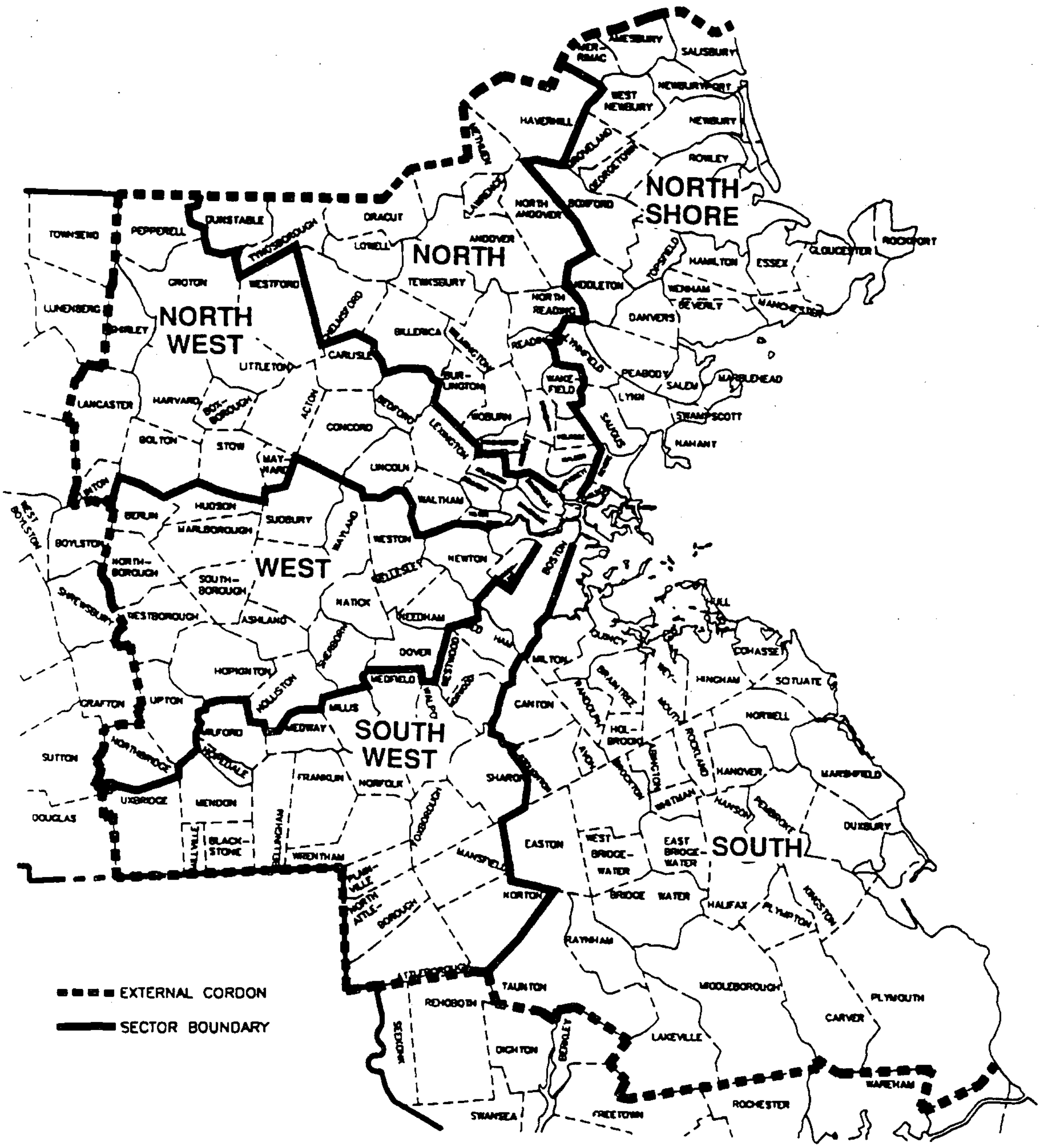

FIGURE 1 Boston region external cordon line and sector boundaries.

mation may not be accurate or up to date, which in turn may result in inaccuracies and inefficiencies in the sample design. This is inherent in the application of small sample design techniques; after all, replacing outdated data is the reason for conducting surveys. An examination of the errors introduced by using the existing data for sample design can be conducted after the new survey is analyzed and compared with sample design input assumptions.

3. On the basis of the sample size estimates from the previous step, the survey stations were then classified into three different groups according to their 1987 ADT:

–Low-volume stations (ADT less than 10,000),
–Medium-volume stations (ADT between 10,000 and 35,000), and
–High-volume stations (ADT higher than 35,000).

The station at which the highest proportion of traffic needed to be surveyed was chosen as the critical station for each ADT group. The number of completed and valid surveys required at each station was generated by applying the critical cell proportion to each station in the ADT group. This was done because it is difficult to design a survey method to survey the exact number of samples needed at each station.

The sample design procedure resulted in the following required sampling proportions for the three ADT groups:

- Low-volume stations: 10 percent of the inbound traffic crossing the cordon during the survey period.
- Medium-volume stations: 6 percent of the inbound traffic crossing the cordon during the survey period.

- High-volume stations: 5 percent of the inbound traffic crossing the cordon during the survey period.

These percentages represent the final proportion of traffic for which completed and valid surveys are needed. To generate an estimate of the required number of complete and valid surveys, the number of license plates that needed to be recorded was estimated by adjusting for the following factors:

- Plate recording and matching error: it was assumed that 85 percent of recorded plates could be matched with the registry files to obtain the home addresses of the respondents.
- Nonresponse: it was assumed that 25 percent of the surveys mailed would be returned. This takes into account surveys not delivered because of inaccurate address matching, errors in matching, and nonresponse.
- Incomplete surveys: it was assumed that 95 percent of the returned surveys would be complete.

Because of the combined effect of these assumed rates, it was estimated that surveys would be returned for only 20 percent of the recorded plates (85 percent × 25 percent × 95 percent × 20 percent). Table 1 presents an estimate of the number of complete and valid surveys needed at each station, on the basis of estimated 1987 ADT and appropriate non-passenger-vehicle factors; the estimated total regional sample size was 24,900 complete and valid surveys. It should be noted that the actual required number of completed surveys was related to actual traffic volumes recorded during the survey process as well as adjustments for the actual rates for the preceding factors.

SURVEY PROCEDURE

Survey Schedule

The survey was performed in two stages: the first extended from May 7 to June 13, 1991; the second, from September 10 to October 22, 1991. Each station was surveyed for 1 day from 6:00 a.m. to 7:00 p.m. on Tuesdays, Wednesdays, or Thursdays during the survey period. Generally two sites were surveyed per day.

License plate recording and vehicle occupancy and classification counting were conducted for inbound traffic only, and 24-hr ATR counts were conducted in both directions for the full midweek period for each station during its survey week. An observer alternated counting classification and occupancy at 15-min intervals during three 2-hr survey periods: a.m., p.m., and midday. Two types of recording equipment were used for the occupancy and classification counts: denominator boards were used at some locations, and intersection boards programmed for occupancy and classification were used at other locations.

The surveys were mailed within 5 days of plate recording so that the prospective respondent would receive the form no later than 1 week after being observed. Several tasks had to be performed within that 5-day period: transcription and key entry of the plate data, matching with vehicle registry files to obtain home addresses, printing of vehicle-specific data on the forms, and form folding and sealing. Up to 10,000 surveys were mailed each week during the survey period.

Survey Instruments

Three survey forms were required: a mailed survey questionnaire, a vehicle occupancy count form, and a vehicle classification count form. The mailed survey form had to meet several criteria:

- Each form had to contain observation-specific information: observed license plate, as well as the location, direction, date, and time of observation. This was accomplished by preprinting forms that could be form-fed to printers to receive the observation-specific data during the mail-merge process.
- To keep postage costs at a minimum, it was decided to conform to U.S. Postal Service postcard maximum size requirements while ensuring room for necessary survey questions, respondent and return addresses, and appropriate cover information and instructions.
- The paper stock had to be heavy enough to withstand the printing, mail-merge, and mailback processes, but not so heavy that it could not be form-fed.

The survey form, shown in Figure 2, was folded in half before mailing; the respondent then tore off and returned the bottom half of the form. A trifold form was considered and rejected because of the additional folding costs.

License Plate Recording Methods

Several methods are available to record license plate data for surveys of this kind. The most common methods, used in previous studies, include the use of notepad and pencil, audiocassette recorders, laptop computers, and video. Certain aspects of this survey were important to consider in the selection of appropriate plate recording methods:

- It was expected that a significant number of plates would be recorded from Massachusetts, New Hampshire, Rhode Island, and Maine.
- For each state, there are at least 40 plate formats in use for passenger vehicles.
- Massachusetts requires only rear plates on passenger vehicles; therefore, the methods selected must work for reading rear plates.
- In Massachusetts all pickup trucks and vans are required to have commercial plates even if they are used as private passenger vehicles.
- Many of the stations do not have available overhead locations, so plate recording must be conducted from the side of the road.
- The daily traffic volumes at the 50 survey stations vary from about 5,000 to more than 80,000 ADT.

Field-crew training provided the initial means for assessing each method; a pilot survey was then used to further evaluate the methods. Three stations were used in the pilot survey to test the plate recording methods: (a) notepad, audiocassette recorder, and laptop computer were tested at a low-volume station; (b) audio and video were tested at a medium-volume station; and (c) video was tested at a high-volume station. Particular attention was paid to determining the capabilities of crew members with respect to each of the methods. The

TABLE 1 Estimated Sample Size for Each Survey Station

Station	Town	Location	Estimated 1987 ADT	Station Volume Class	Estimated Inbound Traffic 6AM-7PM	Estimated Required Completed Surveys	Matched Plates Required at 22.5% Response	Estimated Plates Recorded at 85% Match Rate
1	Salisbury	I-95 @ N.H. SL	62,000	H	25,110	1,252	5,567	6,549
2	Salisbury	Rt 1 @ N.H. SL	16,800	M	6,804	408	1,814	2,135
3	Salisbury	Rt 1A @ N.H. SL	10,500	M	4,253	255	1,134	1,334
4	Salisbury	Rt 286 E of Rt 1	15,200	M	6,156	368	1,636	1,925
5	Salisbury	Main St @ N.H. SL	6,300	L	2,552	255	1,134	1,334
6	Amesbury	Rt 150 @ N.H. SL	9,700	L	3,929	393	1,746	2,054
7	Haverhill	Rt 108 @ N.H. SL	6,400	L	2,592	259	1,152	1,355
8	Haverhill	Rt 125 @ N.H. SL	32,800	M	13,284	797	3,542	4,168
9	Haverhill	North Ave @ N.H. SL	12,700	M	5,144	309	1,372	1,614
10	Haverhill	Rt 121 @ N.H. SL	7,400	L	2,997	300	1,332	1,567
11	Methuen	I-93 @ N.H. SL	80,000	H	32,400	1,620	7,200	8,471
12	Methuen	Rt 97 @ N.H. SL	8,200	L	3,321	332	1,476	1,736
13	Methuen	Rt 28 @ N.H. SL	25,300	M	10,247	615	2,732	3,215
14	Dracut	Rt 38 @ N.H. SL	12,300	M	4,982	299	1,328	1,563
15	Dracut	Mammoth Rd @ N.H. SL	11,500	M	4,658	279	1,242	1,461
16	Tyngsborough	Middlesex Rd S of Rt 3	16,000	M	6,480	389	1,728	2,033
17	Tyngsborough	Rt 3 @ N.H. SL (S of x36)	62,000	H	25,110	1,256	5,580	6,565
18	Pepperell	Rt 119 @ Townsend TL	12,400	M	5,022	301	1,339	1,576
19	Lunenburg	Rt 2A W of 2A & 225	9,000	L	3,645	365	1,620	1,906
20	Lancaster	Rt 2 @ Leominster TL	43,000	H	17,415	871	3,870	4,553
21	Leominster	Rt 117 W of Lancaster TL	5,300	L	2,147	215	954	1,122
22	Sterling	Rt 62 W of Lancaster TL	5,000	L	2,025	203	900	1,059
23	Clinton	Rt 70 @ Boylston TL	6,300	L	2,552	255	1,134	1,334
24	Northborough	I-290 @ Shrewsbury TL	55,200	H	22,356	1,118	4,968	5,845
25	Shrewsbury	Main St @ Northboro TL	7,500	L	3,038	305	1,354	1,592
26	Shrewsbury	Rt 9 @ Northboro TL	36,000	H	14,580	729	3,240	3,812
27	Shrewsbury	Rt 20 S of N TL & Rt9	20,000	M	8,100	486	2,160	2,541
28	Grafton	I-90 btwn Exit 11 & 11A	57,600	H	23,328	1,166	5,184	6,099
29	Upton	Rt 140 @ Grafton TL	8,200	L	3,321	332	1,476	1,736
30	Northbridge	Rt 122 @ Grafton TL	8,300	L	3,362	334	1,485	1,747
31	Bellingham	Rt 126 S of S Main St	14,700	M	5,954	357	1,588	1,868
32	Uxbridge	Rt 16 E of Rt 146	5,200	L	2,106	211	936	1,101
33	Uxbridge	Rt 146A E of Rt 146	10,000	M	4,050	243	1,080	1,271
34	Wrentham	Rt 121 @ R.I. SL	5,600	L	2,268	227	1,008	1,186
35	N Attleboro	I-295 @ R.I. SL	25,000	H	10,125	505	2,246	2,642
36	Attleboro	County St @ R.I. SL	7,800	L	3,159	316	1,404	1,652
37	Attleboro	Rt 123 W of Rt 1	11,200	M	4,536	271	1,204	1,417
38	Attleboro	I-95 @ R.I. SL	72,000	H	29,160	1,458	6,480	7,624
39	Attleboro	Rt 1 @ R.I. SL	20,000	M	8,100	486	2,160	2,541
40	Attleboro	Rt 1A @ R.I. SL	24,000	M	9,720	583	2,592	3,049
41	Attleboro	Rt 152 W of Thurber Ave	5,600	L	2,268	225	999	1,175
42	Rehoboth	Rt 118 @ Attleboro CL	6,900	L	2,795	279	1,242	1,461
43	Taunton	Rt 44 btwn N & S Walker	15,000	M	6,075	365	1,620	1,906
44	Dighton	Rt 138 N of Center St	8,300	L	3,362	336	1,494	1,758
45	Taunton	Rt 24 S of Rt 140	43,000	H	17,415	871	3,870	4,553
46	Taunton	Rt 79 @Taunton/Berk CL	5,000	L	2,025	203	900	1,059
47	Lakeville	Rt 140 @ Freetown TL	20,000	M	8,100	486	2,160	2,541
48	Lakeville	Rt 105 @ Rochester TL	2,500	L	1,013	101	450	529
49	Middleboro	I-495 @ Rochester TL	32,000	H	12,960	648	2,880	3,388
50	Plymouth	Rt 3 1.5 mls N of Bourne	27,600	M	11,178	671	2,981	3,507
		TOTAL:	1,030,300		417,300	24,900	110,700	130,200

traffic volume and speed ranges over which each method might be used by qualified crew members were estimated. The following summarizes the evaluation of each method.

Notepad

The notepad method demonstrated that one person could record as many as 600 license plates per hour under ideal conditions; achieving the ideal required a steady stream of vehicles so that they could be recorded at 5-sec intervals. A well-disciplined recorder using a notepad could do this by recording every other vehicle where the headways approximated 2 to 3 sec on a steady basis or even in platoons. Recording accuracy varied greatly among the field personnel, however. Some difficulties occurred due to violation of the minimum headway limit and efforts of the recorder to record too many numbers in a given period.

It was recognized that ideal conditions probably would not occur during the main survey. Therefore, it was decided that the notepad method would be appropriate only at low-volume stations in the main survey.

COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF PUBLIC WORKS

A Message from the Secretary of Transportation

The Massachusetts Department of Public Works, in cooperation with the Federal Highway Administration, is conducting a study to improve the traffic conditions in the Eastern Massachusetts area. We need your help and opinions in order to plan improvements effectively.

Your answers to this survey are completely confidential. The success of this timely and important survey depends heavily on your participation. Please take a few minutes to answer the questions on the attached survey form. Your prompt completion and return of this questionaire will be greatly appreciated.

Sincerely,

Richard L. Taylor
Secretary of Transportation

YOUR INFORMATION COUNTS

No matter how much or how little you travel, **YOU ARE IMPORTANT.** You are one of the few people picked to help us understand the travel patterns in this area. Please fill in the questionnaire, tear it off and drop it in the mail. It only takes a minute, and it makes a difference. Thanks!

Detach here and mail

Travel Questionnaire

32 9

Your vehicle (License # 671483) was observed travelling on RT 146 EB, UXBRIDGE at 6:45AM (Time) on 09/18/91 (WED) (Date).

If vehicle observed is not yours, check here ☐ and return form.

PLEASE PROVIDE THE FOLLOWING INFORMATION:
Your answers are completely confidential.

1. Where were you driving from? (Where did this trip begin?)
   Number ____ Street or nearest intersection ____
   Town/City ____ State ____ Zip Code ____
2. Where were you driving to? (Where did this trip end?)
   Number ____ Street or nearest intersection ____
   Town/City ____ State ____ Zip Code ____
3. How many people including the driver were in the vehicle? ____
4. Which of the following best describes the reason for this trip? (Please check one FROM box and one TO box.)

FROM	TO
1 ☐ Home	1 ☐ Home
2 ☐ Pick up or drop off someone	2 ☐ Pick up or drop off someone
3 ☐ Work	3 ☐ Work
4 ☐ Work-related	4 ☐ Work-related
5 ☐ School	5 ☐ School
6 ☐ Shopping	6 ☐ Shopping
7 ☐ Social activities	7 ☐ Social activities
8 ☐ Recreation	8 ☐ Recreation
9 ☐ Eat out	9 ☐ Eat out
10 ☐ Personal business	10 ☐ Personal business
11 ☐ Other ____	11 ☐ Other ____

5. How long did this trip (one-way) take?
   Approximately ____ minutes
6. Comments ____

After completing, please tear off form at dotted line and drop the survey in the mail. Thank you.

FIGURE 2 External cordon survey travel questionnaire.

Laptop Computer

Recent studies have examined the use of laptop computers to collect traffic data, including license plate data (*7*). Proponents cite the cost savings inherent in direct data entry but recognize that recording rates may not be sufficient for high-volume roads (*8*). During the pilot survey, it was found that the laptop required typing skills beyond those available in the field crew. In addition, the recording rate was lower than for the audiocassette method. So, despite the considerable potential savings in the office processing of the license plate data, the laptop computer method was not used in the main survey.

Audiocassette

The audiocassette method was used successfully in the Boston region in 1977 to conduct the Central Artery Origin and Destination Study (*9*). More than 500,000 license plates were recorded during that survey.

During the pilot survey, it was found that one person taking care and equipped with a good-quality audiocassette recorder and microphone could record at a rate of 1,000 license plates per hour, on the basis of a 15-min test interval. The ability to endure such a high rate varied among field personnel. Both small headways and large gaps in the traffic stream tended to reduce the recording capacity. On the basis of the pilot survey, the audiocassette method was chosen for use at medium-volume locations.

However, problems arose during the main survey. The transcription rate from audiotape was lower than expected, declining to 80 license plates per hour for difficult tapes. In addition, the plate matching rate was significantly lower than for either the notepad or video methods. Therefore, the audiocassette method was replaced after about 2 weeks into the main survey; subsequently, the video method was used at medium- as well as high-volume stations.

It should be noted that a recent study has examined the use of automatic speech recognition for transcribing traffic data from audiocassettes in order to reduce costs (*10*) but without sufficient success to recommend the method at the time of that study.

Video Camera

Closed-circuit television was used as early as 1972 to record license plate data for an O-D survey in Rhode Island (*11*). The use of video cameras to record license plates for this survey was viewed initially with reserve. Previous applications exhibited a labor-intensive and costly process of viewing tapes and transcribing license plates. In addition, the previous applications, although successful, had been relatively site-specific and had involved elaborate and costly setups. For example, the Rhode Island study required extensive equipment assembly and programming, including dedicated platform vehicles, computer equipment, and loop detectors. Similarly, the field equipment used by the California Department of Transportation (Caltrans) to monitor compliance with high-occupancy vehicle (HOV) lane regulations included an instrument van and 110-V source of power (*12*). A more recent Caltrans license plate survey in the Bay Area used expensive off-the-shelf equipment, but the chosen methods required the use of one camera per lane from overhead positions, contributing to fairly high equipment costs (*13*).

In contrast to these applications, the authors were planning to acquire data at a large number of sites under budgetary restrictions that precluded the use of elaborate field equipment. Equipment had to be readily transportable by automobile from one site to another, intended for use by relatively unskilled operators, and inexpensive. It was also critical that the equipment would produce clear, easily readable images of rear license plates on vehicles moving away from the camera at high speeds, under a wide range of ambient light, and at locations where overhead camera positions were not available.

The preliminary training sessions highlighted the difficulty of using unaided visual methods such as notepad, laptop, or audiocassette in reading the rear license plates of vehicles moving away from the observer at high speed on high-volume roads. Therefore, despite reservations regarding the tape viewing and transcription process, the video method was chosen as the only practical way to record plates at the high-volume locations. And, as mentioned previously, the video method supplanted the audio method as the preferred method for medium-volume locations after the main survey was under way.

Plate Transcription and Sampling Methods

After the license data were recorded in the field, the forms (for notepad) and videotapes were collected for transcription. Because of the many plate formats for each state, particular attention was shown toward keying in the plates in the proper formats so that matching with the registry files could be accomplished.

For stations where the notepad and audio methods were used, all plates recorded were key-entered. A subsample of the key-entered plates needed to satisfy sample size requirements for each station was then selected for matching to obtain home addresses for the survey mailout. This was the most efficient method because of the higher proportional sample size at the lower-volume stations where the notepad and audio methods were used.

A different procedure was used at stations where video was used because of the higher cost of transcribing plates from the videotape and the lower proportion of plates needed to satisfy sampling requirements: only the required number of plates needed for matching were transcribed. This was done by first estimating the proportion of traffic required for transcription. For high-volume roads, returned surveys were required from 5 percent of the traffic; therefore, to account for nonmatches and nonresponse, 25 percent of the plates needed to be transcribed. Therefore, the transcriber key-entered all plates in the first 4 min of each 15-min period ($4/15 \approx 27$ percent). This was more efficient than transcribing every fourth plate to achieve the same sample because only 4 min of videotape had to be viewed, rather than the full 15 min. It should be noted that the sampling rate varied by time of day so that equal sample sizes were obtained for three periods: a.m., midday, and p.m.

By the end of the survey, techniques were developed that increased the speed of the video plate transcription process to the point where, when combined with the higher match rate on plates recorded by video, it was viewed as being less costly than transcribing from audiotape. A description of the video equipment used for plate transcription and transcription techniques is included later in this paper.

Plate Matching and Mailing of Survey Forms

Massachusetts, New Hampshire, and Maine plates were matched at CTPS to obtain the home addresses of vehicle owners; the Rhode Island Registry of Motor Vehicles matched the Rhode Island plates. Achieved match rates for video locations approached 85 percent; for notepad locations the match rate averaged 80 percent; for audio stations the match rate averaged about 70 percent.

The matching process appended the home address of the prospective respondent to the license plate files. The files were then transmitted to the mail-merge firm for printing and mailout.

Survey Results

Table 2 gives the number of forms mailed and returned and resultant response rates for each survey station. As shown, more than 110,700 survey forms were mailed; valid responses were received from 29,400 respondents, for an overall response rate of about 26 percent. The response rates varied by station, from a low of 16 percent to a high of 36 percent.

Estimated Survey Costs

The total survey cost, including both consultant and in-house labor and direct expenses, was estimated to be $270,000. Of this amount, direct expenses were approximately $75,000, including $52,000 for printing/postage and $11,000 for video equipment. The overall survey cost estimate includes all labor

TABLE 2 Number of Survey Forms Mailed and Returned

	Estimated Sample Size		Survey Forms			Proportion of Sample Requirement Met	
Survey Station	1987 ADT	1991 Count	Mailed	Returned	Response Rate	1987 ADT	1991 Count
1	1252	1444	5129	1384	27.0%	111%	96%
2	408	282	1795	364	20.3%	89%	129%
3	255	282	405	76	18.8%	30%	27%
4	368	283	1149	239	20.8%	65%	85%
5	255	245	1127	219	19.4%	86%	89%
6	393	109	690	188	27.2%	48%	173%
7	259	264	1274	394	30.9%	152%	149%
8	797	635	3944	982	24.9%	123%	155%
9	309	289	1720	521	30.3%	169%	181%
10	300	300	1759	417	23.7%	139%	139%
11	1620	1620	7530	1859	24.7%	115%	115%
12	332	263	1486	367	24.7%	111%	140%
13	615	555	3396	735	21.6%	120%	132%
14	299	438	1805	300	16.6%	100%	68%
15	279	232	1613	375	23.2%	134%	162%
16	389	383	1782	449	25.2%	115%	117%
17	1256	1480	6322	1762	27.9%	140%	119%
18	301	425	1506	403	26.8%	134%	95%
19	365	214	1169	379	32.4%	104%	177%
20	871	947	3682	1086	29.5%	125%	115%
21	215	265	941	266	28.3%	124%	100%
22	203	301	1258	375	29.8%	185%	125%
23	255	295	1091	299	27.4%	117%	101%
24	1118	1285	4788	1341	28.0%	120%	104%
25	305	429	1398	440	31.5%	144%	103%
26	729	740	3203	861	26.9%	118%	116%
27	486	455	2019	558	27.6%	115%	123%
28	1166	1185	4417	1125	25.5%	96%	95%
29	332	254	1381	445	32.2%	134%	175%
30	334	297	1057	171	16.2%	51%	58%
31	357	632	2616	632	24.2%	177%	100%
32	211	197	997	247	24.8%	117%	125%
33	243	234	1016	233	22.9%	96%	100%
34	227	237	1214	384	31.6%	169%	162%
35	505	610	2299	600	26.1%	119%	98%
36	316	404	1454	353	24.3%	112%	87%
37	271	374	1353	336	24.8%	124%	90%
38	1458	1543	6266	1448	23.1%	99%	94%
39	486	604	2164	435	20.1%	90%	72%
40	583	778	2655	634	23.9%	109%	82%
41	225	358	1345	389	28.9%	173%	109%
42	279	325	1341	421	31.4%	151%	130%
43	365	442	1610	422	26.2%	116%	96%
44	336	334	1594	435	27.3%	129%	130%
45	871	743	4502	1371	30.5%	157%	184%
46	203	383	907	202	22.3%	100%	53%
47	486	521	2194	683	31.1%	141%	131%
48	101	39	368	134	36.4%	133%	340%
49	648	777	2971	822	27.7%	127%	106%
50	671	725	3259	823	25.3%	123%	113%
TOTAL:	24,900	26,500	113,000	29,400	26.0%	118%	111%

and direct expenses required for survey design and planning; conduct of the pilot survey; all main survey field work, including vehicle occupancy and classification count data collection; survey data transcription, editing, and key entry; and preliminary documentation and analysis. (The estimated total cost does not include the cost of the ATR counts.) On the basis of a total of 29,400 completed surveys, the estimated unit cost was $9.18/completed survey.

CLOSER LOOK AT VIDEO METHODS

This section focuses on the techniques used to collect and transcribe license plate data using video equipment.

Field Equipment

Survey requirements were met by a digital imaging 8-mm camcorder intended for the high end of the consumer market. Although not cheap, at a retail price of approximately $2,300, the camcorder was more than adequate as a camera and an equally suitable playback device. The camcorder fully satisfied the requirements that had been established for its use: it was self-contained and easily portable; it provided clear, stable images of license plates during all daylight hours, even in rain; and it (and ancillary equipment) was readily available at local retail outlets at a cost within the budget.

Site Surveys and Camera Placement and Operation

The general location of each recording site was established by the overall survey design. Within each general location, it was necessary to identify a specific location at which the camera and its operator could be situated safely and at which an appropriate line of sight was provided for viewing traffic. Figure 3 is a copy of a site station map showing recommended camera locations and other features.

At all but one site cameras were set up on or adjacent to the highway shoulder between 10 and 20 ft from the pavement edge. Only traffic on inbound lanes was observed. A single camera was used to record traffic on one lane of two-lane

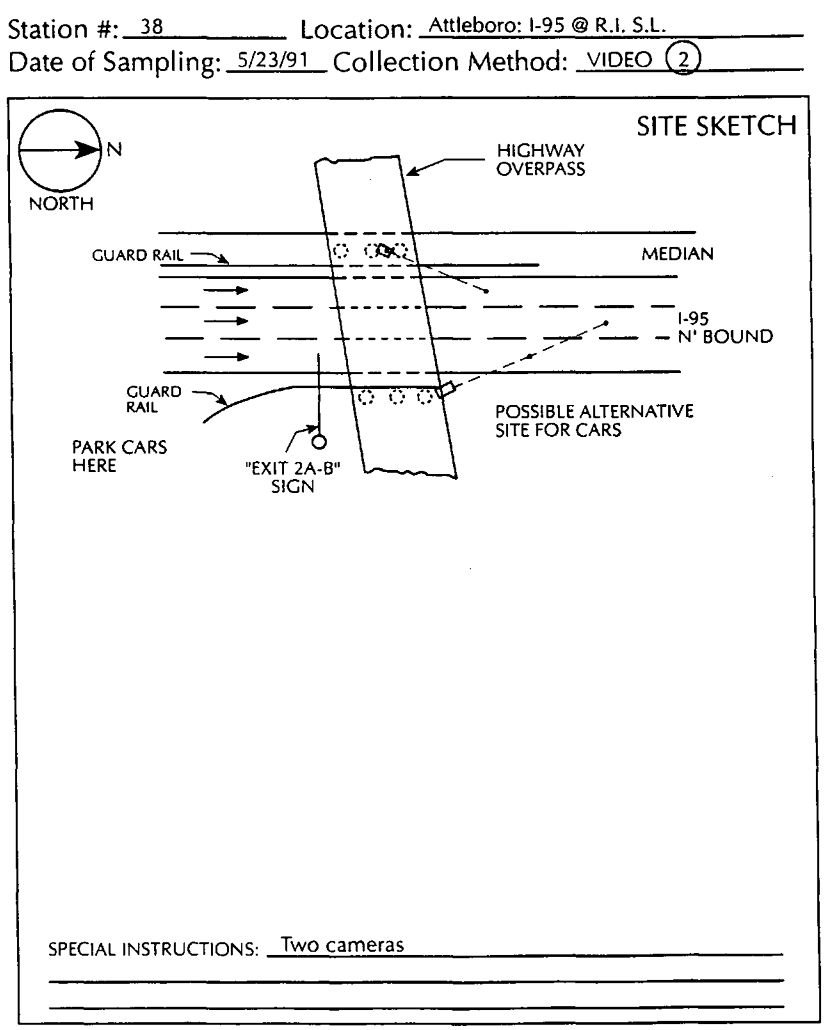

FIGURE 3 Typical external cordon survey station site map.

undivided highways and on both lanes in the inbound direction of four-lane expressways. On six- and eight-lane expressways, two cameras were used: one on the right shoulder and one on the median.

In those instances where only one lane of traffic was to be recorded, the point of sharpest focus was set at the center of the field of view at the center of the observed lane. When a single camera was used to record license plates in two lanes, the point of focus was at the joint of the two lanes.

Office Equipment for Plate Transcription

The camcorder was used initially as the playback device. It was first thought that its high-fidelity playback features would be important in ensuring jitter-free, clear license plate images in the freeze-frame display mode. It turned out that this level of sophistication was unnecessary and that a standard 8-mm player coupled to a remote shuttle controller and an ordinary television provided clear, stable video images of license plates for manual reading and transcription.

Special Techniques To Facilitate Transcription

The techniques just described, such as the use of one camera to videotape two lanes of traffic, and the sampling method significantly reduced the amount of time needed to transcribe license plates from the videotape. An additional technique was developed during the survey to aid the transcription of plates when traffic flow was light.

At high volumes the time intervals between observed vehicles are small, and no problem is experienced in acquiring enough records from a given sampling period. When traffic flows are light, however, the intervals between vehicles or platoons of vehicles are long, and much transcription time can be wasted searching for video frame sequences containing vehicle license plate images.

The most efficient procedure requires the camera operator to block the camera lens for a few seconds at a ½ min or so before the approach of a vehicle or a platoon of vehicles. This allows the viewer to display the tape in the fast-forward/play mode when the blocked (black) interval appears on the screen, shifting into the slow/play mode when images reappear.

Further Refinements

The video camcorder has proved to be a very useful tool for collecting license plate records in moving traffic; indeed, for high-speed, high-volume facilities the video camera appears to be the only feasible means to collect such data. The major disadvantage of the video method is the high cost of manual transcription of license plate data from videotape. The availability of systems that allow the automatic recognition of plate data from videotape will reduce costs substantially. Automation of the transcription process requires the acquisition of high-resolution video images and the availability of computer software capable of locating a license plate against its background and then "reading" the information on the plate.

Such systems recently have been used in Great Britain for O-D studies, but only to record and read European front license plates. Adaptation of these systems for use in this survey was not practicable within the time frame required. However, more recently, one of this paper's coauthors participated in a study to adapt these systems to record American plates. Preliminary results are promising: a 50 percent plate recognition rate was achieved. Further refinements are necessary, but this emerging technology will allow significant reductions in the cost of using video technology in surveys of this kind.

CONCLUSION

Several methods are available to conduct external cordon O-D surveys. For situations in which restrictions regarding traffic delays prevent the conduct of roadside interviews or handing out of postcards, this study has shown that video can be used to obtain the needed information, using off-the-shelf equipment and techniques to minimize costs.

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REFERENCES

1. *Urban Origin-Destination Surveys*. FHWA, U.S. Department of Transportation, July 1975.
2. McKinstry, D. L., and L. G. Nungesser. An Evaluation of On-Site Administered Origin-Destination Survey Methodologies: Postcard Mail-Back Vs. Interview. *Proc., 3rd National Conference on Transportation Planning Methods Applications*, April 1991.
3. Barton-Aschman Associates, Inc. *Phoenix Metropolitan Area External Trip Study, Volume 1: Survey Procedures Manual*. Report FHWA/AZ 86/226-1. Arizona Department of Transportation, Phoenix, Dec. 1986.
4. Stokes, R. W., and T. Chira-Chavala. Design and Implementation of Inter-City Origin-Destination Surveys. In *Transportation Research Record 1236*, TRB, National Research Council, Washington, D.C., 1989, pp. 23–33.
5. Stopher, P. R. Small Sample Home-Interview Travel Surveys: Application and Suggested Modifications. In *Transportation Research Record 886*, TRB, National Research Council, Washington, D.C., 1982, pp. 41–47.
6. Smith, M. Design of Small-Sample Home-Interview Travel Surveys. In *Transportation Research Record 701*, TRB, National Research Council, Washington, D.C., 1979, pp. 29–33.
7. Collura, J., P. McOwen, and D. Demko. *Field Testing of Automated Data Collection in Transportation*. University of Massachusetts, Amherst, Sept. 1984.
8. Bonsall, P. W., F. Ghahri-Saremi, M. R. Tight, and N. W. Marter. The Performance of Handheld Data-Capture Devices in Traffic and Transport Surveys. *Traffic Engineering and Control*, 1988, pp. 10–19.
9. Tippetts-Abbet-McCarthy-Stratton. *Boston Central Artery 1977 Origin-Destination Study*. Executive Office of Transportation and Construction, Commonwealth of Massachusetts, Nov. 1978.
10. Dew, A. M., and P. W. Bonsall. Automatic Speech Recognition—Evaluation of Automatic Transcription of Audio Tape for Registration Plate Surveys. Presented at the 3rd Annual Conference on Survey Methods, Jan. 1990.

11. Danielson, R. F., R. S. Brown, R. M. Hanchett, and W. C. Allinson. A Closed Circuit Television System for Traffic Surveys. *Traffic Quarterly*, Eno Foundation for Transportation, Vol. 28, Jan. 1974, pp. 87–100.
12. Billheimer, J. W., K. Taylor, and C. Slade. *Use of Videotape in HOV Lane Surveillance and Enforcement: Final Report*. Report DOT-T-91-02. Department of Transportation, State of California, March 1990.
13. Fahey, R. M., and B. B. Chuck. *License Plate Videotaping as an Origin and Destination Survey Method Along Highway Corridors*. Public Transportation Branch, District 4, California Department of Transportation, July 1989.

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