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Travel Time Data Collection Field Tests - Lessons Learned

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13. ABSTRACT (Maximum 200 words)

This report summarizes the process and lessons learned from the Standardized Travel Time Surveys and Field Test project. The field tests of travel time data collection were conducted in Boston, Seattle, and Lexington in 1993. The methodologies tested include: license plate matching using video cameras, license plate matching using portable computers, floating car, probe vehicle (cellular phone reporting), AVI equipped buses, and volume data collected from loop detectors. The ultimate goal is to develop a nationally uniform program of travel time data collection and reporting in support of congestion management, and trend and intercity comparison.

This document can be used by state or MPO planners as guidance for collecting travel time data. It includes examples and procedures on: survey design, methodology selection, equipment and staff requirements, step by step survey procedures, post-survey data processing, analysis, and report production. The document has detailed description and comparison of six data collection methods, focusing on their operational characteristics, strengths, weaknesses, costs, and effectiveness with respect to particular settings and sample size attainment. In conclusion, it stresses the importance of establishing standardized survey procedures and consistent data collection and processing practices in order to achieve overall efficiency and effectiveness in travel time data collection and applications.

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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectare (ha) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gm)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x - 32)(5/9)]°F = y°C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5)(y + 32)]°C = x°F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0			1			2			3		4		5
CENTIMETERS	0	1	2	3	4	5	6	7	8	9	10	11	12	13

QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10286.

Updated 9/29/95

Table of Contents

List of Figures

List of Tables

Travel Time Data Collection Field Tests
-
Lessons Learned

Executive Summary

Travel time is considered the single most effective measure for transportation system performance and congestion. However, travel time data have not been collected consistently or sufficiently in most urban areas. A survey conducted by the Federal Highway Administration (FHWA) in 1991 indicates that: 1) little effort is being expended nationally to collect travel time data; 2) whatever data exist are collected sporadically; and 3) data are not collected in a manner which would allow meaningful intercity comparisons or trend analyses.

Highway engineers have traditionally used floating car, aerial photography, or radar methods to capture average car flows, traffic density, and travel speeds. Travel surveys are performed to obtain samples of trip time and mode selection, and the data are collected via trip diaries or traveler interviews. More recently, spot speeds along with other traffic parameters such as volume and lane occupancy can be obtained via loop detector or video surveillance systems. License plate matching is also used to track vehicle license plates at various observation locations and thus capture the elapsed times across roadway segments.

Travel time can also be estimated by travel models using volume, density, and roadway capacity as key predictors. Speed formulas are specified as a function of facility type, roadway geometry, link attributes, and most importantly, volume and capacity ratio. Calibrating a speed and volume relationship requires not only a thoroughly defined model specification but also a panel of data including travel time and speed measurements, as well as the associated traffic and roadway attributes.

Whether travel time is derived from field observations or model-based projections, a multi-step process of sample design, data collection, data processing, and analysis is required. Because of its dynamic and dispersive nature, especially during congestion, a few samples of floating car measurements or isolated spot speeds simply cannot address the complexity of traffic congestion over a transportation network. The need to collect better and more systematic data is evident.

In order to evaluate the cost and effectiveness of a range of alternative methods for travel time data collection, the Federal Highway Administration initiated a travel time survey and field test project in 1993. This project identified and tested six data collection methods: license plate matching with video, license plate matching with computer, floating car, probe vehicle, automated vehicle identification (AVI) bus, and loop detector. Tests were performed in Boston, Seattle, and Lexington, Kentucky in the summer and fall during 1993.

A total of 15 freeway corridors and principal arterial streets (5 in each city including the route from downtown central business district [CBD] to airport), ranging from 3 to 15 miles each, were surveyed in the field tests. Each route was divided into 3 segments and each segment was defined by two adjacent observation locations. Two or more data collection methods were usually performed simultaneously on the same route for comparative analyses. Multiple lanes (up to 4 lanes) were covered, with each lane assigned to a surveyor with a portable computer, or video camera set up on an overpass bridge, or roadside, overlooking the traffic. A floating car with a driver and recorder would report the times when passing through the observation sites and any additional points along the route. Loop detector locations were identified on the survey routes and volume and occupancy data were collected. Each survey day was divided into two survey sessions, 2 to 6 hours in each of the peak traffic direction. Each route was surveyed for at least one day and for selected routes up to three days. As a result of the field tests, 1,500 lane hours of license plate videotapes and tens of thousands of computer records of license plate numbers, volume counts, occupancy, or floating car records were collected.

Data processing, analysis, and report generation require a thoroughly designed process in each step. Computer software programs and procedures were developed for processing multiple data sources and data types. Data screening criteria were developed and inserted in data processing steps to eliminate outliers and false matches. A multi-layer data structure was created to store and report the information by location, date, time period, direction, and methodology. Standard reports were developed to present summary information of average and distributed travel times and speeds over specific route segments and time periods. Sample rates and summary statistics were calculated for methodology comparisons and data analyses.

Methodology evaluation focused on: sample rate, accuracy, operational strengths and limitations, sample efficiency, and cost. The strengths and weaknesses and a generic cost analysis of each test methodology are presented in this report. When permitted by sample size, a series of reports and graphics can be produced to demonstrate the type and range of travel time and speed information and variations. These data can be used as the basis for further development of transportation system performance measurements.

In summary, there is no conclusion of a single best methodology for all occasions. Selecting methodologies for travel time data collection relies largely on metropolitan planning organizations (MPOs) to identify data needs and the priority of data collection. The key factors come down to sample size requirements and sampling efficiency of the techniques. A floating car survey is easy to perform but requires a sound sample plan. It is most suitable for a network with moderate traffic conditions. License plate matching (either video or portable computer) shows promising results in gaining large sample size, but also leaves ample room for more improved data gathering and processing techniques. One advantage of the video method is the ability to retain traffic scenes on video tapes for other data analyses (traffic count, density, vehicle mix, and traffic density). The AVI bus has a high level of accuracy and recognition rate but depends on infrastructure location and a fleet of vehicles to provide a meaningful sample base. The Probe vehicle method provides a larger sample set and route coverage than a traditional floating car method but requires a better designed communication and data receiving process to raise the accuracy of data collection.

Other conclusions resulting from the field tests and data collection process include:

- A multi-step process for travel time data collection is required that includes: survey and sample design, methodology selection, survey planning, field data collection, data processing, analysis, and report production.

- The scope (number of route segments, lane miles, survey days, and lane-hours) and schedule should be defined and coordinated by local transportation agencies and MPOs.

- Sample size requirements and sampling efficiency are the key factors in selecting appropriate methodologies for travel time data collection. There is a need in research to develop guidance on minimum sample size requirements for travel time data collection.

- Consistency and regularity of travel time data collection is essential for traffic and congestion monitoring, travel models improvement, and many other applications in transportation planning and management.

- Standardized survey procedures (e.g., forms, synchronized clocks, labeling and cataloguing, survey logs, and data formats) are crucial to the quality of data collection and the efficiency of data processing.

- Standard data formats and data processing procedures will minimize data errors and the data processing time.

- A standardized program for travel time data collection and reporting will be useful for national travel time trend analyses and intercity comparisons.

1 Introduction

Consistent and continuous travel time data collection can provide valuable information for monitoring transportation system performance and congestion. By definition, travel time is the amount of time of vehicles traversing a segment or the route. Average speed is computed by taking the length of the highway or street segment under consideration and dividing it by the average travel time of that segment.[1] To measure travel time systematically, the total travel time or delay in congestion can be compared with the normal travel time to determine the level and effects of congestion. A standardized travel time data collection program can be used for traffic and congestion monitoring, trend analyses across roadways or intercity comparisons. Accurate travel time and speed measurement are also essential in travel demand forecasting, traffic simulations, fuel and emission estimation, and air quality models.

Although travel time is considered the most effective measure for congestion, travel time data have not been collected consistently and sufficiently in practice. Traditionally, transportation planners and highway engineers use floating car methods and traveller interviews to collect origin-destination (O-D) or link travel time on urban roadways. More recently, loop detectors and video surveillance systems are used to detect spot speeds along with other traffic parameters such as volume counts, density, and vehicle classification. While these techniques may be most commonly used in collecting travel time and speed data, they are also hindered by lack of sample size and poor representation in capturing the scope and range of various traffic conditions.

License plate matching is another way of collecting link or a route travel time data. The concept of this method is to capture vehicle license plates of traffic streams between a pair of upstream and downstream locations over any route segment. The elapsed time is calculated whenever there is a matched plate captured at both locations. With the advent of portable computers, video imaging and sensing technologies, automatic vehicle identification (AVI) device, the data collection and processing for license plate matching (or an equivalent Vehicle ID) become more possible. It offers a promising approach in gathering larger and perhaps more efficient sample size of travel time data for transportation planning and traffic management applications.

In order to test the cost and effectiveness of a range of existing and emerging data collection techniques and methodologies, a field test of travel time data collection project was conducted in Boston, Seattle, and Lexington, Kentucky in 1993. This document summarizes the field test process and lessons learned from the study. Chapter 1 describes the background of the study, including selection of the participating MPOs for the field test, and methodology selection. Chapter 2 provides a description of the six methodologies tested. It summarizes, by methodology, the key results and findings of the field tests and describes the concept and design of the methodology, field operations, equipment and costs, data processing, sample rate, and its strengths and limitations. Chapter 3 details the field test design and process. It describes the five steps in conducting a travel time survey: survey design, survey plan and schedule, training/pilot test, field survey/data collection procedures, and data collection of roadway attributes. Chapter 4 describes the standardized data processing, analysis, and reporting of travel time data based on a unified database structure. Chapter 5 presents the conclusions.

1990 Urban Congestion Monitoring Work Shop

In May 1990 the FHWA sponsored a "National Urban Congestion Monitoring Workshop."[2] The workshop participants made the following priority recommendations:

- An HPMS-based congestion monitoring activity should be provided for reporting for urbanized areas with a population of 200,000 or more. Monitoring of urban congestion must provide detail for all major urbanized areas nationwide.

- National travel time data are required to permit trend analysis of travel times by urban area groups. A number of possible methods are available for consideration and could be identified and synthesized in a TRB synthesis-type project. A number of metropolitan areas/cities do not conduct frequent travel time surveys. A more uniform and rigorous random sampling method could be developed to obtain comparison purposes. An option would include examining specific generic corridors for their travel time trend patterns, e.g., city hall to the airport or one around a beltway. An ideal system would monitor average travel times by the major flow patterns, suburb to city center, city center to city center, etc. The design, synthesis, and development of collection techniques are viewed as priority items.

1991 FHWA Surveys of Travel Time Studies

In response to this recommendation, in 1991 the Office of Highway Information Management issued a call for copies of urban travel time studies in the United States. The reports received showed a variety of methods available to perform and present travel times, although only a few are used regularly. These studies were usually done at irregular intervals for MPOs. The responses showed that (1) little effort is being expended nationally to capture travel time data, (2) that the data are collected sporadically, and (3) that they are not collected in a manner which would allow meaningful intercity comparisons nationally.

1993 Field Tests

A Standardized Travel Time Survey and Field Tests Project[3] was initiated by the Office of Highway Information Management of FHWA in 1992. Field data collection and tests of survey methodologies were conducted in the summer and fall of 1993 in Boston, Massachusetts, Seattle, Washington, and Lexington, Kentucky. The Volpe National Transportation Systems Center (Volpe Center) administered the project for the FHWA and coordinated research activities during the field tests with the three selected MPOs and corresponding agencies. The principal agencies participating in the field tests were:

- Boston Central Transportation Planning Staff (CTPS)
- Boston SmartRoute Systems
- Puget Sound Regional Council (PSRC)
- Washington State Transportation Center (TRAC)
- Lexington-Fayette Urban County Government (LFUCG), Traffic Engineering Division

Professor Paul Shuldiner of the University of Massachusetts Amherst and Mr. Sal D'Agostino of Computer Recognition Systems (CRS) teamed up to assist in the methodology design and training of license plate matching method using video. The CRS License Plate Reading System (LPRS) was selected in a contract for the testing of automatic processing of videotaped vehicle license plates using the machine-vision system.

Selection of MPOs

The FHWA extended an invitation, through their regional offices, to any MPOs who desired to participate to submit a letter of interest. 32 MPOs expressed high interest in participating in the field tests and improving travel time data collection for their needs in congestion management requirements and regional transportation planning activities. Interested MPOs were also asked to provide the following information about their experience in collecting travel time data:

- Did they have a plan or a regular program to collect travel time data?
- What has been the geographic coverage of previous or planned travel time surveys (central Business district, entire urban area, specific corridors, etc.)?
- What data collection methods were used for travel time surveys (floating car, license plate matching, and interviews, etc.)?
- What computer hardware and software were used to collect, store, or process the travel time data?
- What mapping capabilities were used to identify route information? Did the MPO have a geographic information system (GIS) to support the display/analysis of travel time data?
- Was there an intelligent transportation system (ITS) project or operational testing being conducted in the MPO's area that may provide advanced technologies in collecting travel time data (e.g., highway surveillance, probe vehicles, automatic vehicle location (AVL), real-time travel information)?
- Was the MPO a participant in such an ITS project? If not, was the MPO willing to coordinate with the participating agencies to conduct a travel time survey?

Of the 32 cities and agencies who responded to the FHWA request for participants, only three were selected. The following criteria were used to select the final three participants:

- Two large metropolitan areas with recurring congestion problems;
- One small urbanized area with population over 200,000;
- Advanced traffic management systems, ITS, or travel demand management (TDM) programs in

use in the area that could provide valuable input to travel time data collection;
- Highly interested and committed to participate in the project;
- Highly qualified technical staff and flexibility to coordinate with other agencies to support this project;
- Regular contract arrangements with or experience in hiring local university students to participate in field surveys; and
- Airport within or adjacent to the metropolitan area.

Boston Central Transportation Planning Staff (CTPS), Puget Sound Regional Council (PSRC), and Kentucky's Lexington-Fayette Urban County Government (LFUCG) were the final three selectees for the travel time study, with San Francisco's MTC and Knoxville's MPC as alternative candidates.

The three MPOs selected met all the of the criteria and were representative of the nation in terms of geographic location, size, and urbanization characteristics. All three had recurring traffic congestion problems and were strongly motivated to participate in the travel time study. Both Boston and Puget Sound had very strong technical staff and on-going ITS and traffic monitoring programs that could provide useful input to this project. Lexington, with its 250,000 population, was representative of a medium-size urban area. Its extensive loop detector network and surveillance system enabled the whole range of alternative data collection methods (license plate matching with video and portable computer, floating car, and loop detector volumes) in the field tests.

Selection of Methodologies

A review of literature and current data collection practices was conducted as part of the project to identify existing and new methodologies for travel time and speed data collection. Table 1-1 describes the characteristics of nine methodologies. The first six methodologies were tested in the project.

Six methodologies were included in the field surveys. Each MPO was asked to field test one or more of the following methodologies:

1. License Plate Matching with video
2. License Plate Matching with portable computer
3. Floating Car
4. Probe Vehicle
5. AVI (automatic vehicle identification) bus
6. Loop Detector

Table 1-1. Overview of Travel Time Survey Methodologies

Methodology	Data Type	Characteristics	
License Plate Matching - Video	Link	**Sample:** ▸ Capture up to 60% of vehicles passing lane, 1800 plates/hour w/plate reader ▸ Capture 90% of plates, w/ manual read from video; 10 hours per 1 hour of tape ▸ Full plate **Limitations:** ▸ Capture through traffic only ▸ Difficult to trace origin, destination, and direction ▸ Equipment intensive for data collection	**Training:** ▸ High operator skill required **Technology Readiness:** ▸ Currently being tested **Other Traffic Data:** ▸ Traffic volume ▸ Vehicle mix ▸ Headways/Density
License Plate Matching - Portable Computer	Link	**Sample:** ▸ Degradation of observer performance over time ▸ Typically partial plate **Limitations:** ▸ Same as above ▸ High speed limitation ▸ Labor intensive for data collection	**Training:** ▸ Moderate operator skill level required **Technology Readiness:** ▸ Currently available
Floating Car	Link O-D	**Sample:** ▸ Typically 6-12 data samples collected per segment; ▸ No limitations on segment selection **Limitations:** ▸ Sample size limitation ▸ Labor intensive for data collection	**Training:** ▸ Minimal training required **Technology Readiness:** ▸ Currently available **Other Traffic Data:** ▸ Delay ▸ Speed cycles
Probe Vehicle	Link O-D	**Limitations:** ▸ Data collection procedure needs to be better developed ▸ Labor intensive for data collection and processing ▸ Quality of data may not be consistent **Training:** ▸ Minimal training	**Technology Readiness:** ▸ Currently available **Other Traffic Data:** ▸ Delay ▸ Speed cycles
AVI	Link Spot	**Limitations:** ▸ Lane discrimination available in some options ▸ Infrastructure dependent	**Technology Readiness:** ▸ Currently available
Traffic Detectors (loop detectors, etc.)	Spot	**Limitations:** ▸ Infrastructure dependent ▸ Accuracy level is not consistent	**Technology Readiness:** ▸ Currently available **Other Traffic Data:** ▸ Traffic volume ▸ Lane occupancy

Table 1-1. Overview of Travel Time Survey Methodologies, Continued

Methodology	Data Type	Characteristics	
AVL (GPS, etc.)	Link O-D	**Limitations:** ▹ GPS accuracy may not be sufficient ▹ Infrastructure dependent ▹ Customized software program for travel time data collection needs to be developed	**Technology Readiness:** ▹ Currently being tested
Surveillance (fixed location)	Spot	**Limitations:** ▹ Limited to spot speed ▹ Equipment or infrastructure dependent	**Technology Readiness:** ▹ Currently available **Other Traffic Data:** ▹ Traffic Volume
Traveller Interview	O-D	**Limitations:** ▹ Response rates ▹ Data accuracy	**Technology Readiness:** ▹ Currently available

The methodologies selected in the surveys included both conventional and new technologies that are now being used in practice. The surveys emphasized route/segment travel times that would in turn produce average route/segment speeds. Among the six methods, license plate matching using video cameras and an automatic license plate reading system were chosen to be tested in all three cities on all fifteen selected routes. As continuous data and traffic scenes could be captured using video, this method was selected as the baseline methodology for the field tests. Data collected on videotapes presented a valuable data source for future research. The database established from the license plate matching was used to compare the data collected by each of the other methods tested.

Matching MPOs to methodologies for testing depended on the capabilities and resources of the MPOs, their current methods of obtaining travel time data, their current plans/needs for travel time survey data, and any existing ITS activity in their area. A summary of the selected methodologies by city is shown in Table 1-2 below.

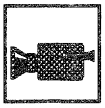
Table 1-3. Selected Methodologies

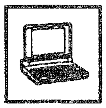
Methodology		Boston	Seattle	Lexington
License Plate Matching	Video	√	√	√
	Portable Computer		√ Palmtop	√ Laptop
Floating Car				√
Probe Vehicle		√		
AVI			√	
Loop Detector			√	√

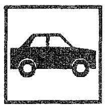
Surveys were performed on five selected highway corridors or principal arterials, including downtown business district (CBD) to the major airport, in each of the three cities. Two or more methodologies were usually performed simultaneously, covering the same route, distance, and time periods. Comparative analyses were thus performed across the methodologies, cities, and roadway types. Statistical analyses of travel times and speeds were conducted and focused on sample issues and variance over different speeds and time periods.

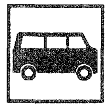
2 Methodology Description

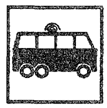
The six tested data collection methods for travel time, speed, and volume data are described in this chapter:

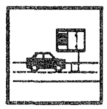

License Plate Matching - Video


License Plate Matching - Portable Computer


Floating Car


Probe Vehicle (Cellular Phone Reporting)


AVI

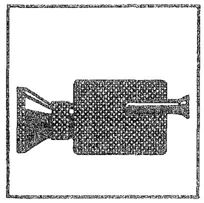

Loop Detector

Data are collected manually by observers in test vehicles or via video cameras, portable computers, or loop detectors at predesignated survey locations and existing roadway segments. The route and segment travel time and speed observations are emphasized in all tested methodologies although origin-destination (O-D) travel time, spot speed, and volume data can also be collected with these techniques.

The methodology description includes:

- Methodology concept and design
- Field operations
- Data processing
- Equipment requirements
- Costs
- Sample rate
- Key operational features
- Methodology strengths and limitations

License Plate Matching - Video



Methodology

License plate matching with video cameras involves the recording of vehicle license plates at an upstream cross section of a roadway and matching them with license plates recorded at downstream locations. Cameras, situated on bridges spanning the roadway or at roadside locations, record the plates of vehicles in the traffic stream moving past the location in a single traffic lane and in a single direction of travel. Elapsed times are calculated and recorded for each matched plate. The number of segments, lanes, and hours which can be covered by this methodology are determined by equipment, personnel, or other cost factors.

Field Operations

This technique involves a 1-2 person team for each observation point — start, midpoints, and end of the study route (at least 2 points are required). Each observation point may cover all or some of the lanes of traffic; one camera set-up is required per lane. Low-volume routes or single-lane coverage may require only one person. Survey hours can be selected to obtain samples to capture time of day (AM peak, PM peak, and off peak) and day-to-day variations.

Data Processing

The processing of the video data (tapes made of the traffic stream) is a multi-step effort:

Tape Processing. The tapes made of the traffic stream are processed through a machine vision system that automatically reads the license plates captured on video tape. Tape data can also be extracted manually. The tape processing of the video test data was performed by Computer Recognition System's License Plate Reading System (LPRS). The system's output consists of a list of plate numbers associated with location and time stamps. Plate data from tapes can also be extracted manually.

Plate Matching. The license plates collected from multiple lanes at one location are matched with the plates at the following downstream location. This process is performed for each consecutive route segment. The lapsed time is recorded, and speeds are calculated based on the known distance for the segment. A series of data screening programs are utilized to perform license plate matching and to produce a database of travel time records.

Data Analysis. Data is filtered to remove outliers and false matches. The remaining valid records are used to produce route summary and detailed route segment reports including sample rate, maximum, minimum, and mean travel time and speed, and standard deviation for each time period. Group records are assigned and sorted by date, route, direction, route segment, and time period (15- or 30-minute time slice).

Equipment Requirements and Costs

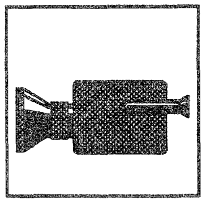
A complete equipment set is required for each station. The major items required to cover a three-lane segment for 4 hours include:

	Unit Cost
Video Camera (6)	$ 2,300
Tripod (6)	$ 200
Monitor (2)	$ 200
Marine Battery (6)	$ 70
Video Tapes (24)	$ 12

Total Data Acquisition Costs

The total costs are estimated on the basis of 10 days of survey on a generic route. The costs include field

License Plate Matching - Video



surveys, equipment and supplies, and video license plate processing. Data processing and report generation are not included.

Generic Route Description: a 10-mile route, 10 days, 3 segments, 4 observation sites, 8 hours/day, and 3 lanes.

Labor:	$ 26,880
Equipment and Supplies:	$ 41,760
Plate Processing:	$ 96,000

Sample Rate

- Capable of capturing 50% of vehicles passing.
- Field test results produced 40-100 samples per 15-minute time period for a three-lane freeway segment.
- The license plate reader can process 1800 plates per hour (1 second/plate to process). Manual reading can capture 90% of the vehicles passing, but requires 10 labor hours to process one hour of video tape.[4]
- Data showed acceptable average lapsed times and standard deviations.

Operational Features

- Equipment intensive.
- Field training and special skills required.
- Infrastructure independent.
- Particularly well-suited for highway use; can capture plate data at speeds up to 100 MPH.
- Could be permanently installed for unmanned operation with the appropriate remote controls (focus, angle, aperture, and focal length), transmission, housing, and lighting.

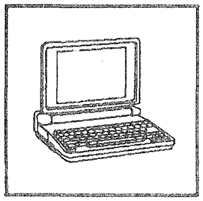
Strengths

- Full 6-digit license plate numbers/characters can be collected, reducing the possibility of false matches.
- No degradation of performance over time.
- Does not directly interfere with moving traffic.
- Captures large and more evenly distributed samples over vehicle flows.
- Provides sufficient samples for hour-to-hour day-to-day comparisons.
- Electronic license plate recognition is the least labor intensive technique for license plate capture. No manual data recording or transcribing is required.
- The video tape permanently captures the traffic scene and can be reviewed for extracting other traffic parameters (volume, lane occupancy, vehicle classification, headway, etc.).

Limitations

- Constraints on camera location: angle of camera to traffic, location of the sun, road geometry, etc.
- Limited success in low light situations as well as adverse weather conditions.
- Plate template is calibrated to recognize certain plate conventions. Out-of-state, commercial plates or plates with poor contrast may not be captured.
- Video license plate processing is not a standardized procedure. Only a limited number of companies offer either manual or automated tape processing services. Taping requirements are different from one service provider to another due to differing video recognition technologies.
- Video imaging technology is still evolving and is market driven. Applications are more advanced and more widely used overseas than in the US.
- Public's privacy concerns.

License Plate Matching - Portable Computer



Methodology

This field data collection method has became available with the advent of the portable PC (laptop/palmtop). License plate matching using portable computers involves the recording of vehicle license plates at an upstream cross section of a roadway and matching them with license plates recorded at downstream locations. Operators equipped with portable computers at the roadside or on bridges spanning the roadway enter the plate numbers of vehicles in the traffic stream moving past the location in a single traffic lane and in a single direction of travel. Partial plates (e.g., 4 instead of the full 6 characters) are usually entered to increase the license plate capture rate. The number of segments, lanes, and hours which can be covered by this methodology is limited only by equipment, personnel, or other cost factors.

Field Operations

A team is assigned to cover each observation point — start, midpoints, and end of the study routes (at least 2 points are required). Each observation point may cover all or some of the lanes of traffic, one observer per lane is required. Observers enter target license plates of passing vehicles directly into a laptop/palmtop computer which automatically provides a date and time stamp for each record. Computer clock times are synchronized across all lanes at all locations before the survey. An additional observer may be assigned to each team as a back-up/reliever.

Data Processing

At the end of each survey session, data entered in the portable computers are downloaded into a main laptop computer. A standard license plate matching process is used to match the license plates collected at one location with the plates at the downstream location. A series of data screening procedures to eliminate false matches, resulting from partial-plate matching (see Chapter 4), are performed to provide a valid data set of travel time records. The lapsed times and speeds are calculated on the basis of the known distance between points. Standard route and segment reports are produced to include: sample rates, maximum, minimum, and mean travel time and speed, and standard deviation in each time period.

Equipment Requirements and Cost

Laptop/Palmtop	$ 2,500/$ 600
Connectivity Pack Software	$ 80

Generic Route Costs: Based on one 10-mile route, 10 days, 3 segments, 8 hours/day, and 3 lanes (data processing and reporting costs are not included).

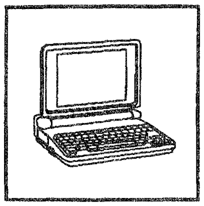
Labor:	$ 14,400
Equipment and supplies:	$ 21,600

Sample Rate

- Captured nearly 60% of the volume at some locations using partial plate recording (4 characters).
- Recording rate on freeways varied dramatically over the 4-hour periods and among individual performers.
- Resulted in 100 to 200 matches per hour on a 2-lane arterial segment. This is considered a highly sufficient sample rate for travel time analysis.

Strengths

- Equipment easy to use and very portable.
- Requires minimal training.
- Provides a representative sample of the entire driving population.

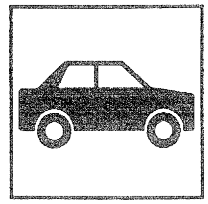


- Infrastructure independent.
- Particularly well-suited for arterial use.
- No manual data transcribing is required.

Limitations

- Could be labor intensive for multiple lane and location data collection.
- Partial 4-digit license plate collection increases the possibility of false matches.
- Degradation of observer performance over time.
- Ineffective for high speed highway locations.
- Results can be adversely effected or prohibited by severe weather conditions.
- Delay data not captured - aberrations rely on research and operator notes for viewable roadway area.

Floating Car



Methodology

The floating car method of collecting travel time and delay data affords considerable flexibility in evaluating the quality of traffic flow. The floating car method, one form of the test car methodology, involves driving a vehicle along the study route in the traffic stream and recording the time it takes to travel between predefined segments. The test car moves with the traffic passing as many vehicles as pass it. Other possible operating conditions for the test car method are:

- Average-Car technique — the vehicle travels according to the driver's judgement of the average speed of the traffic stream.
- Maximum-Car technique — the vehicle is driven at the posted speed limit unless impeded by traffic conditions.[5]

Before the test runs are begun, the beginning, intermediate and end points are identified so that the test car may be driven past the locations in accordance with the selected operating condition. In addition, major intersections or other control points are selected along the study route as reference locations. Time readings are taken at these locations to permit the development of travel speeds by sections along the traveled route.

Field Operations

The test car is driven to a point that is located a little in advance of the start of the study route. At this point, the operator or recorder fills in the date, route, and other identifying information on a data sheet.

As the car is driven past the beginning point, the recorder uses a stopwatch to note the time. The vehicle is driven the length of the study route according to the selected operating condition. Time readings are taken as the vehicle passes the predetermined check points. As the test car passes the end of the study route, the recorder stops the stopwatch and notes the total time for the test run.

If delays are being recorded, when the test car is stopped or forced to travel slowly, the recorder can use a second stopwatch to measure the duration of each delay. The location, duration, and cause of each delay are recorded in the appropriate places on the data sheet. While travel time delays were observed and noted during the course of the test, a delay study was not undertaken.

While travel time and delay data were collected manually for this test, data can also be collected in the floating car operation by various recording devices such as voice recorders, portable computers, voice recognition devices, or in-vehicle data loggers.

Data Processing

The recorded times at each check point are manually transcribed from the field data forms and entered into a computer, where a program converts the data into the elapsed segment times and average travel speeds for that segment. The complete list of floating car trip records are also generated to include all the check points and recorded times.

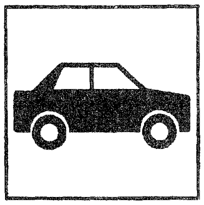
Equipment Requirements

- Test vehicle
- Stopwatch/Clock
- Data collection forms/Notepad

Operational Costs

Generic Route Costs: Based on one 10-mile route, 10 days, 3 segments, 8 hours/day, and 3 lanes.

Labor: $ 7,680 ($ 15,360 if 2 persons/car)
Equipment: Test car or rental



Other Costs: Gasoline, mileage

Sample Rate

- Sample is usually small with this method.
- Sample is usually limited to a few measurements per day.

Key Operational Features

- Typically one driver and one recorder for each test car. Possible for driver only with a pre-programmed in-vehicle device.
- Multiple runs by each test car can be implemented for short route.
- Suitable for any roadway type (freeway or arterial).
- Limited sample points for the same time duration.

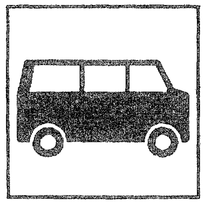
Strengths

- Techniques easy to implement (anywhere and anytime).
- Training and preparation requirements are minimal.
- Flexibility to collect additional data elements: travel time, running time, stop and delay, general traffic conditions, and incidents.

Limitations

- Limited by sample size for statistically significant measurements.
- Data can be affected by driver behaviors.
- Limited for multiple runs during congestion periods.
- Labor intensive for large scale implementation.
- Cost/unit sample collected is high. The cost of labor in relation to the amount of data collected is high.

Probe Vehicle (Cellular Phone Reporting)



Methodology

The probe vehicle methodology is a type of floating car survey. However, it does not rely on the small number of test cars typically used in floating car surveys. Instead, this method relies on an organized group of private and/or public vehicle drivers to call in their times when passing predefined locations to a data collection center. Unlike a floating car method in which the operator records the information manually in the vehicle, the driver reports the data in real time to the data receiving center using a cellular phone or two-way radio.

Field Operations

In the Boston test, Smart Route Systems, a traveler information service, provided for the use of a portion of its 150 vehicle fleet which routinely covers over a dozen major routes in and around Boston. These probes usually make two runs per day, one each in the AM and PM peak-hour direction. In order to spread the probe vehicles throughout the peak and non-peak periods, drivers were selected on the basis of their work location, home location, and work hours. The test fleet also included approximately 70 Logan Airport Express buses, which have regularly scheduled runs on the half hour, from surrounding communities to the airport. The three bus routes selected for the test all go through the downtown Boston area and tunnel to the airport.

Reporting locations were predetermined along the study route. During system operation, drivers called the central communications center as they passed each reporting location. An operator at the center manually recorded the driver's identification, location, and the time. This data could have been recorded directly into a database.

Each probe in the study had access to a cellular phone which was used to call into the central location where their times were recorded. Buses communicated their times and locations via 2-way radio. If cellular phone lines were busy when the drivers attempted to report a location, the call would have to be replaced. In this event drivers were asked to note the actual time they passed the reporting location.

Drivers were instructed to drive naturally, at the prevailing speed of the traffic flow, and to change lanes whenever appropriate.

Data Processing

Data was manually entered into a database and sorted by date, time, direction, and location. Standard reports were produced to show sample rate, mean travel times and speeds, and standard statistics. A separate report can also be produced to list the whole trip records.

Operations Requirements

- Data communications center
- Organized fleet of public/private vehicles
- Communications device (cellular phone/2-way radio)
- Synchronized clocks
- Data communications formats and procedures

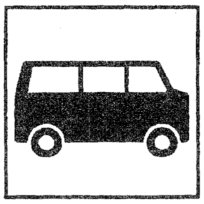
Sample Rate

The probe method may provide more samples in consecutive days, especially during peak hours, than the traditional floating car approach.

Key Operational Features

- Utilizes cellular phones for real time travel time reporting.

Probe Vehicle (Cellular Phone Reporting)



- Requires special training for familiarizing drivers with the check point locations, reporting time, and routine procedures.

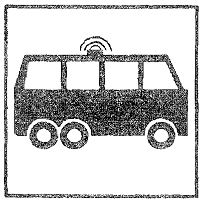
Strengths

- Allows more data to be collected than the floating car technique, but probably with a lesser degree of accuracy.
- Allows for data collection on a regular basis.
- Can support collection of delay/accident data.

Limitations

- Time accurate only to within a minute or two.
- Drivers missing check-in points.
- Operator at the communications center may receive several calls at the same time, causing the drivers to redial to transfer the information.
- Variations in travel times can occur when drivers are unable to call in exactly at the specified reporting locations.

Automatic Vehicle Identification (AVI)



Methodology

The use of automatic vehicle identification (AVI) for travel time data collection requires: 1) vehicles each equipped with a transmitter which has an electronically coded ID, 2) sensors placed in the roadway which can detect the AVI vehicles when passing by the sensor locations, and 3) recorders which record the vehicle IDs and time stamps. This methodology, similar to license plate matching, captures vehicle IDs with time stamps at fixed locations. The difference is that only vehicles with AVI transmitters are targeted for data collection, and a high percentage recognition rate is achieved. This AVI use is like electronic registration number recognition used in electronic toll collection applications. It offers the ability to identify uniquely and automatically a vehicle as it is moving at normal highway speed along the road.

Field Operations

The inductive loop-based AVI system used for this test was an established system installed on a 7-mile section of Route I-5 North in the Seattle area. 49 busses were equipped with a 4-1/2 inch vehicle transmitter (in this case a puck, although many types of AVI tags are available) which provides inductively coupled communication through a standard roadway loop to a vehicle detector/receiver. The puck continuously transmits a unique coded radio frequency (RF) message, used for vehicle identification, through any vehicle detection loop to a digital detector containing a receiver capable of decoding the transmitted code. As the vehicles equipped with transmitters pass over the sensor loop, they are identified by code number (this acts as the vehicle ID), time and date are stamped and recorded in the receiving unit located in roadside cabinets near the loops. The detector/receiver can be interfaced with a computer directly via a RS-232 serial port or via modem over phone line transmission. This system accurately detects/identifies vehicles for up to speeds of 85 MPH.

Other AVI alternatives include several variations for transmission: low power (microvolts) radio frequency (RF) systems, optical and infrared systems (operates in the visible light spectrum where the transmitter is a sticker on the side of the vehicle), and microwave systems.

Data Processing

A computer program calculates vehicle travel times on the basis of two sequential readers that have identified the same vehicle. Standard reports are produced to show sample rate, mean travel times and speeds, and standard statistics.

Equipment and Operations Requirements

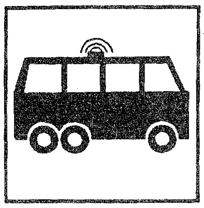
- Sensor loops
- Detector/receiver/interrogator — Active units mounted in or near the roadway capable of electronically detecting the identity of the device on the vehicle.
- Vehicle transmitter/transponder — Passive device (tag, sticker, puck, etc.) carried in/on the vehicle.
- Computer and associated software.

Sample Size

Sample size is limited by the size of the vehicle fleet.

Strengths

- Continuous monitoring/updating of travel times is possible.
- High precision reading of the transmitter.
- Almost 100% capture rate (based on small sample test). A 1993 test of this system by the Washington

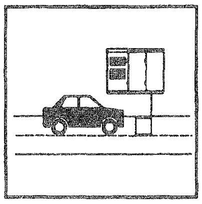


State Transportation Center (TRAC) experienced an 81 to 83% detection rate.[6]
- Can be lane specific.
- Automatic reporting of travel time data eliminates human errors in data collection.
- Consistent and continuous travel time reporting.
- Detects/identifies vehicles up to 85 MPH.

Limitations

- Infrastructure dependent.
- System maintenance/loop reliability problems.
- Clock drift problems require periodic clock adjustment.
- False alarm rate: <2%
- Data collected are limited to the number of vehicles in the traffic stream which are equipped with the transmitting device.

Loop Detector



Methodology

This travel time estimation methodology involves calculating travel times along the roadway segments based on information provided by the use of in-road vehicle detection systems (loop detectors).

Loop detectors are in-road devices which provide accumulative volume counts and occupancy measures in any preset time segments (usually 15 minutes). With proper setting of two loops in close but known distance, the vehicle speed can be measured by converting the passage time of vehicle between two loops.[7] Although spot speed has many potentials for traffic monitoring, the emphasis in this test is to compare volume or occupancy data with the travel time and speed measurements.

Volume and occupancy data can also be used as key predictors for estimating link travel time and speed. More deterministic volume and speed relationships could be developed via regression analyses using a mathematic form. The analyses include variables such as roadway type, geometries, facility class, location, and signal timing of intersection facilities for arterial.

Although the use of loop detector output to estimate travel time was not tested as part of this study, loop detectors were used to capture volume data on the roadways which were involved in the tests. Loop detector data were available on the exiting systems in Seattle and Lexington.

Field Operations

Induction loops are located at regular intervals, either in single or in all lanes along the roadway. The detector senses when a vehicle is present on top of the loop and when the vehicle leaves the loop area. Each detector is connected to a roadside control cabinet which transmits the signal from the roadside to a traffic operations center (TOC). A computer in the TOC receives the signals.

Data Processing

Software products are available to produce discrete or accumulative data from a loop detector which include volume counts, occupancy, and speed measurements. The data can be loaded into a standardized and unified database system as a link attribute by the date, time, direction, lane, and the loop affiliated link/segment location. The volume and speed data from loop detectors can be presented in the standard route and segment reports and compared with other travel time and speed measurements.

Equipment Requirements

There are many types of induction loops and traffic counters on the market. The cost rises according to the hardware and software requirements, type of installation (permanent or temporary), and maintenance.

Strengths

- Readily available on a range of traffic parameters: volume, occupancy, spot speed, or vehicle classification.
- Continuous reporting of travel time estimates are based on real-time volume and occupancy data.

Limitations

- Highly infrastructure dependent.
- Occupancy data are not usually reliable.
- Consistency and accuracy of spot speeds need to be improved across speed range and vehicle types.
- Maintenance required on detectors to ensure reliability.

3 Field Test Design and Survey Procedures

Standard Survey Procedures Used

Since one of the purposes of these tests was to be able to compare various methodologies, survey procedures developed for these field tests were used in each of the cities. Survey design and data collection procedures used for these studies are categorized into the following five steps:

Step 1 - Survey Design
Step 2 - Survey Data Collection Plan and Schedule
Step 3 - Training/Pilot Test
Step 4 - Field Survey Data Collection Procedures
Step 5 - Roadway Attribute Data Collection

Standardized survey procedures (e.g., forms, synchronized clocks, labeling and cataloguing, survey logs, data formats, etc.) are crucial for standardized data collection and processing as they assure the overall quality of the data collected. Data processing and analysis can be more costly and time consuming than field data collection. If large volumes of data are collected, greater organization and use of consistent data formats are required. Standardized data formats and data processing procedures will minimize data errors and data processing time while enhancing the effectiveness of data collection and analysis.

Step 1 - Survey Design

Route Selection

The goal of route selection was to collect an adequate number of O-D pairs to represent the major urban traffic routes or typical trip distance in the study areas. MPO project staff and the Volpe Center staff jointly identified five primary highways or principal arterial streets, including the downtown CBD to the airport for each city participating in the field tests. There were several general considerations for selecting primary routes and origin-destination pairs representing the regional traffic patterns, travel distance, and travel times:

- CBD to the principal airport for the urban area
- Largest employment centers based on census tracts to five residential zones randomly located in the urbanized area
- Largest residential zones to the CBD
- Employment zones to other principal suburban employment centers
- Principal suburban employment centers to each other and to the CBD
- Urban places located just outside the urbanized area boundary in regions which are expected to be included in the urbanized area after the next census.

The selected routes have captured the following characteristics used in the selection criteria:

- Representative of the road classifications (highway, arterial) and configurations (radial, circumferential)
- Significant daily travel volume and congestion
- Vehicle classes and other alternative modes
- HOV lanes
- Availability of loop detectors, or other volume data availability
- Peaking characteristics.

Figures 3-1 to 3-3 show the selected survey routes in the three field test cities.

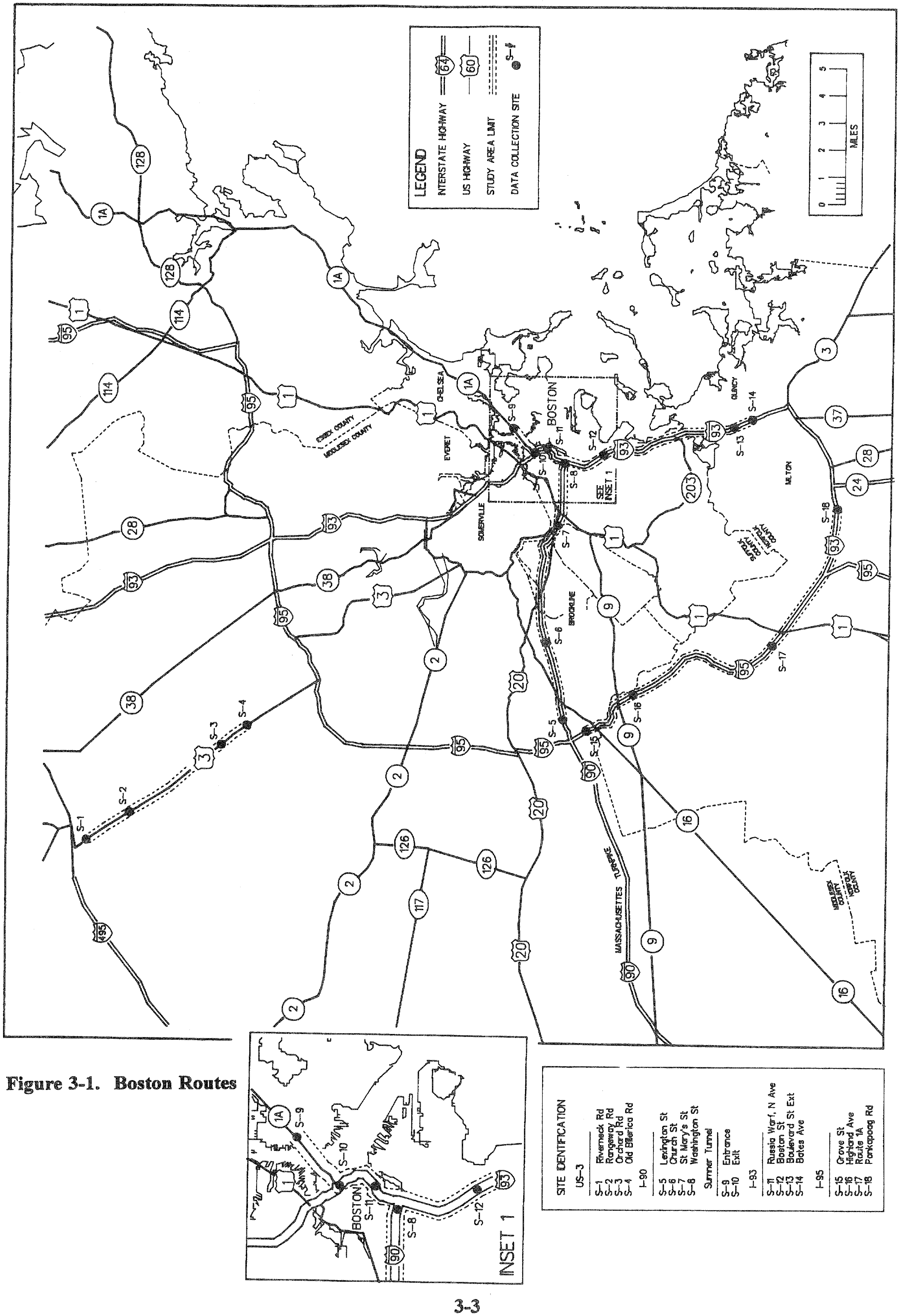


Figure 3-1. Boston Routes

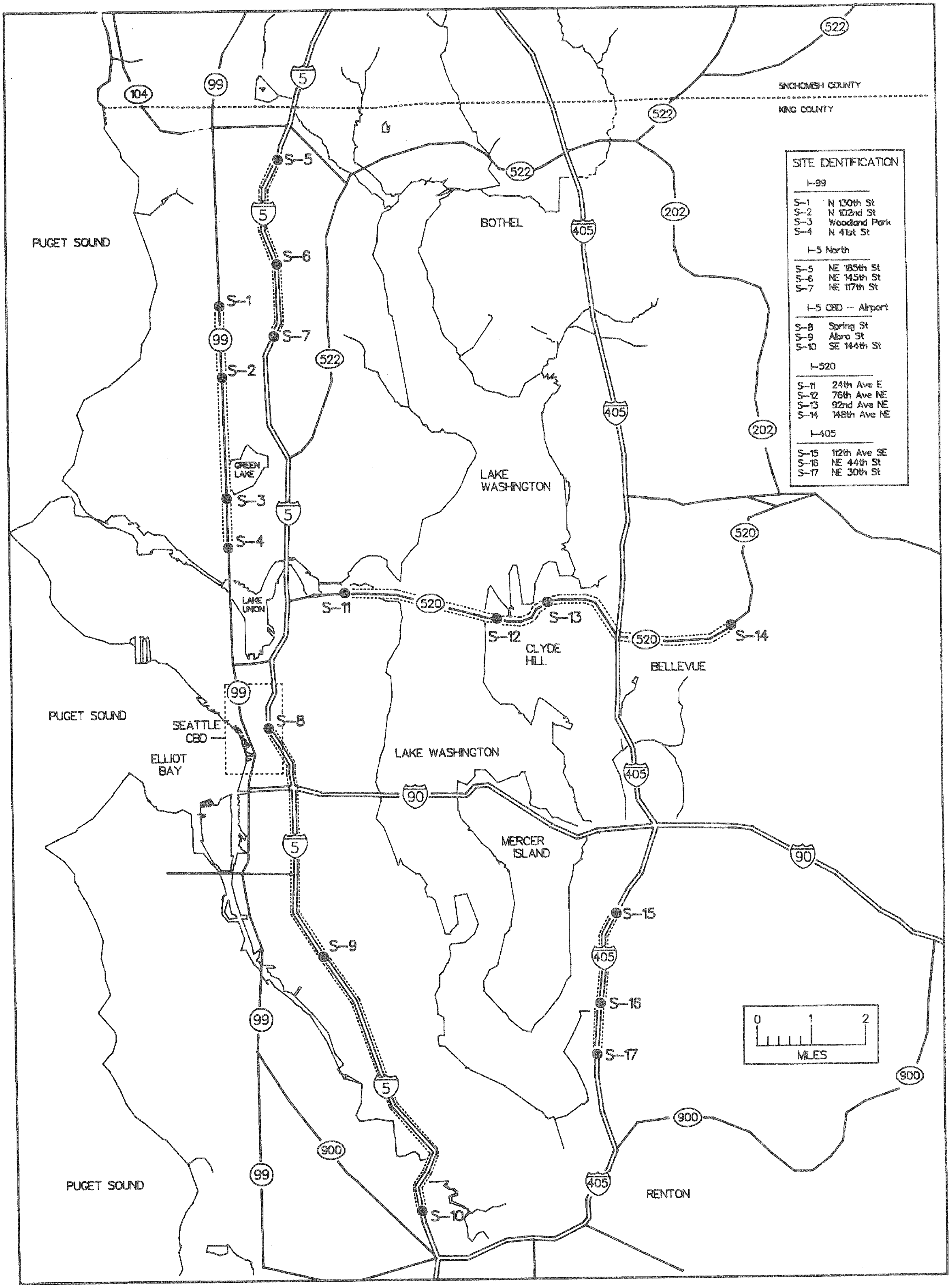


Figure 3-2. Seattle Routes

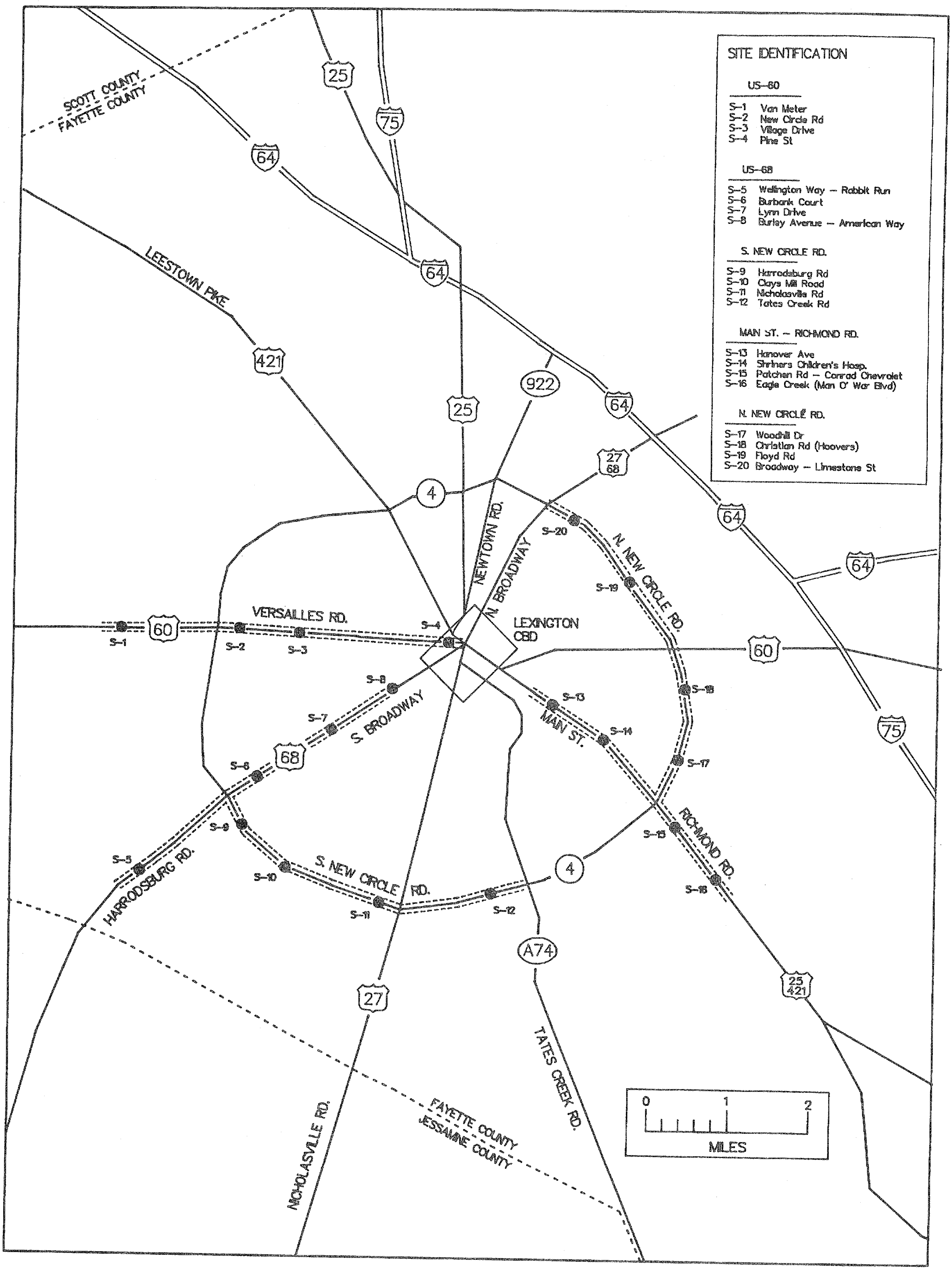
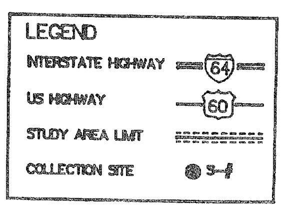


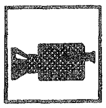
Figure 3-3. Lexington Routes



Road Segment Definition/Observer Locations

Once the routes were selected, the segments into which each would be divided was defined. Usually two to three consecutive segments from the entire length of each of the five routes were selected. For each city, all sites were scouted and locations selected prior to the field test/survey. Survey sites were consistent across all of the methodologies to be tested to ensure suitability and compatibility of coverage. The locations for the video license plate method were selected first since they had the most restrictive criteria. Positions for the laptop and floating car methodologies included the same locations as the video methodology. No preparation was required for the AVI or loop detector methodologies since they were part of existing on-line systems.

Since route segment determination impacts the equipment and personnel requirements, selection was conducted jointly between MPO staff and the Volpe Center project team. Because of their knowledge of the roadway characteristics in their area, participating MPOs made recommendations on route and segment selection.



The video methodology required that cameras mounted on tripods either at street level or from an elevated location (bridge overpass) be located in such a position to record license plates of vehicles moving in the peak direction. Locations needed to be found for both directions for each lane of traffic. The selection of segments were dictated by the following criteria:

- Location of bridge overpasses, and abutments (suitability of the location for the safe operation of the observers and the equipment)
- Accessibility
- Relative location of on/off ramps (entry/exit points) — frequency of interchanges
- Traffic flow characteristics — proportion of through-trips in the traffic stream (high throughput segments)
- Unrestricted line of vision
- Degree of concealment of cameras from the motorists
- Relative location to signalized intersections (to avoid platoon problems)
- Local street geometry.

There were several additional requirements of the video methodology which limited the selection of observer locations:

- Maximum angle of the camera to the traffic — the maximum horizontal and vertical angles allowed were 25 and 15 degrees respectively
- Position of the sun - sun directly into the lens was avoided
- Lighting conditions - position of shadows, and shade — plates partially in sun and partially in shade may not be readable
- Road geometry — catching plates as the vehicle was on a curve was avoided.

All potential test routes/sites were investigated before the surveys for potential aberration factors which could impact test results, including:

- Seasonal patterns/Weather conditions
- Special/Seasonal events
- Transit strikes
- Blocked railway crossings
- Interrupted flow facilities (toll booth, etc.)
- Road/Bridge construction/Maintenance — all lanes in service
- Non-functioning traffic control signals
- Scheduled speed enforcement

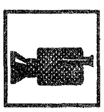
Sampling Plan

Although a sampling plan would be an integral part of any survey plan to ensure confidence in the results, the experimental nature of these surveys did not allow for up-front assessment of the appropriate statistical samples to be used to ensure valid representation. The issue of sample size is particularly acute with methodologies where large coefficients of variation are possible; for example with the use of floating car any level of acceptable statistical precision would require more than the typical few runs. The sampling plan should consider: sample size (number of observations required), sampling periods (from what time periods/days the data will be taken), data collection conditions, data assessment techniques, and data collection schedule.

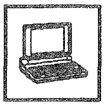
Sample Design

Once the desired sample size has been defined, the scope and schedule of the survey to satisfy those data requirements must be decided. In the case of these tests, the scope was adjusted to stay within the $50,000 FHWA allotment per MPO.

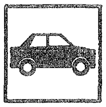
Define Target Vehicles. The classes of vehicles to be captured were defined. For these studies the following applied:



In the video process, all vehicles traveling within the lane(s) covered were captured; however target vehicles were excluded in the plate reading processing via a syntax selection and font identification process. Vehicles excluded were commercial vehicles and out-of-state plates. The participating MPOs helped identify license plate formats in use in their area for plate reader calibration.



In the laptop license plate matching method, Seattle limited the collection to the new centennial plates. Commercial vehicles and out-of-state plates were excluded.



Floating car runs and schedules are determined on the basis of the number of test vehicles, round-trip times for multiple runs, and headway between test vehicles.

Number of License Plate Characters. Full 6-digit license plate numbers were captured using video camera for license plate matching. In the portable computer license plate matching method 4 characters were collected.

Define Lanes to Be Covered. For the video and portable computer methods, up to three lanes per route in any direction were selected. For cases where there were more than three lanes, a determination was made as to which would be covered. Decisions to include or exclude high occupancy vehicle (HOV) lanes, traffic management lanes, and turn on/off lanes were made on a site-by-site basis. Probe and floating car drivers were not instructed to drive in any particular lane; however, if they were traveling in an HOV lane, it was noted.

Days/Times of Survey. Time of year, day of week, and time of day of the surveys were determined. The survey was designed to be of sufficient length to determine daily (6 AM to 7 PM) and weekly (Monday - Friday) flow pattern levels/variations. Field tests were performed over a five-month period beginning in mid-June and ending in early October 1993. The survey design strived to strike a balance between the number of staff required, the sample size desired, and the available equipment. The general guidance was to cover four routes each one full day, and a fifth route an additional two to four days. Single day surveys were conducted on Tuesday through Thursday (avoiding Fridays and holidays). The survey times covered peak AM and PM and, in some cases, mid-day hours. Summer and early fall was selected because of the likelihood of clement weather and the availability of students.

Data Elements to be Collected. The data elements to be collected for each methodology were identified. These included such items as: travel time data, link/segment data, delay factors, observation conditions, area data, and roadway data.

Step 2 - Survey Plan and Schedule

Once the MPOs had been selected for the methodologies to be tested, a preliminary survey plan was developed by the Volpe Center and reviewed by the MPOs. The survey plans include:

- Preliminary Survey Planning
- Equipment
- Personnel
- Data Collection Forms
- Coordination
- Site Checks and Preparations
- Date, Route, Site, and Personnel Assignment
- Equipment Assignment
- Survey Management
- Security and Safety Awareness
- Procedure Documentation

Preliminary Survey Planning

Preliminary Survey Plan/Kick-off Meetings. Preliminary survey plans were provided to each of the MPOs as a guideline to help organize the details of the surveys for that city. The Volpe Center project team met with each of the selected MPOs prior to the field tests to work out the scope of the surveys and to establish survey plans for each methodology. Many decisions needed to be worked out early on. It was the responsibility of each MPO to develop the final travel time survey plans.

These early discussions centered around: scope of survey, route/site selection/preparation, observer location selection, survey dates and times, equipment and personnel procurement, coordination with other agencies, and data elements to be collected. Planning continued up to the survey dates.

Selection of and coordination with the provider of video tape processing services used for this test was predetermined early in the methodology selection phase. The service provider imposed specific requirements for equipment selection and data collection procedures. Since this methodology is not standardized, the requirements differ from one service provider to another.

Lessons Learned

Select and coordinate with the video tape processing service provider early in the planning stages.

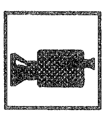
Schedule. The field tests consisted of three phases. The first was a preliminary kick-off meeting followed by preparation of survey plans; the second was field training and testing; and the third was the actual survey. Field tests were performed consecutively and took place over a five month period beginning in mid-June and ending in early October 1993. Table 3-1 shows the schedule for each survey phase for each of the three field test cities.

Table 3-1. Survey Schedule (1993)

City	Participating Agencies	Kick-Off Meeting	Field Training & Testing	Field Survey Schedule
Boston, MA	CTPS SmartRoute Systems Mass Highway	4/26	6/21 - 6/25	6/28 - 7/16
Seattle, WA	PSRC TRAC WSDOT	5/12	7/19 - 7/23	7/26 - 8/20
Lexington, KY	LFUCG, Traffic Engineering Division LFUCG, MPO U. of Kentucky	5/4	9/13 - 9/17	9/20 -10/8

Equipment

Selected MPOs were responsible for buying, leasing, or arranging for the equipment and accessories necessary to collect the travel time data. Scheduling of equipment procurement and assembly was conducted prior to the survey for the first city.



Video equipment requirements were laid out for the MPOs by the Volpe Center. The following equipment had to be acquired (purchased, leased, or borrowed) for the duration of the survey period:

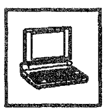
- High 8mm or Super VHS Video camera (one per lane/observer location): black and white, shutter speed of 1/1000, 3x to 4x magnification, >= 400,000 pixels, telephoto lens, 2x extender. Cities were not required to provide video cameras used by the rovers (see page 3-16 for a description of rover responsibilities).
- TV monitor
- Tripods

- Sufficient 8mm tapes to allow for the desired amount of taping (2 hours/tape)
- Marine batteries (deep cycle), adapters
- Cables

Equipment Sharing. Because of the cost and quantity of equipment necessary for the video methodology and in order to maximize the scope of the surveys and route coverage, an equipment sharing agreement was established among the three cities. Each city was responsible for purchasing 1/3 of the total equipment (4 sets per city) necessary for the study. Equipment leasing was considered, but was not as cost effective as purchasing and sharing the equipment among the three cities. The equipment was used first in conducting the Boston surveys, and then shipped to Seattle and Lexington for the following surveys. Each MPO was responsible for preparing (packing, insuring, shipping) the equipment to be sent to the next city. In one case a lending city required the users to provide a certificate of insurance which provided for coverage of the equipment, with a binder for all persons who would be using the equipment, and insured for theft. After the Lexington survey each MPO retained four video cameras and the accessory equipment they had purchased or was purchased for them.

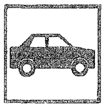
Equipment purchase can be a lengthy endeavor, especially if approval is required from a governing agency. Both Seattle and Lexington went out for competitive bids for their equipment purchases. Both of these cities took advantage of a volume discount offered for the equipment from a Boston-based supplier. Boston was required to utilize an existing blanket procurement contract for some items. Boston's purchases had to be approved by Mass Highway, and Lexington's by the Council of the Lexington-Fayette Urban County Government.

MPOs also agreed in principle to pursue an equipment sharing program with other MPOs to make their equipment available for future applications.

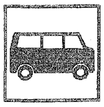


Equipment requirements for the portable computer methodology were as follows:

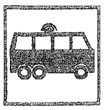
- Portable computers (laptop or palmtop) were required for each observer. Seattle purchased 12 palmtops for data collection and 1 laptop for processing the survey data. Lexington purchased 3 laptops and borrowed 5 from the Lexington County Government.
- Software for transferring data from the collection computers to the processing computer. Watches with a readable display to the second (preferably digital)
- Batteries for the PCs (laptop batteries were not sufficient to last a full 8-hour day.
- Clipboards for recording information on forms
- Pens/pencils.



Test vehicles were the only major required equipment. Lexington used vehicles owned by the city as the test cars. Other necessary equipment was minimal, i.e., a watch with a readable display to the second (preferably digital), a clipboard for recording information on forms, pens or pencils, and phones/radios for communications.

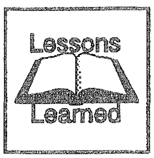


Necessary materials for the probe method were minimal. Vehicles were the only major required equipment and those were readily available. A watch with a readable display to the second (preferably digital), a clipboard for recording information on forms if necessary, pens/pencils, and the cellular phones or 2-way radio (probes used were already equipped).



Major Equipment items for this method were:

- Sensor loops
- Detector/receiver/interrogator — Active element mounted in or near the roadway capable of reading electronically the identity of the device on the vehicle.
- Vehicle transmitter/transponder — Passive device (tag, sticker, etc.) carried in the vehicle to be identified.
- Computer and associated software



Equipment sharing is an effective way to minimize equipment cost.

Ensure that battery capacity is sufficient for the full extent of the scheduled survey time.

Spare equipment is critical for assuring uninterrupted data collection and potential loss of data.

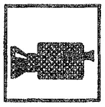
Personnel

MPOs were solely responsible for assigning staff members or hiring of temporary personnel to perform the surveys. Personnel were required to be available for the training as well as field testing. MPOs were required to perform the following personnel related functions: determining personnel availability and functions, recruiting personnel, defining training needs, preparing and scheduling training dealing with all aspects of the data collection task (e.g., equipment, measures, forms, contingencies), and specifying and scheduling personnel requirements for field data collection (identify personnel by function and name). Personnel costs are provided in Appendix A.

Boston has three near-full time staff members and five summer interns who were used for conducting the test.

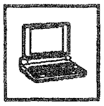
PSRC used a large number of temporary hires (up to 20 people per day) paid by the hour through an employment placement agency. The people participating in the surveys included unemployed workers, retired veterans, and college and high school students looking for summer job opportunities. Many of them were given very short notice and most did not have prior experience in field surveys. Training was performed in the days before the survey.

In Lexington, the Traffic Engineering Division of LFUCG was the prime performer and organizer in the field tests. Many staff members of the engineering division participated in the field work to support the project. The part time student workers from the University of Kentucky (whenever they were needed) had all worked or been trained with the division. The communication and cohesiveness during the field work was evident and very effective.

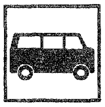


Participating MPOs were required to provide the personnel required to set up and tape the traffic scenes at each of the selected observer locations. The number of personnel required depended on the number of observer locations and the extent of days/times to be covered. An estimated 8 persons for 3-4 weeks were required for each city.

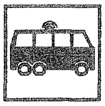
Skills are required in obtaining usable video of the traffic scene. Suitable license plate pictures are necessary since poor images will severely impede the automatic recognition process. Specific requirements include: focusing, sizing image in camera view finder, and periodic changing of video tape (every two hours).



To ensure optimal performance, the portable computer method requires that personnel be relieved frequently (switch shifts after 1 hour). For more efficient collection of plate numbers, two persons per location — one to read plate, and one to enter plate number may be considered.



Personnel for the probe methodology was limited to the regular SmartRoute probe drivers and MassPort bus drivers, who traveled the routes in question and who volunteered to participate in the survey. No additional cost for drivers was required. Personnel for operating the data collection center were required.



The AVI method is primarily passive. Personnel were required only to collect the data from the vehicle detector units.

All equipment and personnel procurement, scheduling, and budgeting were planned and adjusted within the $50,000 FHWA allotment provided to each participating MPO.

Data Collection Forms

During the course of the surveys a considerable amount of data was collected. Forms were provided for the collection. Surveyors also prepared written daily logs of survey activity. In addition to written logs, for the video methodology surveyors also recorded pertinent information at the beginning of each tape and throughout the survey day as required.

Coordination

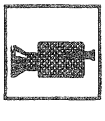
In addition to coordination between project personnel, coordination was required with agencies, such as police and other roadway authorities with jurisdiction over the selected routes and observation locations, to provide support and in some cases permission to be working on the roadway.

In Boston, coordination was required with Mass Highway and the Mass Turnpike Authority for placement of road tubes, parking arrangements, permission to use a building (including arranging for a guard to open and close the facility), and cellular phones. For the Boston probe methodology the cooperation of the MassPort bus drivers and SmartRoute probe drivers was required.

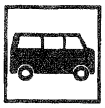
In all cases, police were notified of the survey and provided with the locations involved, the names of the persons in the field, their license plate numbers, and a point of contact.

Site Checks/Preparation

The exact locations of the observers were determined following reconnaissance on a site-by-site basis, prior to the field test/survey. Both the observer set-up locations and the range of vision available to the field crew were verified. Observer positions had to offer a secure place for the observer to set up and maintain an unrestricted line of vision. Ideally observer locations cannot be seen by motorists.



Video methodology required that cameras be mounted on a tripod at street level or from an elevated location. In most instances observations were made from the rear of the vehicle (in Massachusetts only a rear plate is required). In Seattle and Lexington some surveys were of oncoming vehicles whenever the site dictated.

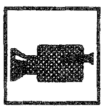


For the Probe methodology in Boston, observation positions were physically marked with an "X" in yellow flagging tape to help buses and probe vehicles locate their call-in points.

No preparation was required for the AVI or loop detector methodologies since they were part of existing on-line systems.

Date/Route/Site/Personnel Assignment

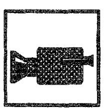
Each team member was given guidance as to the site, date, direction, exact start times and end times for the survey. Location/assignment sheets were distributed to survey the teams, listing the sites to be surveyed; the date, times, and directions; who was responsible for dropping off equipment; and the persons manning each site. Each participant was also given a map showing the location of his or her site, along with locations for parking, nearest restroom, nearest public phone. List of phone numbers for sites, rovers, and local police were provided. Each team had copies of any letters that were sent to the police or community officials explaining what was being done. Rovers were given directions for maneuvering between sites (alternate routes were applicable).



Personnel were assigned to teams and the teams to a particular location. It was attempted to have the teams remain consistent throughout the surveys. An attempt was made to have one full-time team leader at each site.

Equipment Assignment

This task includes cataloguing equipment; verifying operational status/calibration; and pick-up, delivery and storage of equipment.

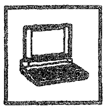


Catalogue/Make Sets. All equipment was catalogued, i.e., identified by type, make, model, and serial number. Equipment was grouped into sets which were numbered. Each set contained all equipment required for a single set-up. A set was assigned to a particular individual. Set numbers were recorded as part of the survey logs and to track any problems. Several spare/back-up equipment items were also provided in the kits. An equipment check list was provided with each kit.

Equipment Management. Equipment was handled slightly differently in each city. In Boston, one person assigned to each site was given responsibility for the equipment. In Seattle, the equipment was distributed and collected by two persons at the beginning and end of each day. In Kentucky, the equipment was distributed and collected by a single van driver. Who was to deliver the equipment was decided up front.

Tape Labeling. Prior to survey date it was required that all video tapes be labeled with the following information: date, route, street, lane, direction, and time. It was vital to use the correct tape in the correct camera.

In addition to the survey equipment, there was a recommended list of personal gear. This list included, clipboard, survey forms, photo ID, business cards, pens/pencils, watch, hat, sunglasses, rain gear, sun block, chair, water or juice, lunch and snacks, trash bag, and paper towels.

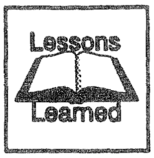


Laptops and palmtops were signed out to the surveyors for this method. The crews took the equipment home with them after each day of survey and were responsible for having it with them on subsequent days.

Survey Management (Rover's Responsibilities)

The responsibilities of the rovers were to offer technical advice and ensure video recording quality. Although the rovers were primarily responsible for the video methodology, they were also helpful in directing surveyors for the portable computer method. Rovers carried extra equipment and supplies (cameras, fuses, batteries, rain gear, etc.), collected video tapes; served as temporary relief and emergency back-up personnel; and collected the tapes at the end of the survey day.

Rovers were on the road at all times, and were available by phone. Rovers also acted as observers in the route segments during the recording interval, recording any unusual incidents which might go unreported.



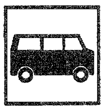
Clear-cut responsibilities for survey decisions should be defined.

Security and Safety Awareness

Since the surveys involved personnel working on or near major roads, safety issues were addressed as part of the training and were considerations throughout the surveys. Safety equipment such as safety vests and cones, caution tape, and filtration masks for locations where vehicle fumes were high, were made available to the teams. Equipment was secured as necessary. Locks and chains were used to secure video equipment to bridges. Teams were equipped with some form of communication. For the video and portable computer methods, sites were selected which provided protection for the survey teams. Sites required adequate shoulder or sidewalks to allow for the equipment as well as for the usual pedestrian movement.

Since traffic observers are occasionally harassed by passing pedestrians or drivers, it was a safety consideration. Surveyors were advised not to engage in any contact with anyone suspected of being violent or abusive. The safety of the surveyors is of paramount importance, and should take precedence over any concerns about equipment or data collection.

Surveyors working on the road were encouraged to wear high visibility reflective clothing, and to protect themselves from dehydration and sun exposure.



Drivers were assured that although consistent and accurate information was important, it was more important that they be in complete control of their vehicles and that their attention be on the road. It was not worth jeopardizing their safety in order to collect a data point. Probe drivers were advised that it might be helpful for a passenger to record the time or other data.

Procedure Documentation

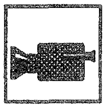
All procedures for the conduct of the field tests were documented. Surveillance and control requirements during field data collection were defined and specified. Sets of instructions indicating all aspects of the data collection process were prepared and distributed. These included:

- Equipment and personnel location
- How, when and where data were to be collected
- Procedures for crew shifts
- Procedures for how to handle contingencies (including when to cancel data collection due to accidents, rain, or snow)

A more detailed discussion of the most critical of these procedures is provided under Step 4 - Field Survey Data Collection Procedures.

Step 3 - Training/Pilot Test

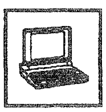
The next step was field training and pilot testing of survey procedures for each of the methodologies. Training and pilot tests were conducted both in house and in the field at actual survey locations. The purpose of the training was to ensure operator familiarity and practice in the use of equipment, use of forms. Pilot tests acclimated the crew to real-life circumstances, allowed practice of on-site coordination, and tested the effectiveness of the training. The training and testing requirements varied greatly by methodology.



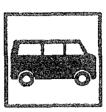
Considerable skill is required in obtaining usable video of the traffic scene. For good results it is necessary to ensure that suitable license plate pictures are obtained since poor images will severely impede the machine recognition process. Training in video data collection techniques required two to three days of both formal in-house and in the field training for each city.

Formal in-house training covered a general discussion of traffic surveys, an introduction to machine vision for survey applications, camera operation, equipment familiarity, camera clock time synchronization, and equipment set-up. Survey planning and procedures, crew assignments, data collection locations, schedules, communications, response to contingencies (e.g., when to cancel due to rain, accidents, etc.) were also covered.

Field training offered a realistic run through of all procedures. Data collectors received feedback on the field test performance. Tapes made during the field test were critiqued to determine their suitability for the plate reader.



In both Seattle and Lexington portable computer training was loosely structured, because it required more individual skills and practice rather than formal instructed training. The dynamics of the operation were such that field crews required at least partially structured familiarity training (practicing data entry) which could take place any time, anywhere, as long as the training was a realistic simulation. In training, each crew and crew member learned his/her own weaknesses and the necessary corrective measures. During the field trials, part of the training involved monitoring the number of entries in order that the number recorded should exceed the number required for statistical reliability. Operator familiarity with the computer hardware and software operations was essential in order to maximize the value of time spent on station. The portable computer method required sustained concentration during the survey especially if performed for high speed traffic lanes.



Training for the probe methodology consisted of distributing, in advance, a set of instructions (survey procedures and forms), photographs of the call-in locations and route maps to the bus/probe drivers. Accuracy was stressed. One week prior to the start of the field test, probe drivers were asked to make practice runs to ensure that they could locate all of the call-in sites and work comfortably with the call-in procedures.

Lessons Learned

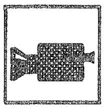
Field training is required to ensure operator familiarization with survey locations, the set-up and use of equipment, and survey procedures.

Step 4 - Field Survey Data Collection Procedures

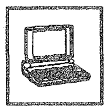
Field surveys and various stages of data collection were led by the MPOs and other participating agencies. MPOs were responsible for managing their survey teams and the data collection effort. Detailed survey procedures were established and used before, during, and after each data collection session. The following sections summarize the procedures and action steps required in setting up and conducting the field surveys.

Synchronizing Time

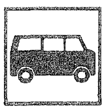
Time synchronization was one of the most critical elements for survey success. Watches of all survey crew members were synchronized prior to the survey and were checked for discrepancies during the training sessions as well as during the survey. Crew members were advised to call "telephone time" number to set their watches daily.



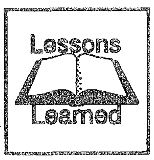
Video camera clocks were synchronized before the survey. These times were turned on and recorded at the beginning of each survey tape. This was not the official time used, however, since the camera clocks did not have seconds.



Portable computer (laptop/palmtop) clocks were synchronized before the survey and were checked for discrepancies during the survey.



Probe vehicle drivers were instructed to set their watches from the "telephone time" daily. Data recorders used the SmartRoutes clocks for bus times.

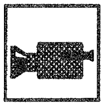


Time synchronization is critical for accurate data collection.

Equipment/Site Set-Up Procedures

This step involves preparation of the work area and equipment setup and adjustment.

Equipment was unloaded as close to the designated survey spot as possible. Safety cones and flagging were arranged to define the work area.

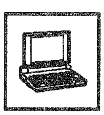


Set Up Camera and Related Equipment. Because of the demanding set-up requirements and the amount of equipment involved, video crews were required to be on-site one hour prior to the start of the survey. Tripods were set up over each of the predetermined markings, making sure that the legs were fully extended. Marine batteries were positioned beneath each tripod. Cameras were attached to the tripods. Camera connections were made to the batteries and to the monitor.

Camera Adjustments. Several adjustments were required including camera angle (enough plate images per frame of video), fences, tilt, center on lane (or area of lane through which the traffic seems to be travelling), image size, focus, exposure, and shutter speed.

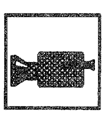
Create a Test Tape. Test tapes, recording a minute or two of traffic, were taken prior to the start time of the survey, (both for the initial setup in the morning and afternoon session). This recording was played back, and the image was frozen and viewed on a monitor hooked up to the video camera. This was done to verify that the camera's video and audio were operational, and to verify that the correct camera settings (image size, exposure and focus). Adjustments were made as necessary and reverified with a new test tape. This step was necessary since it was not possible to check the image size after the survey tape was started (without the use of the rover's equipment).

Load and Start Survey Tape. Cameras were to be set up and ready five minutes prior to the start of the survey. A check was made to ensure that the tapes were rewound. The cameras were put into a pause mode ready to record. At the exact time of the survey the cameras were started. Start times were set beforehand. In some instances all tapes were started together, in others a staggered start time was used. In Boston, each camera was started according to the operator's watch at a predetermined scheduled time. In Lexington, where 2-way radio communications were available, all cameras were started on a time mark given by a rover.



Prior to each day of survey, the license plate capture program resident on each portable computer was initiated with the date, time, route, lane, direction, and surveyor name. Laptops were connected to the marine batteries used for the video methodology.

Survey in Session



Data collection consisted of video-taping the traffic scene according to instructions provided. The traffic scene for each route segment was captured for 4 to 10 hours per day, 1 to 3 days per route segment. The major steps were as follows:

Time Checks. An audio time check message was required to be made at the beginning and end of each tape. The initial time check was made when the camera was first turned on to record. The start message/script was recorded which included the following information: name, date, route lane, direction, camera set number, time (hour/minute/second - with a voice mark), initial camera settings (shutter speed, F-Stop [exposure], etc.). In addition at the beginning of each tape, the camera date and time were also displayed and recorded on the tape for 10 seconds.

Lessons Learned

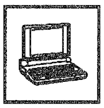
Time marks on the video tapes were critical for accurate plate times.

Camera Adjustments. Camera checks were a continuing process. Conditions change for many reasons, and adjustments must be made as soon as possible to ensure maximum readable plates. When checking the cameras, the operator always considered whether it was the best picture possible, or if it could be improved. These checks were not limited to fifteen-minute intervals, but were done as required. At each check, camera settings were verified. Fifteen minutes was the maximum time a camera was left unchecked. Subsequent time checks noted the time and any camera adjustments.

- **Focus.** To refocus as necessary (usually only if on a heavily travelled road where trucks/busses were causing vibrations which were jarring the camera).
- **Apperature.** To compensate for changing lighting conditions. Setup in the morning was typically in complete darkness and as the sun rise progressed, adjustments to the camera settings were necessary. Adjustments were also necessary as clouds came in and out.
- **Filtering.** To compensate for glare as the sun moved behind the camera, it was sometimes necessary to add polarizing filters to the camera lens.
- **Angle.** Initial settings for the morning darkness often required that the camera be angled down steeply, but as the lighting improved, cameras were focused further out. Also as traffic built up it was sometimes necessary to tilt the camera down more steeply to capture plates which would otherwise be obscured by the vehicle following.
- **Power.** Occasionally a camera would shut itself off (due to malfunction, overheating, or interruption of power). When this happened, it was very important that a new start time be entered onto the tape, and a special note be made in the survey log.

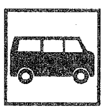
Changing Tapes. Video tapes were required to be changed after 2 hours of taping. The used tape was removed from the camera and the recording tab closed (they were not rewound). A new tape was inserted and a time check script was recorded. Used tapes were stored safely. Tapes were labeled prior to the survey.

Miscellaneous Actions. To protect cameras and portable computers from adverse weather conditions (rain and wind), teams were provided with plastic sheets and bags, and tiedown materials for the tripods.

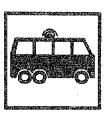


Once the data capture software was started, the data capture program required only the plate characters to be entered. As the operator hit the return button, the program automatically assigned the current time. The program also had the ability to capture operator notes; this feature was used to note any interruptions/breaks in the collection process. Palmtop batteries needed to be changed as necessary.

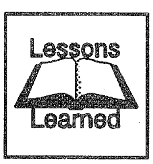
Observers in each test car were responsible for recording the run sheets. Each sheet included identifying information for the run and the times the vehicle passed the predefined observation locations. Delay information was also gathered (although not used for this test). For signalized routes, the test vehicles entered the test route at various points in the light cycle.



Probe vehicles reported via cellular phone or 2-way radio (or manually) the travel times they experienced on predefined route segments. Probes also passed along any delay information required. Probes conducted their survey for 5 to 10 days of the field test. SmartRoute probe drivers reported their time twice a day, once in the AM and once in the PM. MassPort bus drivers reported in on each pass through the route segments defined. At their entry/exit points and at each observer location point, probe vehicles reported their location via cellular phones, and buses via 2-way radio. The probes also conveyed their usual data regarding delays, incidents, and accidents. Probes gave the following information at each call-in: driver name, vehicle ID (license plate number), route, direction of travel, check point name, time when they passed the checkpoint. If the phone line was busy, the probe drivers were instructed to write down the times.



Buses equipped with the AVI devices travelled their regularly scheduled routes. As the bus passed the detector, the bus ID was captured along with the current time.



The video method requires that any interruption in taping be meticulously documented.

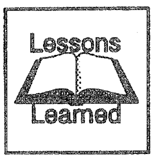
Daily Log. All surveyors were required to keep a daily log during the surveys which included:

- Identifying information
  - Surveyor name, date/time, route, segment, lane, direction, general route, and traffic conditions

- A description of aberration factors
  - Incidents (breakdowns, accidents, construction and maintenance, funeral processions, speed enforcement, emergency vehicles, etc.)
  - Weather conditions (clear, rain, fog, snow, other)
  - Illumination (dawn, day, twilight, night)
  - Pavement condition (dry, wet, icy, etc.)

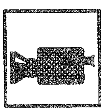
- Methodology specific information
  - Equipment ID, tape numbers, camera settings, description of where the camera was focused, interruptions in taping (power interruptions), and equipment malfunctions.

Communication. Each team was equipped with cellular phones or two-way radios enabling continuous communication. Crews were instructed to use the phone/radio to seek advise from other operators or the rovers. Phones/radios allowed a way to reach each survey team in the event that the survey needed to be postponed or stopped.



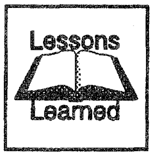
Standardized data collection procedures are essential to ensure the performance and quality of data collection.

End of Survey Day



Breakdown. Once the final tape for a session was completed for each camera, the operators began breaking down equipment. Cameras were turned off and lenses were capped. Cameras were disconnected from their batteries and dismounted from their tripods. All equipment was repacked into its original set bags. A check was made to ensure that equipment sets were in tact. Once the cameras were securely stowed, the tripods and other equipment were disassembled, stored, and reloaded into the vehicle. All safety equipment was recovered and re-stowed. Approximately 1/2 hour was required after the end of taping to break down and repack the equipment.

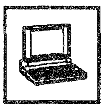
Equipment Care/Cleaning. Camera equipment required cleaning and proper storage. On days when it was humid or raining, the cameras required particular care at the end of each day.



Data collection for the methodologies tested requires that equipment is functioning properly. Even the smallest technical difficulty can result in no data being collected.

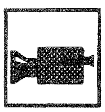
Battery Recharging/Replacement. Cellular phone batteries needed to be recharged each night. Marine batteries were recharged once at the beginning of the survey and again after each week of survey.

Equipment Replacement. Teams were responsible for contacting a rover to replace any parts which malfunctioned during the day. Any missing or damaged equipment was reported to a rover.

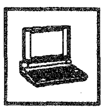


Data files were downloaded to a laptop computer. Portable computer batteries needed to be replaced nightly.

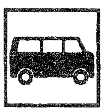
Collection of Survey Data. Survey data (video tapes, portable computer data files, data sheets), were collected daily (brought to a central location or downloaded to a central computer). At this time any new instructions or information was passed along to team members.



At the end of each day, the video tapes were collected by the rovers. Teams would assemble, as necessary, to pass on any new instructions. Persons responsible for the equipment would take it home or to the site at which it was to be stored overnight.



Surveyors met to submit data at the end of each session. The information was collected by a download of data from the laptops/palmtops to a main laptop computer.



Drivers who were unable to contact the data collection center during the run were asked to call in or fax their data sheets to the center at the end of the day.

Run sheets were collected at the end of each survey session.

Data from the roadside vehicle detectors/recorders were transmitted daily via a phone line to a central computer.

Step 5 - Roadway Attribute Data Collection

Raw Data Assembly

During and after the field surveys, the MPOs and corresponding agencies compiled the raw data collected from the fields and sent them to the Volpe Center for subsequent data processing. The license plate video tapes were catalogued and shipped to the contractor for the video license plate processing using an automatic license plate reading system.

The participating agencies were also requested to send in any written logs (general weather and traffic conditions, accidents, exact survey start and break times, etc.) prepared by the surveyors. Additional data forms were sent to the MPOs to collect detailed cost data and physical measurements for the survey routes and methodologies.

To properly set up the parameters for data processing and analysis, participating MPO's were asked to provide specific route and segment data. These include: route name, segment description (beginning, mid, and end nodes), roadway type, land use along the route, length, number of lanes, HOV lanes, posted speed limit, number of entrances/exits within the segment, entrance/exit ramp volume, number of signalized intersections, AM peak volume, PM peak volume, noon volume, percentage trucks, and percentage cars.

Not all the roadway attributes were available at the time of the surveys. The list of data elements can be expanded and included in the standard route/segment description reports when the data become available. The route/segment length and volume from the loop detector table are used and analyzed with the travel time data in the data processing and reporting process.

4 Data Processing, Analysis, and Reports

Data processing, analysis, and reporting of collected data were conducted in sequential steps which include: raw data assembly, data loading and conversion into standard data format, data screening and validation, license plate matching, database creation, and report generation. In order to process a variety of data types and multiple data sources resulting from the field test data collection, a unified database structure, with analysis procedures, were developed for standardized data processing, reporting, and analysis of travel time and speed data.

The database is organized by specific route, segment, date, time (in 15-minute or 30-minute time periods), and traffic direction. Standard statistics such as number of valid sample observations (sample rate), mean travel time and speed, standard deviation, maximum and minimum travel time, and number of extreme outliers, are generated after a series of data processing steps and screening procedures. The unified database structure allows the processing and reporting not only of travel time and speed data, but also of those corresponding roadway attribute and volume data. The standardized processing and data formats provide a baseline for comparative analysis of data collected from various methodologies. The units of measure for route length and speed are in miles and miles-per-hour (mph) since they were based on the mile post and speed limit data used at the time of the survey. These measures could be converted into metric units in the data processing procedures.

Database Structure

The data types are generally distinguished by floating car records and license plate data. Floating car, probe vehicle, or AVI bus data are collected for a set of pre-selected vehicles at a series of pre-selected locations. License plate data are collected from all vehicles passing fixed data collection locations. Video cameras, portable computers, or sensors/detectors provide a means to collect license plate numbers (or other vehicle IDs) and to record the time of the observation. Because of the unique nature of location, time, and vehicle ID as the key elements in travel time data collection, a unified database structure is designed for all data types in each of the travel time data collection methodologies. Standard reports developed for license plate matching and processing can also be applied to and generated for data collected from other methods.

Roadway attributes (number of lanes, number of intersections, freeway entrances/exits, posted speed limit, etc.) and volume/occupancy data collected from loop detectors are maintained in separate data files. They can be linked to the route and segment files in the main database and presented in the route and segment standard reports.

The main database contains the main body of data records. Each record contains vehicle ID (e.g., a license plate number) and a time stamp as the two key data elements, along with a set of variables (city, route, node, date, time, direction, lane number, and methodology) for data or grouping identification. This database structure is applicable to all methodologies.

Raw Data Assembly and Conversion

Data collected from the field require subsequent transformation, screening, and loading of initial data sets to the centralized database. Some data sets received in written forms (floating car and probe vehicle methods) require additional editing and data entry to transfer the data into an electronic format. Standardized forms and data formats are essential to transforming and loading this data. Standardized logs, labeling, and cataloguing of video tapes or computer files (date, time, location, lane number, tape serial number, etc.) are critical steps in the standardized survey procedures to ensure more efficient file organization and management.

Synchronized clock times on personal watches, built-in video clocks, and computer clocks are essential during the travel time surveys. Errors caused by computer power-off, dead battery for video camera, or switching tapes during videotaping need to be corrected using field survey logs.

License Plate Video Tape Processing

During this test a machine vision system, was used for reading license plates recorded on videotapes. The Computer Recognition System's (CRS) License Plate Reading System (LPRS) was chosen for the testing of automatic license plate processing using a video imaging technology. The CRS Plate Reader can read license plates of vehicles moving at speeds up to 100 mph. It takes less than a second to process a triggered license plate. The recognition rate resulted from this processing falls into a range between 10 to 40 percent of the vehicle flows, depending on the location and the quality of the license plate pictures. Besides the CRS system, several other existing machine vision technologies with the potential to read license plates were examined prior to the selection.

Each two-hour tape was processed using the system, and digitized output was produced on a diskette file. Each license plate record contains a six-character license plate number, the associated time stamp, date, site location ID, lane number, and direction. An example of license plate records is shown in Table 4-1. The data were loaded into the centralized database for license plate matching and report processing.

Table 4-1. Output of License Plate Video Processing

Plate #	Time	Date	Site-Lane-Direction
116TJL	8:30:01	6/30	A3-1-NB
440WIY	8:30:13	6/30	A3-1-NB
671RVK	8:30:13	6/30	A3-1-NB
688NTR	8:30:15	6/30	A3-1-NB
025189	8:30:23	6/30	A3-1-NB
126TNX	8:30:28	6/30	A3-1-NB
387VEV	8:30:30	6/30	A3-1-NB
796SBZ	8:30:31	6/30	A3-1-NB
577248	8:30:32	6/30	A3-1-NB
617CGM	8:30:35	6/30	A3-1-NB
689546	8:30:38	6/30	A3-1-NB
VAC617	8:30:40	6/30	A3-1-NB
149PKC	8:30:40	6/30	A3-1-NB
430917	8:30:44	6/30	A3-1-NB
647RXI	8:30:49	6/30	A3-1-NB
577TAD	8:30:50	6/30	A3-1-NB

Computer License Plate Processing

Computer license plate files were created on laptop or palmtop computers after each data collection session. Each license plate file contained from hundreds to a thousand license plate records entered during a 2- to 4-hour session. Each record contains a 4-digit (3 numbers plus an adjacent character) license plate number and a time stamp. Each data file was marked by date, route, site name, direction, lane #, and data entry person's name. At the end of data collection session, the data files were downloaded into a main laptop computer for subsequent license plate processing and matching.

License Plate Matching

License plate matching is performed for any given route segment for license plates captured between an upstream location and a downstream location. The standard matching procedure is designed to perform license plate matching for each consecutive route segment on a route where data are collected. In license plate matching, data collected from all lanes at one location are combined for matching with the data collected at another location. The whole range of data collection during a survey session (2 to 6 hours) is processed, and the matching results are produced for each 30-minute time slice duration.

The software can be designed to be fully automated and user-interactive. Options are provided for the user to select any data source, review data, conduct an analysis, or extract a report. The user can select any route(s), date(s), segment(s), hour(s), and lane(s) for license plate matching and reports. The user can also change the time slice value to generate a detailed analysis or change the threshold speed limits when traffic conditions skew the speed level. Standard reports will usually be produced utilizing standard analysis procedures.

All Lanes

Although license plate matching can be performed by lane, the standard procedure combines data collected from all lanes at one location to match those at the next location. Obviously, this increases the number of plate matches between any two locations while disregarding any lane speed variation. If a high sample rate is assured, license plate matching by lane (or cross lanes) can be performed to determine potential speed variation between lanes (HOV lanes, traffic management lanes, or normal lane variation), or lane changing behavior (for merging or exiting traffic).

Full Range Matching

Standard license plate matching is designed to capture all the possible matches during an entire data collection session (up to six hours in some occasions). The program is designed to capture multiple or false matches (e.g., via partial plate matching) over a large time span when the accuracy of plate recognition and the logic of plate matching can be tested.

After the precision level and accuracy rate are tested, a more improved matching procedure can be designed with a narrower window of time after congestion delay is considered. It would reduce the processing time considerably from the standard license plate matching procedure.

Interim File of Matched Plates

The plate matches are stored in an interim file before the report generating procedure is initiated. The elapsed time is calculated for each match, along with the matched license plate number, times recorded at both locations, and the source IDs for the original data files. The interim file can be printed as a list of records (see Tables 4-2 and 4-3) or reviewed on the screen at the user's option. The information is useful for cross-checking of matched plates with the original source data.

Table 4-2. Laptop License Plate Matches

License Plate

City: Lexington Route: Richmond Road Direction: E Page 1
Sites: Patchen Road (Conrad Chevrolet) to Eagle Creek (Man O'War Boulevard)

Number of Plates Site 1	Number of Plates Site 2	Matches
5868	5695	1083

Date	License Plate	Time1	Time2	Elapsed Time	ID1	ID1 Description	ID2	ID2 Description
9/21/93	Y727	15:59:14 PM	17:17:52 PM	01:18:38	RICHAR	RICHARD COMBS	ERIC L	ERIC LARSON
9/21/93	B622	15:59:30 PM	16:01:50 PM	00:02:20	RICHAR	RICHARD COMBS	ERIC L	ERIC LARSON
9/21/93	B622	15:59:30 PM	16:34:33 PM	00:35:03	RICHAR	RICHARD COMBS	JONATH	JONATHAN
9/21/93	D763	15:59:58 PM	16:01:55 PM	00:01:57	RICHAR	RICHARD COMBS	JONATH	JONATHAN
9/21/93	H621	16:00:30 PM	16:23:37 PM	00:23:07	RICHAR	RICHARD COMBS	JONATH	JONATHAN
9/21/93	8161	16:00:33 PM	16:01:56 PM	00:01:23	SHANNO	SHANNON REYNOLDS	ERIC L	ERIC LARSON
9/21/93	W355	16:01:18 PM	16:04:01 PM	00:02:43	SHANNO	SHANNON REYNOLDS	ERIC L	ERIC LARSON
9/21/93	M030	16:01:21 PM	16:07:42 PM	00:06:21	SHANNO	SHANNON REYNOLDS	ERIC L	ERIC LARSON
9/21/93	C200	16:01:28 PM	16:03:43 PM	00:02:15	RICHAR	RICHARD COMBS	JONATH	JONATHAN
9/21/93	A653	16:01:30 PM	16:03:53 PM	00:02:23	SHANNO	SHANNON REYNOLDS	JONATH	JONATHAN
9/21/93	Z744	16:01:48 PM	17:32:10 PM	01:30:22	RICHAR	RICHARD COMBS	JONATH	JONATHAN
9/21/93	D627	16:02:10 PM	16:15:38 PM	00:13:28	SHANNO	SHANNON REYNOLDS	ERIC L	ERIC LARSON
9/21/93	J780	16:02:27 PM	17:48:57 PM	01:46:30	SHANNO	SHANNON REYNOLDS	ERIC L	ERIC LARSON
9/21/93	Z181	16:02:37 PM	16:04:11 PM	00:01:34	SHANNO	SHANNON REYNOLDS	ERIC L	ERIC LARSON
9/21/93	Z181	16:02:37 PM	17:43:49 PM	01:41:12	SHANNO	SHANNON REYNOLDS	ERIC L	ERIC LARSON
9/21/93	4609	16:02:56 PM	16:59:50 PM	00:56:54	RICHAR	RICHARD COMBS	JONATH	JONATHAN
9/21/93	B397	16:03:13 PM	16:05:44 PM	00:02:31	RICHAR	RICHARD COMBS	JONATH	JONATHAN
9/21/93	X139	16:03:15 PM	16:05:56 PM	00:02:41	SHANNO	SHANNON REYNOLDS	ERIC L	ERIC LARSON
9/21/93	V234	16:03:17 PM	16:05:52 PM	00:02:35	RICHAR	RICHARD COMBS	ERIC L	ERIC LARSON
9/21/93	G123	16:04:38 PM	16:06:05 PM	00:01:27	RICHAR	RICHARD COMBS	JONATH	JONATHAN
9/21/93	9644	16:04:47 PM	16:21:55 PM	00:17:08	SHANNO	SHANNON REYNOLDS	JONATH	JONATHAN
9/21/93	A247	16:04:50 PM	16:06:06 PM	00:01:16	SHANNO	SHANNON REYNOLDS	ERIC L	ERIC LARSON
9/21/93	X154	16:04:51 PM	16:06:11 PM	00:01:20	RICHAR	RICHARD COMBS	ERIC L	ERIC LARSON
9/21/93	N140	16:04:53 PM	16:06:08 PM	00:01:15	SHANNO	SHANNON REYNOLDS	JONATH	JONATHAN
9/21/93	G773	16:04:54 PM	16:07:33 PM	00:02:39	RICHAR	RICHARD COMBS	JONATH	JONATHAN
9/21/93	J147	16:04:59 PM	16:13:41 PM	00:08:42	RICHAR	RICHARD COMBS	JONATH	JONATHAN
9/21/93	J097	16:05:00 PM	17:09:34 PM	01:04:34	SHANNO	SHANNON REYNOLDS	JONATH	JONATHAN
9/21/93	9523	16:05:33 PM	16:07:46 PM	00:02:13	SHANNO	SHANNON REYNOLDS	JONATH	JONATHAN
9/21/93	4135	16:05:53 PM	16:17:13 PM	00:11:20	RICHAR	RICHARD COMBS	ERIC L	ERIC LARSON

Table 4-3. Video License Plate Matches

License Plate

City: Boston Route: Route 93 S/SE Direction: N Page 1
Date: 7/13/93 to 7/13/93 Time of Day: 06:30:00 AM to 11:00:00 AM
Sites: Boulevard Street Extension

Number of Plates Site 1	Number of Plates Site 2	Matches
8188	9314	980

Date	License Plate	Time1	Time2	Elapsed Time	ID1	ID1 Description	ID2	ID2 Description
7/13/93	121572	06:32:07 AM	06:42:34 AM	00:10:27	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	506BGH	06:33:52 AM	06:44:00 AM	00:10:08	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	908BMV	06:33:55 AM	06:44:03 AM	00:10:08	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	490GXB	06:34:00 AM	06:44:13 AM	00:10:13	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	651448	06:34:06 AM	06:44:16 AM	00:10:10	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	347HVN	06:34:10 AM	06:44:19 AM	00:10:09	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	CIZ705	06:34:18 AM	06:44:24 AM	00:10:06	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	902994	06:34:52 AM	06:45:20 AM	00:10:28	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	982778	06:35:17 AM	06:45:59 AM	00:10:42	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	D18325	06:37:36 AM	06:49:10 AM	00:11:34	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	771VVD	06:37:59 AM	06:49:39 AM	00:11:40	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	596CBX	06:38:58 AM	06:51:41 AM	00:12:43	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	42262	06:39:07 AM	06:51:21 AM	00:12:14	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	C66548	06:40:37 AM	06:53:04 AM	00:12:27	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	AMY979	06:43:14 AM	06:54:24 AM	00:11:10	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	381RDR	06:43:21 AM	06:54:37 AM	00:11:16	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	046802	06:43:51 AM	06:55:21 AM	00:11:30	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	655MKC	06:44:01 AM	06:55:36 AM	00:11:35	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	C76846	06:45:04 AM	06:56:49 AM	00:11:45	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	524291	06:45:07 AM	06:56:51 AM	00:11:44	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	814BVN	06:45:42 AM	06:57:29 AM	00:11:47	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	299GBV	06:45:43 AM	06:58:31 AM	00:12:48	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	AVP590	06:46:48 AM	06:58:22 AM	00:11:34	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	176342	06:47:26 AM	06:59:16 AM	00:11:50	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	926BSX	06:47:57 AM	06:59:31 AM	00:11:34	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	277VZO	06:48:00 AM	06:59:39 AM	00:11:39	A0235	A0235.NRS	A0220	A0220.NRS
7/13/93	270052	06:48:50 AM	07:00:07 AM	00:11:17	A0235	A0235.NRS	A0220	A0220.NRS

30-Minute Time Slice

The 30-minute time slice is set as the default value for the grouping of travel time records because some methodologies do not generate enough samples in a smaller time range. The 15-minute time slice should be adopted as a standard breakdown for travel time data collection and reporting when sufficient sample size can be obtained.

False Match Screening

A false match is revealed as an outlier with either a very large or small elapsed time separated from the average. False matches are usually caused by partial plate reading (e.g., 4 characters instead of 6) and thus result in false matching of two different vehicles. The Seattle test of license plate matching using palmtop computer (3 number and 1 letter) produced a high percentage of false matches. It was determined that the dominant plates recorded are the Washington State new centennial license plates which consists of three numbers followed by a letter from "A" to "F" in the fourth position. The Washington State Department of Licenses has been making the plates in sequential alphabetical order since the new plate was designed for the Washington State centennial in 1986. At the time of the survey, the state was just beginning to distribute out plates with the letter "F".

Other false matches occur when vehicles travel at an unusually high or low speeds and are captured multiple times at multiple observation locations. In either the case of false matches or extreme outliers, the observations should be eliminated from the valid sample base.

The initial or standard rules for rejecting outliers are based on the maximum (85 mph) and minimum (15 mph) speed limit as the threshold values for upper and lower bound of travel speed in a normal situation. The maximum and minimum speeds are then converted into the maximum and minimum elapsed times for a specific route segment. An elapsed time falling outside the boundary of normal elapsed time is automatically rejected from the data set in the elapsed time screening procedure.

The lower boundary of 15 mph minimum speed limit should be reduced or totally released for congestion conditions when very low speeds are present.

License Plate Matching Reports

A series of reports are automatically produced, or manually selected, as the result of the license plate matching process.

Site Status Report

At the user's option, the site status report can be generated producing a summary of the license plates recorded at a location. The report summarizes the total and subtotal number of license plate records by date, route name, site, direction, lane number, hour, and surveyor (for laptop or palmtop method).

This report is particularly useful for the early detection of data acquisition discrepancy by location, hourly distribution, and surveyor's performance. Timely adjustment or reassignment of the crew, equipment set-up, and survey operations can be made to improve the overall performance.

Elapsed Time Distribution

The interim file of matched plates (see Table 6-3) is used to produce the plots of elapsed time and speed distribution in Figures 4-1 and 4-2. The data used is based on a 4-hour survey on a 5-mile segment of the Southeast Expressway in Boston. Table 4-4 displays the same elapsed time distribution in 10-minute increments of each 30 minute time slice.

The plots in Figures 4-1 and 4-2, and Table 4-4 show that travel times surveyed for this segment reach a peak in the time slice of 8:30-9:00 am. Both plots show a split pattern after 9:30 am. It could be caused by either lane speed variation when speed picks up, an unadjusted camera breakdown, or clock errors during the survey. Table 4-4 shows 21 observations discernable as outliers with greater than normally observed elapsed time.

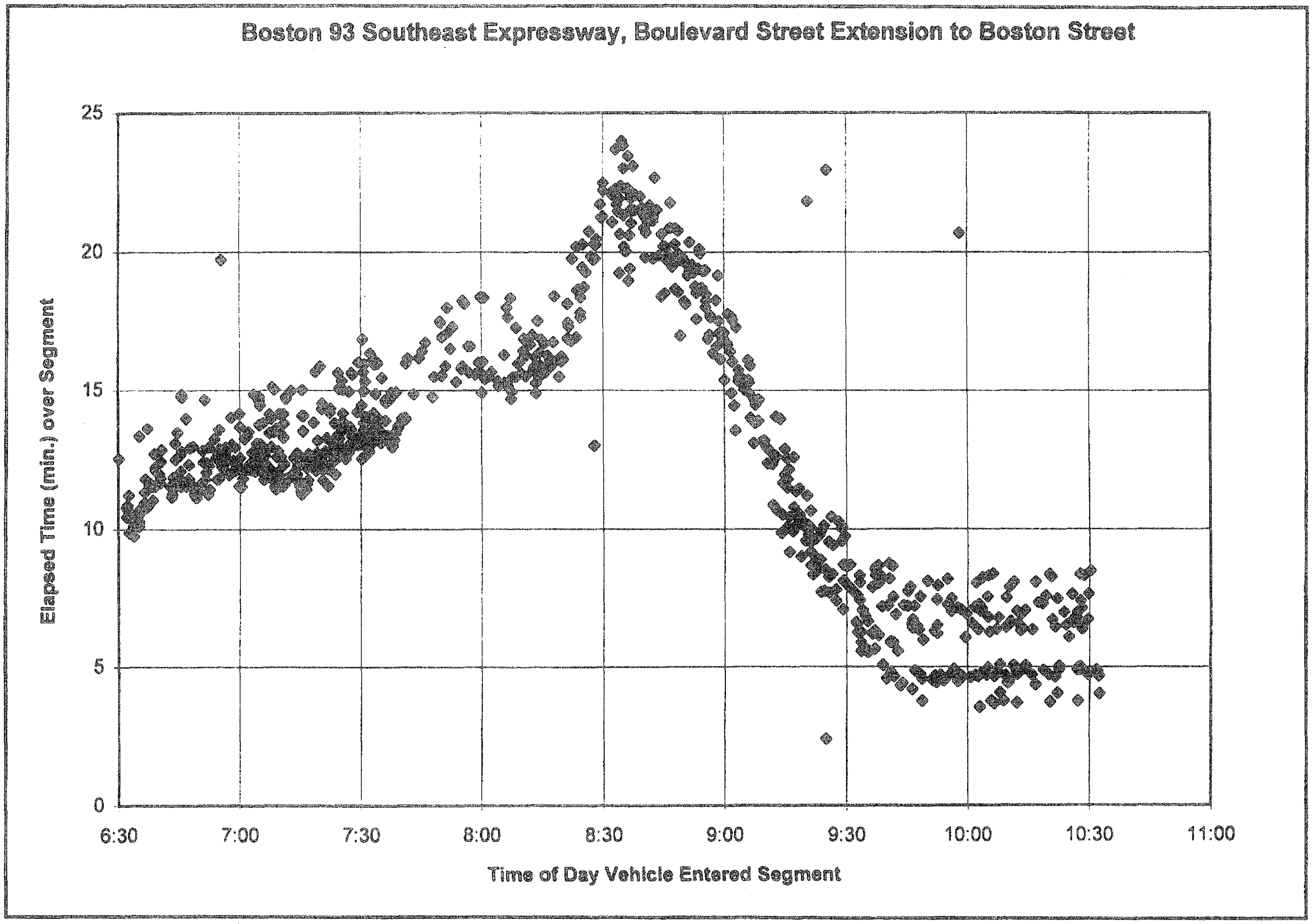


Figure 4-1. Plot of Elapsed Time Distribution

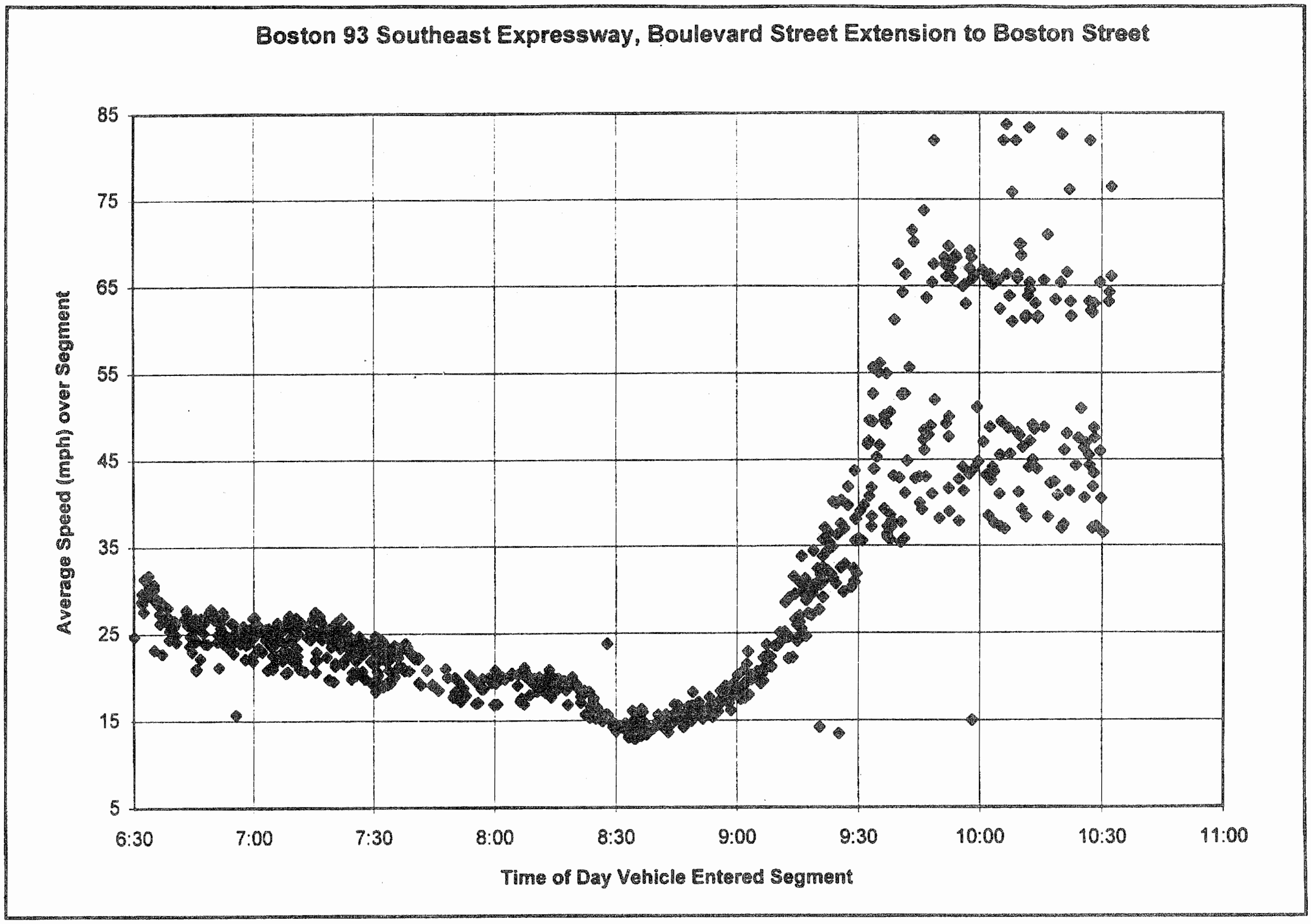


Figure 4-2. Plot of Average Speed Distribution

Table 4-4. Elapsed Time Distribution Report

City: Boston State: MA Route: Route 93 S/SE Date: 7/13/93
Direction: N
Site 1: Boulevard Street Extension Site 2: Boston Street

Time	0-10	10-20	20-30	30-40	40-50	50-60	> 60 min	Total
06:30AM - 07:00AM	2	123	0	1	0	0	7	133
07:00AM - 07:30AM	0	188	0	0	0	0	3	191
07:30AM - 08:00AM	0	105	0	0	1	0	1	107
08:00AM - 08:30AM	0	86	10	0	0	1	3	100
08:30AM - 09:00AM	0	56	62	0	1	0	0	119
09:00AM - 09:30AM	37	80	2	0	0	1	1	121
09:30AM - 10:00AM	102	0	1	0	0	0	1	104
10:00AM - 10:30AM	100	0	0	0	0	0	0	100
SubTotals:	241	638	75	1	2	2	16	975

Segment Status Report

Table 4-5 illustrates the standard segment status report derived from the same segment data displayed in Table 4-4 after the extreme outliers were removed from the sample set using the screening procedure. The report shows travel time and speed variations over a 4-hour period, as well as standard statistics (number of valid elapsed time observations, means, standard deviations, maximum and minimum elapsed time, number of outliers) in each 30-minute time slice of the survey period.

The stability, spread, and variance of the traffic flows are effectively captured within or across the 30-minute periods. Table 4-5 indicates that the duration of congestion starts from on or before 6:30 am at the segment and continues for 3 hours until 9:30 am if an average speed of 30 mph is deemed as the threshold (minimum acceptable speed) for congestion. The intensity level of this congestion period is measured as 3.0 (the ratio of off-peak average speed over the peak hour speed).

Volume counts can be printed in the report and compared with travel time and speed measurements if the data are available from loop detectors. The last column shows the number of elapsed times falling outside (plus and minus two standard deviations) the mean elapsed time.

Table 4-5. Segment Status Report

Upper speed limit 85 mhp <==> Lower speed limit 15 mph

City: Boston Route: Route 93 S/SE Date: 7/13/93
Direction: N
Segment: 2 of 3 Boulevard Street Extension to Boston Street
Distance: 5.16 mi Posted Speed: 55 mph Average Speed: 25.56 mph

Time	# of Plates Site 1	# of Plates Site 2	Plate Matches	Average Elapsed Time	Stand. Dev.	Maximum Elapsed Time	Minimum Elapsed Time	Average Speed	Vol	Elapsed Times Outside of +/- 2 Std
06:30 - 07:00AM	747	693	125	00:11:55	00:01:19	00:19:43	00:09:46	25.98		5
07:00 - 07:30AM	1,057	1,043	188	00:12:55	00:01:05	00:16:01	00:11:16	23.96		9
07:30 - 08:00AM	1,163	1,246	105	00:14:42	00:01:29	00:18:23	00:12:33	21.05		4
08:00 - 08:30AM	1,057	1,211	92	00:16:49	00:01:36	00:20:28	00:13:01	18.41		7
08:30 - 09:00AM	1,044	1,062	64	00:18:50	00:01:09	00:20:37	00:16:08	16.44		2
09:00 - 09:30AM	1,120	1,374	116	00:11:43	00:02:45	00:17:46	00:07:05	26.41		4
09:30 - 10:00AM	1,035	1,224	102	00:06:26	00:01:26	00:08:45	00:03:47	48.06		0
10:00 - 10:30AM	932	1,081	99	00:06:00	00:01:22	00:08:23	00:03:42	51.60		0

Route Summary Report

Table 4-6 shows the average elapsed times and speeds of the three segments comprising the route. This table can be produced as the final report using a standardized and automated procedure. The information is useful for performance monitoring, planning, and development of system performance and congestion measurements. The validity of the database and sample size will assure a high confidence level of statistical results when the process is more fully tested and established.

Table 4-6. Route Status Report

City: Boston   Route: Route 93 S/SE   Date: 7/13/93
Direction: N

Segment:		
1 of 3	Bates Avenue to Boulevard Street Extension	0.74 mi
2 of 3	Boulevard Street Extension to Boston Street	5.16 mi
3 of 3	Boston Street to Exit 22 - Russia Wharf/Northern Avenue	2.25 mi
	Route Total:	8.15 mi

	Segment 1		Segment 2		Segment 3		Route	
Time	Average Elapsed Time	Average Speed	Average Elapsed Time	Average Speed	Average Elapsed Time	Average Speed	Average Elapsed Time	Average Speed
06:30AM - 07:00AM	00:01:42	26.19mph	00:11:55	25.98mph	00:02:13	61.02mph	00:15:49	30.90mph
07:00AM - 07:30AM	00:01:40	26.52mph	00:12:55	23.96mph	00:02:15	60.21mph	00:16:50	29.04mph
07:30AM - 08:00AM	00:01:39	26.91mph	00:14:42	21.05mph	00:02:13	60.88mph	00:18:34	26.33mph
08:00AM - 08:30AM	00:01:40	26.63mph	00:16:49	18.41mph	00:03:01	44.74mph	00:21:30	22.74mph
08:30AM - 09:00AM	00:02:05	21.33mph	00:18:50	16.44mph	00:04:44	28.51mph	00:25:39	19.06mph
09:00AM - 09:30AM	00:01:14	35.84mph	00:11:43	26.41mph	00:04:00	33.70mph	00:16:58	28.82mph
09:30AM - 10:00AM	00:01:12	36.93mph	00:06:26	48.06mph	00:03:44	36.12mph	00:11:23	42.96mph
10:00AM - 10:30AM	00:01:14	35.98mph	00:06:00	51.60mph	00:03:01	44.65mph	00:10:15	47.67mph

Floating Car Report

The data from the floating car, probe vehicle, or AVI method are stored in the same database structure used for the license plate method. Standard reports developed for license plate matching methods are also generated to produce travel times, speeds, and standard statistics for any route segment defined by site points. Lower sample rates are, however, expected in the reports with these methods. Multiple matches resulting from the same vehicle ID in separate trips are usually detected and eliminated from the eligible matches when the maximum and minimum speed screening procedure is applied. Tables 4-7, 4-8, and 4-9 exhibit the three segment status reports of floating car surveys on Richmond Road in Lexington, Kentucky, where laptop computer matching as well as video license plate matching were also tested on the same route segments.

Table 4-7. Floating Car Segment Status Report - #1

Upper speed limit 85 mhp <==> Lower speed limit 15 mph

City: Lexington Route: Richmond Road Date: 9/21/93
Direction: W
Segment: 1 of 3 Eagle Creek(Man O'War Boulevard) to Patchen Road(Conrad Chevrolet
Distance: .80 mi Posted Speed: 35 mph Average Speed: 25.02 mph

Time	# of Plates Site 1	# of Plates Site 2	Plate Matches	Average Elapsed Time	Stand. Dev.	Maximum Elapsed Time	Minimum Elapsed Time	Average Speed	Vol	Elapsed Times Outside of +/- 2 Std
07:00 - 07:30AM	7	7	7	00:01:54	00:00:26	00:02:36	00:01:21	25.96		0
07:30 - 08:00AM	5	5	5	00:01:53	00:00:25	00:02:39	00:01:22	25.40		0
08:00 - 08:30AM	5	5	5	00:01:48	00:00:21	00:02:20	00:01:14	26.62		0
08:30 - 09:00AM	6	6	6	00:02:04	00:00:20	00:02:26	00:01:31	23.19		0

Table 4-8. Floating Car Segment Status Report - #2

Upper speed limit 85 mhp <==> Lower speed limit 15 mph

City: Lexington Route: Richmond Road Date: 9/21/93
Direction: W
Segment: 2 of 3 Patchen Road(Conrad Chevrolet) to Shriners Children's Hospital(Shriners Lane)
Distance: 1.35 mi Posted Speed: 45 mph Average Speed: 31.13 mph

Time	# of Plates Site 1	# of Plates Site 2	Plate Matches	Average Elapsed Time	Stand. Dev.	Maximum Elapsed Time	Minimum Elapsed Time	Average Speed	Vol	Elapsed Times Outside of +/- 2 Std
07:00 - 07:30AM	7	7	7	00:02:54	00:00:11	00:02:32	00:02:00	35.04	894	0
07:30 - 08:00AM	5	5	5	00:03:33	00:00:56	00:04:35	00:02:10	22.82	1227	0
08:00 - 08:30AM	5	5	5	00:02:26	00:00:13	00:02:40	00:02:07	33.20	866	0
08:30 - 09:00AM	6	6	6	00:02:17	00:00:06	00:02:29	00:02:12	35.43	753	0

Table 4-9. Floating Car Segment Status Report - #3

Upper speed limit 85 mhp <==> Lower speed limit 15 mph

City: Lexington   Route: Richmond Road   Date: 9/21/93
Direction: W
Segment: 3 of 3   Shriners Children's Hospital(Shriners Lane) to Hanover Avenue(Mentelle Park)
Distance: .90 mi   Posted Speed: 45 mph   Average Speed: 32.94 mph

Time	# of Plates Site 1	# of Plates Site 2	Plate Matches	Average Elapsed Time	Stand. Dev.	Maximum Elapsed Time	Minimum Elapsed Time	Average Speed	Vol	Elapsed Times Outside of +/- 2 Std
07:00 - 07:30AM	6	6	6	00:01:31	00:00:04	00:01:35	00:01:23	35.80		0
07:30 - 08:00AM	6	6	6	00:02:00	00:00:20	00:02:24	00:01:32	27.00		0
08:00 - 08:30AM	5	5	5	00:01:31	00:00:05	00:01:37	00:01:23	35.76		0
08:30 - 09:00AM	6	6	6	00:01:31	00:00:05	00:01:39	00:01:25	35.60		0

A special report is also designed for the floating method. Table 4-10 shows the Richmond Road Floating Car Survey Summary Report of a complete list of trip records with times recorded on all check points.

Table 4-10. Floating Car Survey Summary Report

Route: Richmond Road Date: 9/21/93
Direction: W

ID	Ashland Avenue	Hanover Ave Mentelle Pk.	Chinoe	Shriners Hospital	Children's Lakeshore	Fontaine	Water Company	Lexington Mall	New Circle Inner	New Circle Outer	Patchen Rd. French Qua.	Conrad Chev.	Mount Tab.	Locust Hill	Eagle Creek
HATHAWAY	07:07:31	07:07:17	07:06:13	07:05:47	07:05:28	07:05:08	07:04:53	07:04:43	07:04:30	07:04:23	07:04:10	07:03:47	07:03:20	07:02:54	07:02:13
HATHAWAY	07:23:50	07:23:35	07:22:32	07:22:00	07:21:38	07:21:20	07:20:57	07:20:47	07:20:30	07:20:23	07:20:07	07:19:41	07:19:19	07:18:57	07:17:35
HATHAWAY	07:38:07	07:37:46	07:36:45	07:36:14	07:35:54	07:35:36	07:35:12	07:35:00	07:34:42	07:34:32	07:34:16	07:33:30	07:33:13	07:32:52	07:31:35
HATHAWAY	07:57:51	07:56:10	07:54:26	07:53:48	07:53:18	07:52:28	07:51:28	07:51:08	07:50:42	07:50:30	07:50:11	07:49:39	07:49:17	07:48:54	07:47:51
HATHAWAY	08:11:41	08:11:23	08:10:26	08:10:00	08:09:41	08:09:20	08:09:08	08:08:55	08:08:36	08:08:31	08:08:17	08:07:53	08:07:23	08:06:57	08:05:33
HATHAWAY	08:26:09	08:25:52	08:24:49	08:24:20	08:24:00	08:23:43	08:23:18	08:23:09	08:22:51	08:22:40	08:22:25	08:21:40	08:21:17	08:21:03	08:19:51
HATHAWAY	08:39:48	08:39:34	08:38:26	08:37:55	08:37:33	08:37:14	08:36:53	08:36:45	08:36:28	08:36:21	08:36:09	08:35:43	08:35:12	08:34:43	08:33:31
HATHAWAY	08:53:44	08:53:26	08:52:27	08:52:00	08:51:32	08:51:21	08:51:00	08:50:51	08:50:34	08:50:25	08:50:10	08:49:46	08:49:20	08:48:46	08:47:20
CECIL	07:05:30	07:05:12	07:04:05	07:03:38	07:03:20	07:02:59	07:12:41	07:02:31	07:02:14	07:02:04	07:01:49	07:01:26	07:00:59	07:00:36	07:00:05
CECIL	07:19:50	07:19:32	07:18:29	07:18:04	07:17:45	07:17:24	07:17:00	07:16:47	07:16:28	07:16:19	07:16:05	07:15:36	07:15:15	07:14:54	07:14:06
CECIL	07:35:01	07:33:54	07:32:38	07:32:04	07:31:44	07:31:25	07:31:03	07:30:51	07:30:33	07:30:23	07:30:08	07:29:34	07:29:11	07:28:52	07:27:44
CECIL	07:53:25	07:52:07	07:50:31	07:49:55	07:49:30	07:48:40	07:47:47	07:47:28	07:47:03	07:46:53	07:46:38	07:45:48	07:45:24	07:45:05	07:44:05
CECIL	08:07:56	08:07:40	08:06:41	08:06:13	08:05:52	08:05:33	08:05:13	08:05:01	08:04:42	08:04:32	08:04:21	08:03:43	08:03:31	08:02:55	08:01:58
CECIL	08:24:04	08:23:47	08:22:44	08:22:10	08:21:51	08:21:32	08:21:11	08:21:00	08:20:35	08:20:27	08:20:14	08:19:53	08:19:28	08:18:50	08:18:00
CECIL	08:37:51	08:37:33	08:36:33	08:36:03	08:35:37	08:35:14	08:34:57	08:34:45	08:34:26	08:34:18	08:34:07	08:33:48	08:33:23	08:32:49	08:31:51
CECIL	08:51:42	08:51:27	08:50:23	08:49:54	08:49:35	08:49:17	08:48:56	08:48:44	08:48:22	08:48:13	08:47:58	08:47:25	08:46:59	08:46:36	08:45:54
HERRINGTON	07:09:39	07:09:21	07:08:15	07:07:48	07:07:21	07:07:09	07:06:49	07:06:40	07:06:23	07:06:14	07:06:07	07:05:38	07:05:13	07:04:45	07:03:20
HERRINGTON	07:25:54	07:25:37	07:24:41	07:24:14	07:23:54	07:23:36	07:23:10	07:23:00	07:22:41	07:22:30	07:22:09	07:21:42	07:21:18	07:20:40	07:19:06
HERRINGTON	07:43:05	07:41:51	07:40:45	07:40:11	07:39:49	07:39:28	07:39:08	07:38:50	07:38:27	07:38:15	07:37:57	07:35:36	07:35:15	07:34:55	07:34:14
HERRINGTON	08:01:32	08:00:25	07:58:25	07:58:01	07:57:40	07:57:21	07:57:02	07:56:51	07:56:37	07:56:28	07:56:15	07:55:51	07:55:26	07:54:52	07:53:12
HERRINGTON	08:18:11	08:17:49	08:16:45	08:16:15	08:15:53	08:15:30	08:15:06	08:14:57	08:14:41	08:14:32	08:14:15	08:13:37	08:13:16	08:12:50	08:12:23
HERRINGTON	08:39:41	08:39:23	08:38:23	08:37:50	08:37:26	08:37:07	08:36:48	08:36:44	08:36:23	08:36:13	08:35:59	08:35:35	08:53:13	08:34:45	08:33:09
HERRINGTON	08:55:47	08:55:28	08:54:30	08:54:03	08:53:40	08:53:18	08:52:56	08:52:46	08:52:29	08:52:22	08:52:05	08:51:45	08:51:22	08:50:55	08:49:52

5 Conclusions

Travel time data collection requires a multi-step process involving survey and sample design, methodology selection, planning, field data collection, data processing, analysis, and report generation. To make the data collected more useful, the process should be performed in a consistent and continuous manner in a scope defined and managed by MPOs and local transportation authorities. The information collected is viable in many aspects of transportation planning and traffic management. These applications include: improvement of transportation system performance measures, traffic and congestion monitoring, traffic impact assessments, travel demand forecasting, and evaluation of various transportation improvement projects. A standardized travel time data collection program can also be developed for national travel time trend analyses and intercity comparisons.

Standardized survey procedures (e.g., forms, synchronized clocks, labeling and cataloguing, survey logs, and data formats) are crucial to the quality of data collection and the efficiency for data processing. Data errors and processing time can be minimized with standard data formats and data processing procedures. To present the information more effectively, standard reports can be produced in a systematic format organized by route, segment, date, time periods, and traffic direction. The information is easy to understand and can be used as an effective measure of congestion. The travel time and speed measurements can also be compared and analyzed along with other traffic and roadway attributes (traffic volume, vehicle mix, roadway capacity, and vehicle-miles-travelled) using the standard and unified database structure. A comprehensive and integrated transportation system performance and data management system can be developed.[8]

Selection of appropriate technique(s) for collecting travel time data depends on the roadway characteristics and traffic patterns. Sample size requirements and sampling efficiency of the collection methods are key factors in methodology selection. Minimum sample size required should be decided by the unique roadway travel time variation and traffic and congestion patterns in general. The stability (or variation) of traffic flows by roadway segment, time of the day, day of the week, or seasonal variation should be considered and examined. There is certainly a need in research, perhaps through the data collected from the field tests, to develop guidelines for sample size requirements for travel time data collection.

The field test study concludes that, there is no single best methodology for travel time data collection. Selecting an appropriate methodology relies first on the performing MPO to identifying its data needs and the scope and priority of its data collection. The floating car method may still be the most convenient and flexible one to use for many purposes. However, it should be implemented with a careful sample design and sampling plan in order to reach a meaningful statistical sample. The more rigorous license plate matching method (video, portable computer, or AVI) offers the capability of obtaining a larger sample size in a continuous data form. This method, however, leaves ample room for improved operating procedures and techniques to increase its performance consistency. The concept of license plate matching is proven as a viable method for travel time measurement. With the advance of computer, electronic and communication technologies, it is likely that information sensing, transmitting, and displaying will be greatly enhanced. Travel time data gathering and reporting may eventually be conducted in a real time situation. Table 5.1 is a summary of the six tested methodologies for travel time data collection. The advantages and disadvantages of each methodology is described by its operational characteristics, expected sample rate, and its effectiveness. The more enhanced performance parameters could be resolved and specified with improved techniques and operating procedures. Regardless of the methodology empoyed, the overall effectiveness in the collection and use of travel time data depends on the complete process -- a consistent practice of travel time data collection, processing and analysis.

Table 5.1 Comparision of Travel Time Data Collection Methods

Methodology		Operational Characterisics							Sample Rate				Effectiveness				
		Measurement Type	Infrastructure Dependent	Observation Locations	Equipment Intensive	Labor Intensive	Technology Readiness	Training/Special Skills	% Volume Captured	Matches Per Segment Per Hour	Sample Efficiency	Data Accuracy	Route Type	Lane Discrimination	Captures Traffic Dynamics	Measure of Congestion	Other Traffic Data
License Plate Matching	Video	Link[1]	No	Fixed	Yes	No	Dev.[3]	High	Highway 10-40%	160-400	Increases with Machine Recognition Rate	High	Highway Arterial	Yes	Yes	Good	Volume, Vehicle Mix, Headway, Occupancy, Density
	Portable Computer	Link	No	Fixed	Yes	No	Yes	Low[5]	Arterial 60%	100-200	Decreases as Traffic Speed Increases	Med[7]	Arterial	Yes	Yes	Good	-
Floating Car		Link O/D	No	Flexible	No	Yes[2]	Yes	Med	3-4 Runs / Peak Period	N/A	Decreases as Congestion Increases[6]	Med[8]	Highway Arterial	No	No[8]	Fair	Delays, Incidents
Probe Vehicle		Link O/D	No	Flexible	No	Yes	Dev.	High	Probe Fleet Size	N/A	Decreases as Congestion Increases[6]	Low	Highway Arterial	No	No	Fair	Delays, Incidents
AVI		Link Spot	Yes	Fixed	Yes	No	Dev.	Low	Equipped Fleet Size	N/A	90%	High	Highway Arterial	No	No	Good	-
Loop Detector		Spot	Yes	Fixed	No	No	Yes[4]	Low	Total Volume	N/A	~100%	Med[4]	Highway Arterial	N/A	Yes	Good/ Fair	Volume, Occupancy

1 Link = link or route segment
2 Per sample required
3 Dev. = developmental
4 Volume/speed relationship needs development
5 Results vary significantly by individual ability

6 As the congestion level increases:
- Minimum sample size required significantly increases
- Run length and number of cars required increases
7 Caused by partial plate matching
8 Can be affected by driver behavior and sample deficiency

References

1 Transportation Research Board, *Highway Capacity Manual*, Special Report 209, TRB, Washington, D.C. 1994.

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3 Liu, Tai K., "Field Tests of Travel Time Survey Methodologies and Development of a Standardized Data Processing and Reporting System", Presented at the National Traffic Data Acquisition Conference, Proceedings Volume II, Rocky Hill, CT, September 1994.

4 Shuldiner, Paul M., "Acquisition and Analysis of License Plate Data Using Video and Machine Vision Technology", Presented at the National Traffic Data Acquisition Conference, Proceedings Volume II, Rocky Hill, CT, September 1994.

5 McShane, William R. and Ross, Roger P., *Traffic Engineering*, (Prentice Hall, New Jersey, 1990.)

6 Butterfield, Earl, Haselkorn, Mark, and Alalusi, Kathy, *Potential of Automatic Vehicle Identification in the Puget Sound Area*, TRAC, July 1994.

7 Texas Transportation Institute, *Speed Measurement with Inductance Loop Speed Traps*, TTI Research Report 1392-8, August 1994.

8 Liu, Tai K., "A Comprehensive, Route Specific, Transportation Data and Management System for Travel Time, Speed, Volume Data Collection and Performance Measurements", Presented at the Fifth National Conference on Transportation Planning Methods Applications, Proceedings Volume I, Seattle, April 1995.

Appendix A - Cost Summary

The FHWA provided $50,000 to each of the three selected MPO's to defray the expenses related to their participation in the tests. Boston's funding included a set aside for SmartRoute Systems of $5,000.

Analysis of Cost Data

Each MPO was required to compile comprehensive cost data for each methodology tested. Tables A-1, A-2, and A-3 show the direct costs of labor and materials summarized on the basis of route by city and methodology. Costs for each methodology are broken down into three categories: personnel, equipment, and other supplies. Personnel costs include the following categories:

Field Survey - the cost of staff or personnel hired explicitly for these surveys.

Field Coordination/Supervision - cost of personnel not conducting the surveys, such as supervisory personnel and rovers.

Planning and Preparation - costs for planing the surveys and preparing the sites. These include up-front meetings with the Volpe Center, any contract negotiations, and equipment procurement.

Training - time spent on training for the survey requirements and procedures; both in the field and classroom time are included.

Raw Data Assembly - costs associated with the collection of data related to the roadway attributes and assembling and transferring of the survey data subsequent to the surveys.

Equipment costs include any pieces of equipment required to perform the survey including costs for purchased or borrowed equipment. Costs for other supplies include the video tapes required for video method and minor items required for surveys, such as safety materials, materials for marking, securing and cleaning the equipment, weather protection for the equipment or personnel, and stopwatches.

Generic Cost Table

To specify the scope of a larger survey, a generic cost table is constructed in Table A-4 based on the information assembled from the field test experience. Table A-4 shows the costs of travel time data collection based on field surveys for ten route/days using three different methodologies. The generic route and data collection for the license plate method is defined for each route with 4 survey sites (3 route segments), 3-lane coverage on each site (12 sets of personnel/equipment). Data are collected for 8 hours a day, 4 hours in each peak hour traffic direction.

For the floating car method, a fleet of eight vehicles is scheduled for each 4-hour survey session, twice a day. With the assumption of an average speed of 30 mph, it would take about 40 minutes for each 20-mile round trip. Each floating car is expected to complete 5 to 6 trips in a 4-hour survey session. Only one person who does both the driving and data collection is assigned to each vehicle for the cost calculation. If two persons are assigned to each floating car, the direct costs would be doubled.

The cost structure is laid out for each of the three methodologies based on the direct labor estimate and the ratio of indirect to direct labor estimate. The parameters (number of sites and lanes, number of hours/lane/day, and $/hour) can be adjusted easily for a specific locality and survey requirements.

The equipment costs reflect those on the current market. The value of investment in equipment, equipment life, and rate of utilizattion should always be considered. The maintenance and repair costs for the video and computer equipment are relatively insignificant and thus not included in the cost table.

The cost for automatic (vs. manual read) video license plate processing, includes the use of a machine-vision system for automatic license plate reading. The costs of video license plate processing in Table A-4 are based on the crude estimates from the contract of automatic license plate processing and a research conducted by the University of Massachusetts at Amherst, involving manual reading and analysis of license plates from video tapes. Since the automatic video license plate processing represents the first operational testing of machine vision technology in the U.S. for travel related data collection, the cost and performance efficiency is expected to improve as the methodology develops and technology evolves.

Table A-1. Direct Cost (per route) - Video License Plate

	Boston	Seattle	Lexington
Scope of Survey			
Number of Routes	5	5	5
Number of Days per Route	1-3	1-3	1-3
Number of Hours Surveyed per Route per Day	8-10	8	4 [1]
Number of Camera Sites per Route	4	3-4	4
Number of Lanes Covered per Site	2-3	2-4	2
Number of Surveyors per Site	1-2	2-3	2
Number of Surveyors per Route	7-8	8	8
Personnel			
Number of Paid Hours per Surveyor per Day	16	12.5	8
Personnel Cost per Surveyor per Day	$144	$100	$52-$128
Personnel Cost per Route per Day	$1008-$1152	$800	$768
Video Tapes			
Number of Hours of Video Tape per Site per Day	16-30	16-32	8
Number of Hours of Video Tape per Route per Day	64-120	72-96	32
Number of Hours of Video Tape	2	2	2
Number of Video Tapes per Route per Day	32-60	36-48	16
Cost per Video Tape	$12	$12	$12
Total Costs for Video Tapes per Route per Day	$376-$704	$612-$765	$192

Notes:
[1] 7-9 am; 4-6 pm

Table A-2. Direct Cost (per route) - Portable Computer License Plate

	Seattle (Palmtop)	Lexington (laptop)
Scope of Survey		
Number of Routes	5	1
Number of Days per Route	1-3	4
Number of Days Surveyed	7	4
Number of Hours Surveyed per Route per Day	4 or 8	2 or 4
Number of Sessions	12 [1]	7 [2]
Number of Sites per Route	3-4	4
Number of Lanes Covered per Site	2-4	2
Number of Surveyors per Site	2-4	2
Number of Surveyors per Route per Session	12	8
Personnel		
Number of Persons Participating in the Data Collection	12	22 [3]
Number of Paid Hours per Surveyor per Session	4	3.5 [4]
Personnel Cost per Surveyor per Session	$32	$23-$56 [5]
Personnel Cost per Route per Day	$768 [6]	$639 [7]

Notes:
(1) 6:30-10:30 am; 2:30-6:30 pm - 4-Hour Sessions
(2) 7-9 am; 11 am-1 pm; 4-6 pm - 2-Hour Sessions
(3) of the 22 persons who participated in various days and sessions, there were 12 full-time and 4 part-time LFUCG employees and 6 students.
(4) 1 hour for set up; 2 hours for data collection; 1/2 hour for breakdown
(5) Hourly wage ranged from $6.50 to $16.00 per hour
(6) 8 hours per day
(7) 7 hours per day

Table A-3. Direct Cost (per route) - Floating Car and Probe Vehicle

	Lexington (Floating Car)	Boston (Probe Vehicle)
Scope of Survey		
Number of Routes	2	5
Number of Days Surveyed per Route	1	5
Duration of Survey (weeks)	2	3
Number of Hours Surveyed per Route per Day	4 [1]	6-12
Number of Trip Reports per Route per Day	34-41 [2]	10-90
Number of Data Collection Points per Route	14-15 [3]	6-12
Number of Lanes Covered per Segment	2	
Number of Surveyors per Car	2	1
Number of Cars/Number of Probes	3	150[4]
Number of Surveyors per Route	6	
Personnel - Floating Car		
Number of Paid Hours per Surveyor per Day	6	
Personnel Cost per Surveyor per Day	$96	
Personnel Cost per Route per Day	$576	
Personnel - Probe Vehicle		
Number of Data Collectors per Day		1-2
Number of Paid Hours per Probe Driver		$0
Number of Hours per Data Collector per Day		8-12
Personnel Cost per Data Collector per Day		$120-180[5]

Notes:

(1) 7-9 am; 4-6 pm

(2) 34 round trips were completed for Harrodsburg Road; 41 round trips for Richmond Road; only peak hour direction times were collected at each check point

(3) Four data collection locations were required to correspond with the video data collection points. The remaining data collection points were added at the discretion of the MPO. Richmond - 15 data collection points; Harrodsburg - 14 data collection points.

(4) Approximately 70 private probes and 80 public probes were registered with the SmartRoute Systems at the time of the survey.

(5) A $5,000 contract was issued by the FHWA and the Volpe Center and paid to SmartRoute Systems to support the travel time data collection using their probe vehicles.

Table A-4. Generic Cost Table

Generic Route: 10 miles, 3 lanes; 3 segments/4 survey sites		Scope of Survey: 10 route-days; 8 hours/day	
	License Plate Matching - Video -	License Plate Matching - Portable Computer -	Floating Car
Personnel			
Number of Persons	8	12	8
Number of Paid Hours	12	8	8
$/Hour	$10	$10	$10
$/Day	$960	$960	$640
Total Direct Labor (10 days)	$9,600	$9,600	$6,400
Indirect Labor Ratio (field coordination, planning, training, raw data assembly)	1.80	0.50	0.20
Total Labor Cost	$26,880	$14,400	$7,680
Equipment and Supplies			
Sets of Equipment	12	12	8
$/Set	$3,000	$1,800	
Equipment Cost	$36,000	$21,600	- n/a -
Other Supplies	$5,760 ($12/video tape)		$4,800 ($.25/mile)
Total Equipment and Supplies	$41,760	$21,600	$4,800
Video License Plate Processing			
Number of Hours of Tapes	960		
Plate Reader:			
$/Hour of Tape	$40-60		
Total Cost	$48,000		
Manual Read:	20 hours/tape		
$/Tape	$200		
Total Cost	$96,000		
Data Processing and Report Generation	Software developed by the Volpe Center and FHWA		

Appendix B - Samples of Data Collection Forms, Schedules, and Correspondence

B-1 Data Collection Forms

B-1-1 Survey Forms / Raw Data

Video Camera Daily Survey Log
Equipment Log and Check List - Video
Floating Car Data - Lexington
AVI Data - Seattle
Seattle Loop Locations
SmartRoutes Data Collection Form
Summary of SmartRoutes Probe Data Collection
Route 128 Summary Data - Boston
Route 128 Road Tube Counts - Boston

Video License Plate Matching

Daily Survey Log

Date: 6/23/94

Survey Time Period: 6 am-12 pm

Surveyor Name: John Smith

Equipment Set #: 3

[X] **Test Tape**

[X] **Communications Check**

City: Boston

Route: Route 3 South

Segment: Treble Cove Road

Direction of Travel: Northbound

Lane: 2

Weather/Roadway Conditions: Clear, dry

Event	Time	Camera Settings	Other
Setup			CB10 unit defective - used spare from rover.
Survey Start	6:32:00 am	F4, 1/1000th, 2x Extender On, Focus 30ft.	Started 2 minutes late. Camrea checked by Rover
	6:32:30 am		Camera Power interupted - restarted 6:33:00
Time Check	6:45:00 am	Took 2x Entender Off	
Time Check	7:00:00 am		
Time Check	7:15:00 am		
Time Check	7:30:00 am		
Time Check	7:45:00 am		Speed Enforcement Activity (7 Minutes)
Tape Change	8:00:00 am		
Time Check	8:15:00 am	Downed camera angle to pick up obscured plates & re-focused	
Tape Change	8:30:00 am	Tape changed -- started 8:32:00	
Time Check	8:45:00 am		
Time Check	9:00:00 am		
Time Check	9:15:00 am		
Time Check	9:30:00 am		
Time Check	9:45:00 am		Car stalled in breakdown lane 1- traffic moving over - reaiming camera to pick up diverted traffic.
Tape Change	10:00:00 am	Rover Check	
Time Check	10:30:00 am		
Time Check	10:45:00 am		Car gone - re-adjusting camera
Time Check	11:00:00 am		
Time Check	11:15:00 am		
Time Check	11:30:00 am	Thunderstorm Approaching	
Time Check	11:45:00 am	Beginning to Rain	
Survey End	12:00:00 pm		

Equipment Malfunction / Replacement:
Replaced fuse in CB-110 unit

Other:
Lots of pedestrian activity - need additional cones/flagging
Rover collected all tapes

Video Equipment Log and Checklist

Route Number:
Segment Number:
Location Description:
Date:

Equipment Set Number:
Survey Team Number:

	In-Hand	Make	Model	ID/Serial Number
Cannon L1 Video Camera				
Camera Remote				
Camera Case				
CL-2x Lens Extender				
Camera Batteries				
Camera Remote Batteries				
Video Leads (red & black)				
S-Video Cable				
Linear Polarizing Filters				
UV Lens Filter				
DC-10 DC Adapter				
CB-110 Car Battery Adapter				
CA-100A AC Power Adapter				
Battery/Cigarette Lighter Adapter/Cables and Splitters				
5" Color Monitor				
Monitor Cable/Adapter				
Monitor Case				
Black Fabric				
Marine Battery				
Tripod				
High 8mm Metal Evaporated Video Tapes				
Tape Labels				
Other				
Watch				
Pen/Paper				
Safety Cones				
Cellular Phone				
Chains/Locks				
Manuals/Forms/Phone Numbers				
Gas Mask & Filters				
Water Proofing Bags/Material				
String				
Tape				
Knife				
Safety Vest				
Rain Gear				
Fuses				
6" Ruler				
Clipboard				

Lexington Floating Car Data

Route: Richmond Road
Observer: Rob Roemer
Date: 9/21/93
Trip No: 5
Weather: Clear
Direction: P.M. Outbound

Location	Time	Stop #	Delay	Cause
Ashland Avenue	5:35:00			
* Hanover	5:35:32			
Mid-Point	5:36:10			
Chinoe	5:36:33			
* Shriner's Lane	5:37:05			
Lakeshore	5:37:33			
Fontaine	5:37:55			
Water Company	5:38:14			
Mid-Point	5:37:21			
Lexington Mall	5:38:26			
New Circle (Inner)	5:38:44			
New Circle (Outer)	5:58:55			
French Quarter	5:39:16			
[redacted]	[redacted]	1	41 Sec	S
Patchen	5:40:20			
* Conrad Chev.	5:40:32			
Mt. Tabor	5:40:53			
Locust Hill	5:41:15			
Mid Point	5:41:22			
Man O'War	5:41:42			
* Eagle Creek	5:41:52			

* Camera Locations

Symbols of Delay Cause:

S - Traffic Signals
PK - Parked Cars
DP - Double Parking
BP - Bus Passengers Loading/Unloading
T - General Congestion
LT - Left Turns
SS - Stop Sign
A - Accidents

Seattle AVI Data

Station Name: Location 1 - 236th St. SB

630 Serial Number: 1 Loop: 616 (SB) Cabinet: ES 24

Loop Mile Post Location: 178.19 Drift Rate: -0.02 Seconds/Day

Date	Time	Puck ID	Date	Time	Puck ID
Thursday 07/15/93	14:45:47	140	Friday 07/16/93	07:42:14	138
Thursday 07/15/93	15:10:54	128	Friday 07/16/93	07:44:32	102
Thursday 07/15/93	15:13:03	113	Friday 07/16/93	07:57:07	129
Thursday 07/15/93	15:25:47	145	Friday 07/16/93	08:06:19	130
Thursday 07/15/93	15:31:33	102	Friday 07/16/93	08:08:28	141
Thursday 07/15/93	15:47:45	133	Friday 07/16/93	08:09:41	126
Thursday 07/15/93	15:56:35	123	Friday 07/16/93	08:17:35	116
Thursday 07/15/93	16:40:49	140	Friday 07/16/93	11:11:41	132
Thursday 07/15/93	16:58:20	138	Friday 07/16/93	13:56:28	145
Thursday 07/15/93	17:00:51	130	Friday 07/16/93	14:39:29	125
Thursday 07/15/93	17:11:48	101	Friday 07/16/93	15:02:20	111
Thursday 07/15/93	17:12:03	148	Friday 07/16/93	15:35:56	145
Thursday 07/15/93	17:19:28	139	Friday 07/16/93	15:36:28	137
Thursday 07/15/93	17:23:42	124	Friday 07/16/93	15:39:24	135
Thursday 07/15/93	17:29:50	113	Friday 07/16/93	15:43:40	101
Thursday 07/15/93	18:24:50	144	Friday 07/16/93	15:53:48	123
Thursday 07/15/93	18:33:22	146	Friday 07/16/93	16:21:27	112
Friday 07/16/93	06:10:55	117	Friday 07/16/93	17:03:09	110
Friday 07/16/93	06:11:52	144	Friday 07/16/93	17:05:12	146
Friday 07/16/93	06:16:05	120	Friday 07/16/93	17:21:21	121
Friday 07/16/93	06:21:00	127	Friday 07/16/93	17:25:11	113
Friday 07/16/93	06:29:57	108	Friday 07/16/93	17:28:43	107
Friday 07/16/93	06:39:58	116	Friday 07/16/93	17:35:33	124
Friday 07/16/93	06:44:27	138	Friday 07/16/93	17:41:02	122
Friday 07/16/93	06:46:17	107	Friday 07/16/93	18:40:34	149
Friday 07/16/93	06:49:30	145	Monday 07/19/93	06:13:08	117
Friday 07/16/93	06:49:53	148	Monday 07/19/93	06:13:22	128
Friday 07/16/93	07:00:08	124	Monday 07/19/93	06:15:26	148
Friday 07/16/93	07:05:38	123	Monday 07/19/93	06:20:48	126
Friday 07/16/93	07:07:14	110	Monday 07/19/93	06:25:00	141
Friday 07/16/93	07:08:37	121	Monday 07/19/93	06:29:44	147
Friday 07/16/93	07:11:37	139	Monday 07/19/93	06:47:55	104
Friday 07/16/93	07:11:45	122	Monday 07/19/93	06:48:42	142
Friday 07/16/93	07:12:07	113	Monday 07/19/93	06:49:24	111
Friday 07/16/93	07:14:14	103	Monday 07/19/93	07:01:30	127
Friday 07/16/93	07:16:36	149	Monday 07/19/93	07:11:26	133
Friday 07/16/93	07:22:21	134	Monday 07/19/93	07:13:08	122
Friday 07/16/93	07:22:39	112	Monday 07/19/93	07:13:17	113
Friday 07/16/93	07:23:41	115	Monday 07/19/93	7:15:13	146
Friday 07/16/93	07:30:08	142	Monday 07/19/93	07:15:46	125
Friday 07/16/93	07:33:10	127	Monday 07/19/93	07:17:30	109
Friday 07/16/93	07:34:11	109	Monday 07/19/93	07:21:52	137
Friday 07/16/93	07:39:24	105	Monday 07/19/93	07:23:06	149
Friday 07/16/93	07:40:28	120	Monday 07/19/93	07:23:59	144
Friday 07/16/93	07:41:51	140	Monday 07/19/93	07:25:37	123

Bus / Puck Assignment

Vehicle Number	Puck ID	Vehicle Number	Puck ID
700	101	725	126
701	102	726	127
702	103	727	128
703	104	728	129
704	105	729	130
705	106	730	131
706	107	731	132
707	108	732	133
708	109	733	134
709	110	734	135
710	111	735	136
711	112	736	137
712	113	737	138
713	114	738	139
714	115	739	140
715	116	740	141
716	117	741	142
717	118	742	143
718	119	743	144
719	120	744	145
720	121	745	146
721	122	746	147
722	123	747	148
723	124	748	149
724	125	DOT Car	150

Volpe Travel Time Survey - Seattle Area Loop Data

Corridor Location and Direction	Date	Number of Lanes	New ES Station Number	Nearby Loop Numbers	Lane Number	Loop MP Location
SR 99 SB						
N 130th St.	7/23/93					
N 103rd St.	7/23/93					
Zoo (N. Ped. Br.)	7/23/93					
N 41st St.	7/23/93					
I-5/CBD-Airport NB						
Spng St.	7/27/93	2	ES-108D	MN 1	1	165.49
				MN 2	2	
S. Albro Pl.	7/27/93	4, now 5	ES-086D	MN 1	1	161.19
				MN 2	2	
				MN 3	3	
				MN 4	4	
				MNH 5		
S. 144th St.	7/27/93	5?	ES-017D	MN 1	1	
				MN 2	2	
				MN 3	3	
				MN 4	4	
				MN 5	5	
I-5/CBD-Airport SB						
Spring St.	7/27/93	4	ES-108D	MS 1	1	165.49
				MS 2	2	
				MS 3	3	
					4	
S. Albro Pl.	7/27/93	4	ES-086D	MS 1	1	161.19
				MS 2	2	
				MS 3	3	
				MS 4	4	
S. 144th St.	7/27/93	7?	ES-071D	MS 1	1	
				MS 2	2	
				MS 3	3	
				MS 4	4	
				MS 5	5	
				MS 6	6	
				MSH 7	7	
I-405 NB						
112th Ave SE	7/28/93	3	ES-662D	MNH 1	1	
				MN 2	2	
				MN 3	3	
Lk. Wash. Blvd.	7/28/93	3	None	None	1	
				None	2	
				None	3	
NE 30th St.	7/28/93	3	ES-651D	MNH 1	1	6.55
				MN 2	2	
				MN 3	3	

Volpe Travel Time Survey - Seattle Area Loop Data, Continued

Corridor Location and Direction	Date	Number of Lanes	New ES Station Number	Nearby Loop Numbers	Lane Number	Loop MP Location
SR 520 WB						
148th Ave NE	7/29/93	2	None	None		
92nd Ave NE	7/29/93	3	None	None		
76th Ave NE	7/29/93	2	ES-514D	MW 1	1	4.17
				MW 2	2	
24th Ave E	7/29/93	3	ES-504R	MWH 1	1	
				MW 2	2	
				MW 3	3	
SR 520 EB						
148th Ave NE	7/29/93	2	None	None		
92nd Ave NE	7/29/93	2	None	None		
76th Ave NE	7/29/93	2	ES-514D	ME 1	1	4.17
				ME 2	2	
24th Ave E	7/29/93	4	ES-504R	MED 2	1	
				MEHP 2	2	
				MME 2	3	
				MME 3	4	
I-5 North SB						
NE 185th St.	8/3-4-5/93	4	ES-177D	MS 1	1	176.73
				MS 2	2	
				MS 3	3	
				MSH 4	4	
NE 145th St.	8/3-4-5/93	4	ES-167D	MS 1	1	174.6
				MS 2	2	
				MS 3	3	
				MSH 4	4	
NE 117th St.	8/3-4-5/93	5	ES-161D	MS 1	1	173.3
				MS 2	2	
				MS 3	3	
				MS 4	4	
				MSH 5	5	
I-5 North NB						
NE 185th St.	8/3-4-5/93	4	ES-177D	MN 1	1	
				MN 2	2	
				MN 3	3	
				MNH 4	4	
NE 145th St.	8/3-4-5/93	5	ES-168R	MN 1	1	
				MN 2	2	
				MN 3	3	
				MN 4	4	
				MNH 5	5	
NE 117th St.	8/3-4-5/93	5	ES-161D	MN 1	1	173.3
				MN 2	2	
				MN 3	3	
				MN 4	4	
				MNH 5	5	

Smart Routes Data Collection Form for FHWA Travel Time Survey

Date: 7-12-93 From: To: Smart Routes Data Collector: Page 10 of

Time Call Came In hh:mm:ss am/pm	Type Call Time Check (TC) Segment Call-In (Seg)	Driver Name/ Probe ID (license plate) NNNLLL	Route 93 128 3 Tunnel Pike	Direction of Travel North, South, East, West, To Logan, or From Logan	Call in Point Segment Name Entry - Exit # Exit - Exit #	Time Probe Past Call-In Point hh:mm:ss am/pm	Lane 1 2 3 1-2 HOV Breakdown	Delays/ Incidents Construction Police Speed Enforcement	Road Condition Dry Wet Obstacles	Weather Condition Sunny Overcast Drizzle Rain Fog Windy
	Seg	BUS # 111	Tunnel	IN BOUND SUMNER	FT Bmu SUMNER	09:10 07				
	Seg	3168	Tunnel	IN BOUND SUMNER	FT SUMNER BRIDGE	09:10				
	Seg	6	pike	EB	WESTON TOLLS	09:10				
	Seg	4	pike	WB	WESTON TOLLS	9:11 39				
9:13	TC	6	pike	EB	STAR MARKET	9:13 55				
	Seg	111	Tunnel	SB	SUMNER Tunnel	09:16 40				
	3168	3168	Tunnel	NB RTE 93	EXIT SUMNER TUNNEL	09:17				
	Seg	111	Artery	SB	FT BRIDGE High ST	09:18 30				
	Seg	6	pike	EB	ALLSTON TOLLS	09:18 41				
	Seg	4	pike	WB	FRAM TOLLS	09:19				

Smart Route Probe Data Collection

ROUTE	DATE / DIRECTION / NUMBER OF TRIPS										TOTAL	
	6/28		6/29		6/30		7/01		7/02			
Route 128	N	S	N	S	N	S	N	S	N	S	N	S
	7	6	6	4	7	4	6	5	5	4	31	23
	7/05		7/06		7/07		7/08		7/09			
Route 3	N	S	N	S	N	S	N	S	N	S	N	S
	0	2	3	0	0	3	3	4	2	4	8	13
	7/12		7/13		7/14		7/15		7/16			
Route 93	N	S	N	S	N	S	N	S	N	S	N	S
	19	19	19	22	24	18	48	42	19	22	129	123
	7/12		7/13		7/14		7/15		7/16			
Mass Turnpike	N	S	N	S	N	S	N	S	N	S	N	S
	18	15	22	18	25	20	23	17	20	21	108	91
	7/12		7/13		7/14		7/15		7/16			
Sumner Tunnel	N	S	N	S	N	S	N	S	N	S	N	S
	7		9		6		9		12		43	

Roadway Attribute Data

Route: 128
City: Boston
Segments:

1 of 3	Grove Street	to Highland Ave.	2.82 Miles
2 of 3	Highland Ave	to Route 1A	6.25 Miles
3 of 3	Route 1A	to Ponkapoag Road	5.23 Miles
		Route Total	14.30 Miles

General Physical Attributes

Seg	Length (Miles)	HOV Lanes E/W	HOV Lanes W/S	Lanes E/N	Lanes W/S	Entr E/N	Entr W/S	Speed Limit	Land Use	Entr. Ramp Vol.	Exits E/N	Exits W/S	Exit Ramp Vol.	# of Loop Det.	AM Peak Vol. E/N	Noon or AWD Vol. E/N	Noon or AWD Vol. W/S	PM Peak Vol. E/N	PM Peak Vol. W/S	% Truck	% Car	Signalized Intersection
1	2.82	0	0	4	4	2	2	55	I		2	2				6496		4072				0
2	6.25	0	0	3	3	3	3	55	O		3	3			7935	5293	4042	5554	5679			0
3	5.23	0	0	3	3	5	5	55	I		5	5			7872	6093		5223	5801			0
	14.30	0	0	4	4	10	10			0	10	10	0	0	7935	6496		5554	5801			0

Land Use Key:
A - Agricultural
C - Commercial
F - Office
I - Industrial
O - Open
R - Residential
T - Tunnel
W - Water

Commonwealth of Massachusetts - Highway Department

Road Tube Counts
Weekly Sumary for Week of June 25, 1993

File: M0793006.PRN
Station: 000096227102
ID: 000000121927
City/Town: Milton
Location: Rte. I-95 (128), South of Ponkapoag Rd.
Lane(s): 1-1
Direction: South

	Date								
	27	28	29	30	1	2	3	Wkday	Daily
Time	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Avg.	Avg.
01:00	562	293	328	418	450	-	583	372	439
02:00	343	195	236	275	310	-	325	254	281
03:00	182	155	180	193	198	-	258	182	194
04:00	142	150	200	200	233	-	167	196	182
05:00	94	218	239	227	251	-	176	234	201
06:00	154	610	554	621	577	-	333	591	475
07:00	313	1174	1145	1211	1191	-	618	1180	942
08:00	463	1943	1971	1934	1957	-	995	1951	1544
09:00	643	2048	2061	2054	2135	-	1313	2075	1709
10:00	853	1686	1592	2544	1769	-	1693	1898	1690
11:00	1038	1622	1557	1989	1736	-	1966	1726	1651
12:00	1335	1555	1634	1629	1782	-	1950	1650	1648
13:00	1607	1724	1663	1751	1831	-	2057	1742	1772
14:00	1578	1654	1725	1765	1971	2066	1821	1836	1797
15:00	1437	1851	1874	1887	2069	2309	1664	1996	1870
16:00	1470	2555	2707	3051	3062	3147	1644	2904	2519
17:00	1515	3240	3344	3587	3597	3564	1666	3466	2930
18:00	1418	3339	3644	3665	3692	3437	1562	3555	2965
19:00	1310	2198	2641	2647	2750	2774	1485	2602	2258
20:00	1173	1363	1521	1726	1786	2033	1245	1686	1550
21:00	1026	1076	1121	1249	1399	1444	987	1258	1186
22:00	838	832	973	1102	1123	1119	861	1030	978
23:00	603	625	764	847	804	827	713	773	740
24:00	469	652	701	733	684	827	737	719	686
Totals	20566	32758	34375	37305	37357	23547	26819	35878	32208

% Avg Wkday	57.3	91.3	95.8	104.0	104.1	65.6	74.7
% Avg Day	63.9	101.7	106.7	115.8	116.0	73.1	83.3
AM Peak Hr	12:00	09:00	09:00	10:00	09:00	None	11:00
AM Count	1335	2048	2061	2544	2135	-	1966
PM Peak Hr	13:00	18:00	18:00	18:00	18:00	17:00	13:00
PM Count	1607	3339	3644	3665	3692	3564	2057

B-1-2 MPO Provided Raw Data

Physical Roadway Attribute Data - Richmond Road - Lexington
Survey Description - Laptop - Richmond Road - Lexington
Labor Cost Data - Laptop - Lexington
Equipment Cost Data - Laptop - Lexington
Survey Description - Floating Car - Richmond Road - Lexington
Labor Cost Data - Floating Car - Lexington
Equipment Cost Data - Floating Car - Lexington

Lexington, Kentucky

ROADWAY DATA

Route 2 - Richmond Road

		Segment		
		1 Hanover Avenue to Shriners Children's Hospital	2 Shriners Children's Hospital to Conrad Chevrolet	3 Conrad Chevrolet to Eagle Creek Drive
Physical Attributes				
Distance Between Points (Length of Segment) - miles		0.9	1.35	0.80
Number of Lanes	HOV Regular X	2	2	2
Posted Speed Limit		35	45	45
Predominant Land Use Along Segment		residential	commercial	commercial
Other Roadway Attributes				
Number of Entrances Within Segment Ramp Volumes*		61	18	10
Number of Exits Within Segment Ramp Volumes*		61	18	10
Average Traffic Volume* Source of Data:	AM Peak Noon PM Peak	1833 1200 2150	1775 1333 1885	1098 1190 1550
Vehicle Mix*	Truck Car	5% 95%	5% 95%	5% 95%
Number of Signalized Intersections**		1	8	4
Other: Bridges, Tunnels, ramp metering, permanent counters/loop detectors, etc.		1 loop location	2 loop locations	n/a

* If Available; ** Arterial Only

Lexington, Kentucky

SURVEY DATA

Methodology: Laptop

Route 2 - Richmond Road

(Sites Listed North West to South East)

|- Site 1 - Hanover Avenue
Segment 1-----|
|- Site 2 - Shriners Children's Hospital
Segment 2-----|
|- Site 3 - Patchen Drive (Conrad Chevrolet)
Segment 3-----|
|- Site 4 - Prosperous Place / Eagle Creek Drive

Route Description

arterial
suburb to CBD
radial

Length of route
Roadway type (arterial/freeway)
Location relative to CBD, Airport, major residential, industrial and business areas
Connecting (suburb -> suburb, suburb -> CBD)
Radial/Circumferential

Summary of Survey Dates, Hours and Times

9/21/93	7am - 9 am	9/22/93	7 am - 9 am	9/23/93	7 am - 9 am
	4 pm - 6 pm		4 pm - 6 pm		4 pm - 6 pm
				9/30/93	11 am - 1 pm

Total Time For Route = ~~96~~* Hours 108 hours

* 96 to 108 hours due to noon count on 9/30/93

COST DATA

Methodology: Laptop

Route	Site	Personnel - Surveyors				
		Number of Days / Events	Number of Survey Hours	Number of Lanes Covered	Number of Surveyors	Number of Person Hours
1 Harrodsburg Road	1 - Burley Avenue					
	2 - Lynn Drive					
	3 - Burbank Court					
	4 - Rabbit Run					
2 Richmond Road	1 - Hanover Avenue	4/7	14	2	14	49
	2 - Shriners Children's Hospital	4/7	14	2	14	49
	3 - Conrad Chevrolet	4/7	14	2	14	49
	4 - Eagle Creek Drive	4/7	14	2	14	49
3 New Circle Road North	1 -					
	2 -					
	3 -					
	4 -					
4 Versailles Road	1 - General Tool					
	2 - Village Drive					
	3 - New Circle Road					
	4 - Van Meter Road					
5 New Circle Road South	1 - Harrodsburg Road					
	2 - Clays Mill Road					
	3 - Nicholasville Road					
	4 - Tates Creek Road					

```
                          #lanes events
[(1 hr) + (2 hrs) + (½ hr)] 2 x 7 = 49
setup   actual data breakdown
         collection
```

Total Hours: 196

COST DATA

Methodology: Laptop

	Routes				
	1 Harrodsburg Road	2 Richmond Road	3 New Circle Road North	4 Versailles Road	5 New Circle Road South
Personnel - Field Coordination/Supervision					
Number of Persons/Day	n/a	16	n/a	n/a	n/a
Number of Total Person Hours/Day	n/a	32	n/a	n/a	n/a

	Staff	Surveyors
Personnel - Other		
Planning and Preparation for Field Survey (Equipment purchase, organizational meetings, route selection, hiring, ...)		
Duration of this Stage (Number of Weeks)	1.2	
Number of Persons	1	
Number of Total Person Hours	48	
Training		
Number of Days	½ hr / person	4
Number of Persons	1	22*
Number of Total Person Hours	12	196
Raw Data Assembly		
Number of Days	4	
Number of Persons	1	
Number of Total Person Hours	7	

```
                                  per location   events
[( 1 hr)  +  (2 hrs)  +  (½ hr) ] 2    x    4 x  7 = 196
                                            ↑
setup        data     breakdown       # locations
            collection
```

*full time - 12
part time - 4
students - 6

Total 22

Lexington, Kentucky

Page L-8

EQUIPMENT COST DATA

Methodology: Laptop

Item	Quantity		Cost
	Purchased	Borrowed	
Laptop - Surveyor			
Laptop - Data Collection/Processing	3	5	
Software (developed in house)	n/a	n/a	
	* 8238	12200 **	
* 3 @ 8238 /3			
** 4 @ 2500 per 1 @ 2200			
Total:		20,438	

Lexington, Kentucky

SURVEY DATA

Methodology: Floating Car

Route 2 - Richmond Road

(Sites Listed North West to South East)

|- Site 1 - Hanover Avenue
Segment 1-----|
|- Site 2 - Shriners Children's Hospital
Segment 2-----|
|- Site 3 - Conrad Chevrolet
Segment 3-----|
|- Site 4 - Eagle Creek Drive

Route Description

Length of route
Roadway type (arterial/freeway) arterial
Location relative to CBD, Airport, major residential, industrial and business areas OBD
Connecting (suburb -> suburb, suburb -> CBD) suburb - CBD
Radial/Circumferential radial

Summary of Survey Dates, Hours and Times

DATE: Sept. 21, 1993 HOURS: 7 - 9 am & 4 - 6 pm TIMES: 4 hrs. x 3 = 12 hrs.

EQUIPMENT; 3 stop watches
3 vehicles
3 clip boards

PERSONNEL: 6 persons

Lexington, Kentucky

COST DATA

Methodology: Floating Car

Route	Site	Personnel - Surveyors				
		Number of Days	Number of Survey Hours	Number of Lanes Covered	Number of Surveyors	Number of Person Hours
1 Harrodsburg Road	1 - Burley Avenue	1	4	2	6	
	2 - Lynn Drive	1	4	2	6	
	3 - Burbank Court	1	4	2	6	
	4 - Rabbit Run	1	4	2	6	*24
2 Richmond Road	1 - Hanover Avenue	1	4	2	6	
	2 - Shriners Children's Hospital	1	4	2	6	
	3 - Conrad Chevrolet	1	4	2	6	
	4 - Eagle Creek Drive	1	4	2	6	**24
3 New Circle Road North	1 -					
	2 -					
	3 -					
	4 -					
4 Versailles Road	1 - General Tool					
	2 - Village Drive					
	3 - New Circle Road					
	4 - Van Meter Road					
5 New Circle Road South	1 - Harrodsburg Road					
	2 - Clays Mill Road					
	3 - Nicholasville Road					
	4 - Tates Creek Road					

* - Total for Harrodsburg Road

** - Total for Richmond Road

COST DATA

Methodology: Floating Car

	Routes				
	1 Harrodsburg Road	2 Richmond Road	3 New Circle Road North	4 Versailles Road	5 New Circle Road South
Personnel - Field Coordination/Supervision					
Number of Persons/Day	6	6			
Number of Total Person Hours/Day	24	24			

	Staff	Surveyors
Personnel - Other		
Planning and Preparation for Field Survey (Equipment purchase, organizational meetings, route selection, hiring, ...)		
Duration of this Stage (Number of Weeks)	1	
Number of Persons	1	
Number of Total Person Hours	5	
Training		
Number of Days	1	1
Number of Persons	1	6
Number of Total Person Hours	4	6
Raw Data Assembly		
Number of Days	10	
Number of Persons	1	
Number of Total Person Hours	33	

Lexington, Kentucky

EQUIPMENT COST DATA

Methodology: Floating Car

Item	Quantity		Cost
	Purchased	Borrowed	
Stop watches	6		$48.02
Clip boards	6		8.76
Vehicles		3	

B-2 Schedules

SmartRoutes Events/Roadwork Schedule - Boston
Survey Locations/Schedule - Boston

SmartRoutes Events/Roadwork Schedule - Boston - Monday 6/28/93 to Sunday 7/4/93

Date	Time	Event	Time	Roadwork
Monday 6/28/93	19:30 - 23:00	Red Sox/Milwaukee	00:00 - 05:30	Callahan Tunnel
			00:00 - 23:59	St. James Bridge
			00:20 - 23:55	Route 16 WB
			00:30 - 23:59	Alford St. Bridge Closure
			04:50 - 16:00	Rte. 1 Saugus - Lynnfld
			05:00 - 15:30	Rte. 1 Saugus-Lynnfld
			06:10 - 23:59	East Squantum St. 1 Way Detour
			06:30 - 16:30	Route 3 Plymouth
			06:30 - 16:30	495 Marlboro-Milford
			06:40 - 16:00	Rte. 2 Littleton
Tuesday 6/29/93	19:30 - 23:00	Red Sox/Milwaukee	00:00 - 05:30	Callahan Tunnel
	20:00 - 23:00	Boston Pops at the Hatch Shell	00:00 - 23:59	St. James Bridge
			00:20 - 23:55	Route 16 WB
			00:30 - 23:59	Alford St. Bridge Closure
			04:50 - 16:00	Rte. 1 Saugus - Lynnfld
			05:00 - 15:30	Rte. 1 Saugus-Lynnfld
			06:10 - 23:59	East Squantum St. 1 Way Detour
			06:30 - 16:30	Route 3 Plymouth
			06:30 - 16:30	495 Marlboro-Milford
			06:40 - 16:00	Rte. 2 Littleton
Wednesday 6/30/93	14:00 - 16:00	Stars of Lawrence Welk Show	00:00 - 05:30	Callahan Tunnel
	19:30 - 23:00	Red Sox/Milwaukee	00:00 - 23:59	St. James Bridge
	20:00 - 23:00	Boston Pops at th Hatch Shell	00:20 - 23:55	Route 16 WB
			00:30 - 23:59	Alford St. Bridge Closure
			04:50 - 16:00	Rte. 1 Saugus - Lynnfld
			05:00 - 15:30	Rte. 1 Saugus-Lynnfld
			06:10 - 23:59	East Squantum St. 1 Way Detour
			06:30 - 16:30	Route 3 Plymouth
			06:30 - 16:30	495 Marlboro-Milford
			06:40 - 16:00	Rte. 2 Littleton
Thursday 7/1/93	16:00 - 20:00	Wing Fest	00:00 - 05:30	Callahan Tunnel
	17:30 - 19:30	WBOS Earthwatch Concert	00:00 - 23:59	St. James Bridge
	20:00 - 23:00	Boston Pops at the Hatch Shell	00:20 - 23:55	Route 16 WB
			00:30 - 23:59	Alford St. Bridge Closure
			04:50 - 16:00	Rte. 1 Saugus - Lynnfld
			05:00 - 15:30	Rte 3 Plymouth
			06:10 - 23:59	495 Marlboro-Milford
			06:30 - 16:30	Rte. 2 Littleton
			06:30 - 16:30	Batterymarch St/Boston
			06:40 - 16:00	Rte. 106 Kingston
Friday 7/2/93	20:00 - 23:00	Boston Pops at the Hatch Shell	00:00 - 05:30	St. James Bridge
			00:00 - 23:59	Route 16 WB
			00:20 - 23:55	Rte. 1 Saugus - Lynnfld
			00:30 - 23:59	Rte. 1 Saugus-Lynnfld
			04:50 - 16:00	Rte. 3 Plymouth
			05:00 - 15:30	495 Marlboro-Milford
			06:10 - 23:59	Rte. 2 Littleton
			06:30 - 16:30	Batterymarch St/Boston
			06:30 - 16:30	Rte. 106 Kingston
			06:40 - 16:00	Rte. 9
Saturday 7/3/93	11:00 - 18:00	12th Annual Chowderfest	00:00 - 23:59	St. James Bridge
	20:00 - 23:00	Boston Pops at the Hatch Shell	00:20 - 23:55	Route 16 WB
			04:50 - 16:00	Rte. 1 Saugus - Lynnfld
Sunday 7/4/93	13:00 - 18:00	Great Woods Festival Orchestra	00:00 - 05:30	Callahan Tunnel Closure
	20:00 - 23:00	Boston Pops at the Hatch Shell	00:00 - 23:59	St. James Bridge
			00:20 - 23:55	Route 16 WB

COMPARISON OF TRAVEL TIME SURVEY METHODOLOGIES
STUDY LOCATIONS

Five Corridors will be used for travel time studies:

1. Yankee Division Highway (Route 128) - from Grove Street to Ponkapoag Road, 6/28/93 to 7/1/93, 6:30 AM to 10:30 AM, 12:30 PM to 6:30 PM on 6/29/92, 6:30 AM to 10:30 AM and 2:30 PM to 6:30 PM other three
2. Route 3 North - from I-495 to Route 62, 7/8/93, 6:30 AM to 10:30 AM, 12:30 PM to 6:30 PM
3. Southeast Expressway/Central Artery - from Northern Avenue to Bates Road, 7/12/93, 6:30 AM to 10:30 AM, 12:30 PM to 6:30 PM
4.. Sumner Tunnel/ Central Artery Approaches - East Boston Toll Barrier to Surface Artery to Massachusetts Turnpike Extension, 7/13/93, 6:30 AM to 10:30 AM, 12:30 PM to 6:30 PM
5. Massachusetts Turnpike Extension - Yankee Division Highway (Route 128) to Central Artery , 7/14/93, 6:30 AM to 10:30 AM, 12:30 PM to 6:30 PM

For the 5 corridors, the following locations (overpasses) would be used to mount cameras:

1. **Yankee Division Highway (Route 128) NB AM, SB PM**
   - Grove Street
   - Highland Avenue
   - Route 1A
   - Ponkapoag Road

2. **Route 3 North SB AM, NB PM**
   - Riverneck Road
   - Rangeway Avenue
   - Orchard Road
   - Old Billerica Road

3. **Southeast Expressway NB AM, SB PM**
   - Central Artery, pedestrian bridge at Russia Wharf/Northern Avenue
   - Boston Street
   - Boulvard Street Extension
   - Bates Avenue

4.. **Sumner Tunnel/Central Artery/Massachusetts Turnpike SB only, all day**
   - Sumner approach in East Boston - pedestrian bridge
   - Sumner Tunnel exit - Boston Printing Department Building
   - Central Artery,pedestrian bridge at Russia Wharf/Northern Avenue
   - Massachusetts Turnpike Extension, Washington Street

5. **Massachusetts Turnpike Extension** **EB AM, WB PM**

Lexington Street
Church Street
St. Mary's Street
Washington Street

B-3 Correspondence

Letter to State Police - Boston

CTPS

State Transportation Building
Ten Park Plaza, Suite 2150
Boston, MA 02116-3968
(617) 973-7100
Fax: (617) 973-8855

CENTRAL TRANSPORTATION PLANNING STAFF

July 12, 1993

Dear State Police Officials:

The Central Transportation Planning Staff is in the process of conducting traffic videotaping for the Federal Highway Administration (FHWA) and the Massachusetts Highway Department (MHD).

Traffic videotaping is being conducted in these areas from 5:30 A.M. to 7:30 P.M. on the days assigned below. We have listed the Troop which we believe covers the juridiction for each location. This letter will be sent to all troops involved. Cameras will be stationed at the following locations:

Southeast Expressway/Central Artery - 7/13/93	
- Central Artery, pedestrian bridge at Russia Wharf/Northern Ave, Boston	Troop H
- Boston Street, Boston	Troop I
- Boulvard Street Extension, Milton	Troop I
- Bates Avenue, Quincy	Troop I
Sumner Tunnel/Central Artery/Massachusetts Turnpike - 7/14/93	
- Sumner approach in East Boston - pedestrian bridge, Boston	Troop E
- Sumner Tunnel exit - Boston Printing Department Building, Boston	Troop E
- Central Artery,pedestrian bridge at Russia Wharf/Northern Ave, Boston	Troop H
- Massachusetts Turnpike Extension, Washington Street, Boston	Troop E
Massachusetts Turnpike Extension - 7/15/93	
- Lexington Street, Newton	Troop E
- Church Street, Newton	Troop E
- St. Mary's Street, Boston	Troop E
- Washington Street, Boston	Troop E

These traffic videotapes will provide the John A. Volpe Transportation Systems Center the necessary data, in the medium required, to compare travel time survey methodologies.

If you have any questions concerning the project you may wish to speak to the Field Operations Manager, Larry Tittemore, at (617) 973-7099, the Project Manager , Efi Pagitsas, at (617) 973-7106 or Arnie Soolman, CTPS Director, at (617) 973-7146.

Your cooperation in this matter is greatly appreciated.

Very truly yours,

Pagitsas

Efi Pagitsas
Project Manager

HPM-30/2-96(700)EW