4 LICENSE PLATE MATCHING TECHNIQUES

This chapter contains information on travel time collection using license plate matching techniques. In general, license plate matching techniques consist of collecting vehicle license plate numbers and arrival times at various checkpoints, matching the license plates between consecutive checkpoints, and computing travel times from the difference in arrival times (Figure 4-1). Four basic methods of collecting and processing license plates are considered in this chapter:

- **Manual:** collecting license plates via pen and paper or audio tape recorders and manually entering license plates and arrival times into a computer;
- **Portable Computer:** collecting license plates in the field using portable computers that automatically provide an arrival time stamp;
- **Video with Manual Transcription:** collecting license plates in the field using video cameras or camcorders and manually transcribing license plates using human observers; and
- **Video with Character Recognition:** collecting license plates in the field using video, then automatically transcribing license plates and arrival times into a computer using computerized license plate character recognition.

Each section of this chapter contains the following information for these four methods of license plate matching: overview, cost and equipment requirements, data collection and reduction instructions, and previous experiences and applications.

4.0.1 General Advantages and Disadvantages

License plate matching for travel time collection has the following **advantages**:

- Able to obtain travel times from a large sample of motorists, which is useful in understanding variability of travel times among vehicles within the traffic stream;
- Provides a continuum of travel times during the data collection period and ability to analyze short time periods (e.g., 15-minute averages for continuous data); and
- Data collection equipment relatively portable between observation sites.

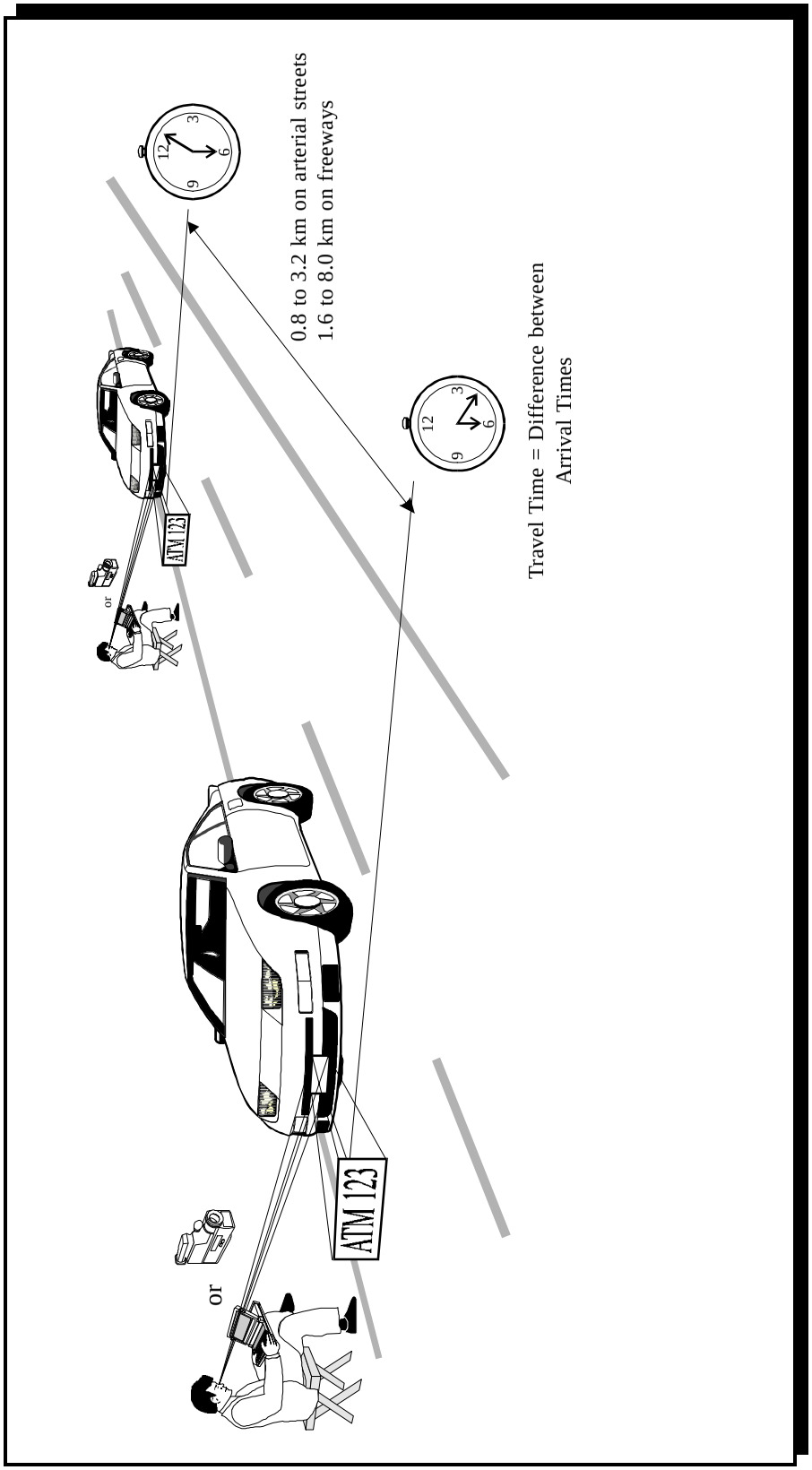


Figure 4-1. Illustration of License Plate Matching Techniques

License plate matching has the following **disadvantages**:

- Travel time data limited to locations where observers or video cameras can be positioned;
- Limited geographic coverage on a single day;
- Manual and portable computer-based methods are less practical for high-speed freeways or long sections of roadway with a low percentage of through-traffic;
- Accuracy of license plate reading is an issue for manual and portable computer-based methods; and
- Skilled data collection personnel required for collecting license plates and/or operating electronic equipment.

Each method of license plate matching also has relative advantages and disadvantages (Table 4-1). This table can be used to select the instrumentation level that best fits the study need and data collection budget.

4.0.2 Designation of Mid-Route Checkpoints

Checkpoints are designated locations along a route where license plate characters and arrival times are noted. The number of checkpoints along a route will vary according to the character of the roadway and the street network configuration. Along roadways with a relatively high level of access, checkpoints should be spaced closer than roadways with lower levels of access. Vehicle trip patterns also affect the designation of mid-route checkpoints, with long-distance trips being more amenable to widely spaced checkpoints. Checkpoints should also be located at major interchanges, intersections, jurisdictional boundaries, and transition points between different roadway cross-sections or land uses.

The following are suggested guidelines for spacing checkpoints for license plate matching (1):

- **Freeways/Expressways** - high access frequency - 1.6 to 4.8 km (1 to 3 mi)
- **Freeways/Expressways** - low access frequency - 4.8 to 8.0 km (3 to 5 mi)
- **Arterial Streets** - high cross street/driveway frequency - 0.8 to 1.6 km (½ to 1 mi)
- **Arterial Streets** - low cross street/driveway frequency - 1.6 to 3.2 km (1 to 2 mi)

These ranges are approximate, and actual segment lengths may vary according to the roadway network and desired detail of study. Corridor and site surveys should be used in selecting the most desirable checkpoints and their spacing. An attempt should be made to select checkpoints that are consistent with current roadway inventory or other databases.

Table 4-1. Comparison of Instrumentation Levels for the License Plate Matching Technique

Instrumentation Level	Costs			Skill Level		Typical Sample Sizes	Level of Data Detail [1]	Accuracy	Automation Potential
	Capital	Data Collection	Data Reduction	Data Collection	Data Reduction				
Manual	Very Low	Moderate	High	Low	Low	Low	Moderate	Low	Low
Portable Computer	Moderate	Low to Moderate	Low	Low	Moderate	Moderate	Moderate	Moderate	High
Video with Manual Transcription	Low	Moderate	High	Moderate	Low	High	High	Moderate to High	Moderate
Video with Character Recognition [2]	High	Moderate	Low	Moderate to High	Moderate to High	High	High	Moderate to High	High

Notes: [1] Refers to the level of data detail throughout the data collection time period.
[2] Assumes that equipment is purchased (versus contracting services).

4.0.3 Observer or Video Recorder Positioning

The positioning of observers or video recorders is paramount to the safe and effective collection of vehicle license plate characters. In general, license plate characters are easiest to read when viewed from as small a horizontal angle as possible (i.e., close to "head-on"). The ideal position in most cases is immediately adjacent to the right shoulder or curb, or possibly in the median of divided facilities. Overpasses can provide a safe vantage point for observing plate characters. Safe vantage points can also be found behind some type of barrier, guardrail, bridge column, etc., particularly along high-speed facilities. For video methods, a telephoto lens increases the number of good vantage points from which to record license plates. Observers should be positioned in inconspicuous locations so that the flow of traffic is not disrupted by curious motorists. In states where front license plates are required, views of oncoming vehicles (recording front license plates) provide the best opportunity to accurately read license plate characters. For observers, an oncoming and departing view of vehicles could provide a second chance to read a rear license plate if the front license plate is missed.

The positioning of observers on the near or far side of an intersection depends upon whether one wishes to include delay from the intersection in the preceding or following segment travel time. Positioning on the far side has been the generally accepted location for most travel time studies. For freeways, entrance and exit ramp connections to the mainlanes are the best checkpoints when attempting to match the cause of congestion with its effects.

4.0.4 Sample Sizes

Vehicle sample sizes typically are not a large concern for license plate matching (as compared to the test vehicle technique) because data collection includes a large number of vehicles. However, the average sample sizes for license plate matching are greater than test vehicle sample sizes because of a difference in the sampled travel time variability for these two techniques. The variability of license plate matching travel time samples generally are higher than test vehicle travel time samples because license plate matching captures a wide range of driving patterns and vehicle types. The test vehicle technique uses a limited number of drivers (data collection personnel) that reduce travel time variability by "floating" with traffic.

Early research in 1952 by Berry (2) found that sample sizes ranging from 25 to 102 license matches were necessary for a given roadway segment and time period. Many subsequent guidelines in the literature report a minimum sample size of 50, including ITE's *Manual of Transportation Engineering Studies* (3). Recent research using video and character recognition confirmed that minimum sample sizes of 50 license matches were adequate for a wide range of travel time variability (Figure 4-2) (4). For planning purposes, 50 license matches can be used as the target sample size. Once travel time data has been collected, procedures in the next several paragraphs can be used to determine whether the actual number of license matches meets the statistically required sample sizes for a given confidence and error level.

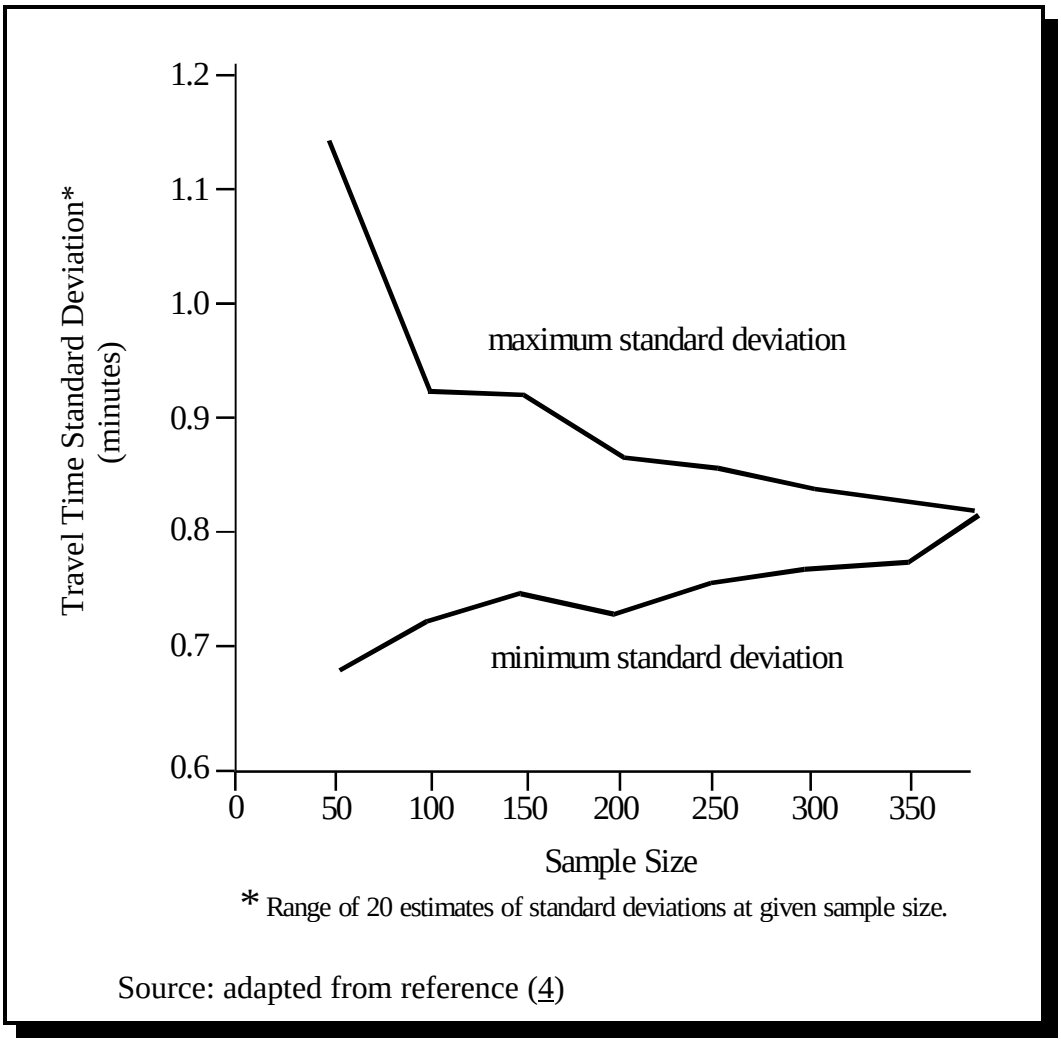


Figure 4-2. Standard Deviation as a Function of Sample Size

The required minimum sample sizes for license plate matching are calculated using Equation 4-1. (More discussion on this and other sample size equations can be found in Section 3.0.2.) This equation is most useful in ensuring that collected data meets minimum statistical sample sizes. This equation was used in combination with travel time variability estimates (Table 4-2) to produce illustrative license matching sample sizes, shown in Table 4-3. Because license plate matching encompasses a large number of motorists with different driving patterns, the travel time variability, and hence the sample sizes, will be larger than those associated with the test vehicle technique.

$$Sample\ Size,\ n = \left(\frac{t \times c.v.}{e}\right)^2 \approx \left(\frac{z \times c.v.}{e}\right)^2 \quad \begin{array}{c} if\ estimated\ sample\ size \\ is\ greater\ than\ 30 \end{array} \qquad (4\text{-}1)$$

Table 4-2. Approximate Coefficients of Variation for License Plate Matching

Source (Reference Number)	Reported Coefficients of Variation	Traffic and Roadway Conditions
Berry and Green, 1949 (5)	0.15 to 0.31	free-flow and congested and arterial streets, 1- to 2-hour time periods
Berry, 1952 (2)	0.12 to 0.25	rural highways and congested arterial streets, 1- to 2-hour time periods
Dandy and McBean (6)	0.05 to 0.33	highways and arterial streets
Shuldiner, D'Agostino and Woodson (4)	0.05 to 0.15	freeway and arterial streets, 15- to 30-minute time periods
Suggested Coefficients (15- to 30-minute time period)	0.10 0.20	freeways and arterials, low to moderate traffic freeways and arterials, congested traffic
Suggested Coefficients (1- to 2-hour time period)	0.25 0.35	freeways and arterials, low to moderate traffic freeways and arterials, congested traffic

Table 4-3. Illustrative License Plate Matching Sample Sizes

Traffic Signal Density (signals per mile)	Average Coefficient of Variation, (%) Table 4-2	Sample Sizes (iterative calculations using Equation 3-4)		
		90% Confidence, ± 10% Error	95% Confidence, ± 10% Error	95% Confidence, ± 5% Error
Low to moderate traffic, 15- to 30-minute period	10	4	5	18
Low to moderate traffic, 1- to 2-hour time period	20	12	18	62
Congested traffic, 15- to 30-minute time period	25	18	27	96
Congested traffic, 1- to 2-hour time period	35	34	48	189

Matching percentages, or the number of matched license plates divided by the number of collected license plates, can be applied to the license match sample sizes in Table 4-3 to obtain planning estimates of required vehicle plates to collect. Matching percentages can range from about **5 to 20 percent** (4,7,8) and depend upon several factors:

- distance between observation sites;
- number of intersecting streets/interchanges;
- percent of through traffic and typical trip length; and
- matching and screening algorithms.

For example, assume that a sample size of 62 vehicles (95 percent confidence level and 5 percent relative error, Table 4-3) is necessary for accurate travel times along a particular section of an arterial street. For arterial streets, the matching percentage is approximately 10 percent. The number of license plates that **should be collected at both observations sites** along this arterial street is approximately [62/0.10], or **620 license plates**. A stationary observer with a portable computer can collect between 400 and 700 plates per hour (assuming sufficient volume), whereas a video camera is capable of collecting between 80 to 95 percent of the total traffic volume (4,8).

EXPERT TIP ☺ Sample sizes are typically not a large concern with the video or portable computer-based license matching techniques. However, minimum sample sizes should be verified with variability values from field data.

4.0.5 License Plate Syntax

Each state in the U.S. has established rules and guidelines for license plate fonts and syntax. For example, one state may distribute license plates with the following syntax: "ATM123", where the first three characters are letters and the last three characters are numbers. Very few states issue plates with more than seven characters (this may help to identify the origin state of the plate). Also, some states do not use numbers or characters that look similar. For example, many states do not use the letters "O" or "Q" because of the similarities to the number "0". Also, some states have different syntaxes for different types of vehicles (e.g., commercial vs. trucks vs. passenger cars). If desired, this syntax can be used to eliminate commercial vehicles or tractor-trailer combinations that typically do not travel at speeds characteristic of the traffic flow. Before collecting license plate data, one should check with the state's department of motor vehicles (DMV) to identify particular license plate syntax rules. The syntax of license plates can help in decreasing the occurrence of misread or mismatched license plates.

4.1 Manual Methods of License Plate Matching

For the purposes of this handbook, manual methods of license plate matching are those that require the field personnel to read license plates in the field and transcribe the plates into a computer in the office after the actual time of data collection. License plates can be collected in the field using simple pen and paper or an audio tape recorder.

4.1.1 Advantages and Disadvantages

Manual license plate matching has the following **advantage** (as compared to other methods of license plate matching):

- Minimum amount of simple field equipment required.

Manual license plate matching has the following **disadvantages**:

- Collection of large samples of license plates in the field is difficult; and
- Transcription of license plates is very labor-intensive (typically 10 hours per hour of data collection).

4.1.2 Cost and Equipment Requirements

The cost and equipment requirements for the manual license plate matching technique are minimal. The cost of license plate transcription and matching may vary depending upon the skill level of personnel used to perform this task. Table 4-4 contains information about hardware, software, and personnel requirements and approximate costs.

Table 4-4. Estimated Costs for the Manual License Plate Matching Technique

Equipment/Personnel	Unit Cost (1998 dollars)
Hardware	
Portable tape recorder, non voice-activated (one per checkpoint)	$30 to $60
Miscellaneous field supplies and equipment (stools or chairs, audio tapes, batteries, fuel for transportation, etc.)	$250
Personnel	
Observer/recorder (minimum of one per checkpoint)	$6 to $10 per hour
License plate transcription and matching (approx. 10 hours per hour of data collection)	$6 to $10 per hour
Study supervision and management	Varies

4.1.3 Data Collection Instructions

The following steps should be performed before license plate collection begins (see Chapter 2 and Sections 4.0.2 through 4.0.5 in this chapter):

1. Define the routes to be studied;
2. Designate the checkpoints and specific locations where observers will be positioned;
3. Define the time period during which data will be collected;
4. Compute number of license plates needed for minimum sample sizes; and
5. Train personnel and practice reading one to two hours of license plates in actual roadside conditions.

Once the necessary planning and preparation have been performed, the following steps should be performed in collecting and matching license plates.

1. **Inventory and check equipment.** All equipment should be inventoried and checked before proceeding to the data collection sites. **Watches and clocks should be synchronized at this time**. Ensure that each observer has a backup power supply (extra batteries).

2. **Arrive at site early.** Observers should arrive at the data collection site 20 to 30 minutes in advance of when they are scheduled to begin data collection. This ensures that observers can find the most suitable and comfortable location, and prepare the equipment. This time can also be used to ensure that **audio tapes are labeled** with the time, date, and specific location of the data collection.

3. **Begin data collection at scheduled times.** Observers should speak clearly into the tape recorder when vehicles pass the checkpoint. Unless several observers are at a single site, vehicle license plates should be sampled from all lanes. At slow vehicle speeds, the full license plate (typically six characters) should be recorded. At higher speeds (greater than 80 km/h or 50 mph), observers may only be able to collect four characters of the license plate. Observers should call out the time approximately every 15 minutes for quality control purposes. These time checks can be used as an additional time check in transcribing the tapes at a later date.

   Several general techniques have been used to make license plate collection using tape recorders easier and more effective. These techniques are summarized as follows:

   - *Reading the first four characters on the plate* - The collection of four characters has been used by most agencies, and experience has indicated that the first four are easier to read than the last four. The collection of all six characters, where practical on lower speed arterial streets, can decrease the occurrence of spurious license matches.

   - *Collection of the plate number while the vehicle is approaching* - This technique allows the observer to record the plate number at the instant the vehicle crosses the designated checkpoint. Headlight glare during low-light periods may require collecting plate numbers while the vehicle is going away.

   - *Collection of as many plates as possible* - The probability of matching plate numbers increases for each additional plate entered; observers should be encouraged to accurately record as many as possible.

   - *Representative sampling of through-lanes* - Studies have shown that speeds vary across lanes, so sampling of all through-lanes is necessary to collect representative speed samples. For high-volume roadways, however, sampling from all through lanes will produce a low percentage of matches. In this case, observers should concentrate on a lane that has a speed representative of the average traffic flow, but also collect a few speed samples from all through lanes. Auxiliary and turning lanes should be avoided because of the low number of matches for the high percentages of turning traffic.

- *Collection during daylight hours* - Although collection during night-time hours is possible, it complicates plate-reading and often creates safety problems.

4. **Take short breaks or use extra personnel.** For tape recording, observers' eyes may become fatigued after one hour of data collection. If the data collection is to last several hours, provisions should be made for short (five-minute) breaks or for extra personnel to relieve the original observers.

5. **Ensure that tapes are labeled correctly.** Once the license plate collection has been completed, ensure that the audio tapes are labeled correctly with the time, date, and specific location of the data collection.

6. **Transcribe the license plates into a computer.** Transcription of the license plates from the audio tapes into a computer is performed in the office. For audio tapes, transcribers should play the tape back at regular speed. A computer program should be used to attach a time stamp to each plate once it has been entered. There are several license plate collection programs that can be used either in the field or office to time stamp license plate entries. Also, some spreadsheets or text editors provide a time stamp feature, as do several basic computer programming languages. License plate transcription from audio tapes takes approximately two to three hours per hour of tape.

7. **Match the license plates.** License plates can be matched using special license matching software, database or statistical analysis software, or spreadsheet functions. The license plate matching should incorporate an algorithm to remove spurious matches, which occur if plate characters are incorrectly read or only four characters are recorded. For example, if only the first four characters are collected, "ATM123" could be matched with "ATM189". Several types of screening algorithms can be used to reduce spurious matches:

   - *Use of "speed limits"* - automatically delete any match that falls outside of preset speeds, typically less than 5 km/h or greater than 125 km/h.

   - *Use of standard deviations* - automatically delete any match that falls outside of three or four standard deviations for the time period.

   - *Visual inspection of travel time/speed profile* - graphs of travel time/speed can be used to visually identify and remove outlying data points.

   The results of the license matching process will be individual vehicle speeds at different times throughout the data collection time period. These speeds can be

averaged for the entire time period (i.e., peak hour or peak period), or for smaller intervals of the entire time period (e.g., 15- or 30-minute summaries). Chapter 7 contains more information on reducing and summarizing data.

8. **Consider destroying all license plate records because of privacy issues.** After license plates have been matched and travel times computed, one may want to consider destroying or deleting all license plate records. This can eliminate potential problems with privacy issues or objections to the permanent storage of license plate records by public agencies.

4.1.4 Previous Experience

Many transportation agencies may have experience with manually collecting license plates for origin-destination or travel time studies. The added requirement of recording the arrival time of each license plate, however, makes the license plate travel time study more complex than an origin-destination study. Because of these complexities and its low-technology nature, the literature contains little information about manual methods of license plate matching.

Schaefer provides guidelines for license plate matching surveys that are applicable for manual methods (9). Schaefer's guidelines address the following practical issues and statistical considerations related to license plate matching surveys:

- performing site visits and developing a survey plan;
- addressing issues related to temporary employees for conducting surveys;
- preparing equipment and training considerations;
- designing license plate surveys (e.g., number of plate characters, sample sizes); and
- considering data analysis techniques and error correction.

Many of Schaefer's guidelines have been addressed in this chapter of the handbook; however, the reader is encouraged to refer to these guidelines for more details on the above considerations.

4.2 Portable Computer-Based License Plate Matching

Portable computer-based methods of license plate matching consist of entering license plates into portable (laptop or palmtop) computers in the field. Full or partial license plates may be entered into the computer depending on typical vehicle speeds, and a computer program provides the time stamp automatically. This method does not require the transcription of license plates or time stamps in the office; only the license matching is performed in the office. A new variation of this portable computer-based method uses voice recognition for license plate entry, as opposed to observers manually entering license plates (more information on this variation is contained in Section 4.2.4, Previous Experiences).

4.2.1 Advantages and Disadvantages

Portable computer-based license plate matching has the following **advantages** (as compared to other methods of license plate matching):

- field computer entry of license plates dramatically decreases reduction time; and
- data collection and reduction can be automated with computer programs.

Portable computer-based license plate matching has the following **disadvantages**:

- accuracy of license plate observations can be problematic;
- low sampling of vehicles in traffic stream due to computer entry limitations;
- moderately high equipment costs for large-scale studies; and
- requires highly motivated and moderately skilled observers because of fatigue.

4.2.2 Cost and Equipment Requirements

The cost and equipment requirements for portable computer-based license plate collection are slightly more than those for manual methods of license plate collection. A large cost savings can be realized because no manual license plate transcription is required in the office; computer programs can be used to match the license plates and time stamps already in a computerized format. Table 4-5 contains information about software, hardware, and personnel requirements and approximate costs.

Table 4-5. Estimated Costs for the Portable Computer-Based License Plate Matching Technique

Equipment/Personnel	Unit Cost (1998 dollars)
Hardware	
Laptop computer and accessories (power supply or additional batteries, carrying case) (one per checkpoint) **or** Palmtop computer and accessories (power supply, additional batteries, carrying case)	$2,500 **or** $750
Miscellaneous field supplies and equipment (stools or chairs, computer diskettes, batteries, fuel for transportation, etc.)	$250
Software	
License plate collection and matching software (see Appendix B for software)	$0 to $100 per computer
Personnel	
Observer (minimum of one per checkpoint)	$10 to $15 per hour
Study supervision and management	Varies

4.2.3 Data Collection Instructions

The following steps should be performed before license plate collection begins (see Chapter 2 and Sections 4.0.2 through 4.0.5 in this chapter):

1. Define the routes to be studied;
2. Designate the checkpoints and locations where observers will be positioned;
3. Define the time period during which data will be collected;
4. Compute approximate number of license plates needed for minimum sample sizes;
5. Obtain or develop license plate collection and matching software (see Appendix B for software);

6. Training and two to three hours of practice reading and entering license plates in actual roadside conditions; and
7. Develop a data management and file naming convention that reduces errors and eases data reduction.

Once the necessary planning and preparation have been performed, the following steps should be performed in collecting and matching license plates.

1. **Inventory and check equipment.** All equipment should be inventoried and checked before proceeding to the data collection sites. **Computer clocks and wrist watches should be synchronized at this time**. Ensure that each observer has a backup power supply (extra batteries).

2. **Arrive at site early.** Observers should arrive at the data collection site 20 to 30 minutes in advance of when they are scheduled to begin data collection. This ensures that observers can find the most suitable and comfortable location and prepare the computer for license plate entry. Observers should use the predefined computer file-naming convention for the license plate entry, or should fill in the site information in the computer program. Typical data items to be collected for each site include:

    - Computer filename that contains license plates;
    - Study route and direction;
    - Time and date of data collection;
    - Location of observer;
    - Roadway cross section characteristics;
    - Weather conditions; and
    - Other comments.

    This information can be stored in the header or first line of the license plate computer file. An example of a data entry screen for this information is provided in Figure 4-3.

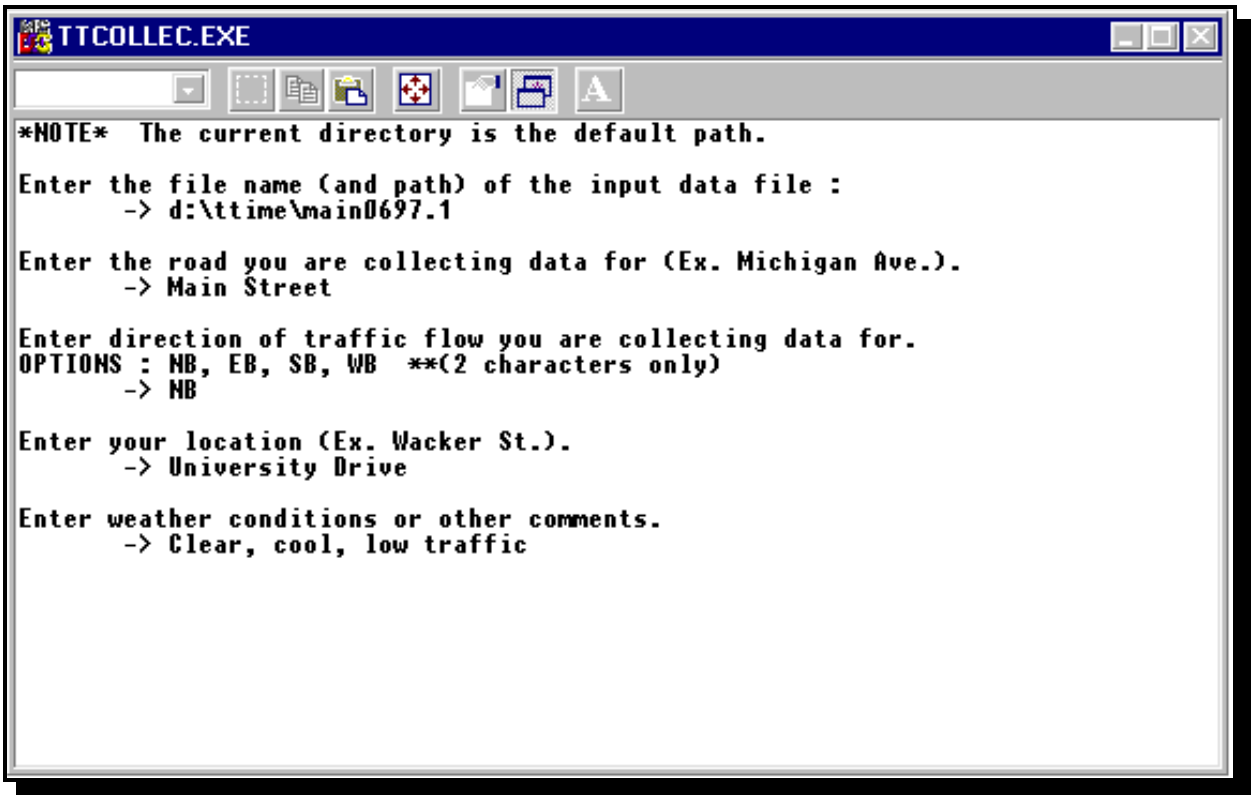


Figure 4-3. Example of Data Entry Screen for Site Information

3. **Begin data collection at scheduled times.** Observers should enter the license plates as soon as the vehicle crosses the designated checkpoint. Unless several observers are at a single site, vehicle license plates should be sampled from all lanes. At slow vehicle speeds, the full license plate (typically six characters) can be recorded. At higher speeds (greater than 80 km/h or 50 mph), observers may only be able to collect four characters of the license plate. If data collection lasts longer than the portable computer battery life, arrangements should be made for a continuous power source or a means to switch spare computer batteries.

   Several general techniques have been used to make license plate collection easier and more effective. These techniques were summarized on pages 4-11 and 4-12.

   - Reading the first four characters on the plate;
   - Collection of the plate number while the vehicle is approaching;
   - Collection of as many plates as possible;
   - Representative sampling of through-lanes; and
   - Collection during daylight hours.

CAUTION !! Vehicle speeds and travel times may vary significantly by lane. If a representative sample of license plates can not be collected from all through lanes, concentrate on the one or two lanes most representative of the traffic stream.

4. **Take short breaks or use extra personnel.** Observers' eyes may become fatigued after as little as one hour of data collection. If the data collection is to last several hours, provisions should be made for short (five-minute) breaks or for extra personnel to relieve the original observers.

5. **Ensure the format and content of license plate files.** Before leaving the site, observers should exit the license plate collection program and ensure that the license plate files are labeled and formatted correctly.

6. **Match the license plates.** License plates can be matched using special license matching software, database or statistical analysis software, or spreadsheet functions. The license plate matching should incorporate an algorithm to remove spurious matches, which occur if plate characters are incorrectly read or only four characters are recorded. For example, if only the first four characters are collected, "ABC123" could be matched with "ABC189". Several types of screening algorithms can be used to reduce spurious matches (see page 4-12):

   - Use of "speed limits";
   - Use of standard deviations; and
   - Visual inspection of travel time/speed profile.

   The results of the license matching process will be individual vehicle speeds at different times throughout the data collection time period. These speeds can be averaged for the entire time period (i.e., peak hour or peak period), or for smaller intervals of the entire time period (15- or 30-minute summaries). Chapter 7 contains more information on reducing and summarizing data.

7. **Consider destroying all license plate records because of privacy issues.** After license plates have been matched and travel times computed, you may want to consider destroying or deleting all license plate records. This can eliminate potential problems with privacy issues or objections to the permanent storage of license plate records by public agencies.

4.2.4 Previous Experience

Several agencies have experience with conducting portable computer-based travel time studies. This method has been used for several applications in the Seattle area. The Chicago Area Transportation Study (CATS) used computerized license plate matching for area-wide travel time studies. The Volpe Center coordinated extensive testing of portable computer-based license plate matching in Boston, Massachusetts; Seattle, Washington; and Lexington, Kentucky. The Texas Transportation Institute (TTI) developed license plate collection and matching software, and also tested portable computer-based license plate matching for evaluating the travel time savings and reliability of HOV lanes in Houston and Dallas. Information about these experiences are contained in the following sections.

Seattle--Comparison of Floating Car and License Matching

Rickman et al. (10) compared portable computer-based license plate matching to the floating car method and examined several issues related to license plate matching. The study conducted by Rickman et al. compared the average travel times from license plate matching results to those obtained from floating car runs (Table 4-6). The conclusions of the comparison found no statistically significant difference in average travel times between average travel times obtained by license plate matching or floating car runs. However, the license plate matching sample sizes for similar time periods were 2 to 15 times greater than floating car sample sizes.

Table 4-6. Comparison of Floating Car and Computerized License Plate Travel Time Methods

Route, Direction and Time Period	Mean Travel Times		Sample Size		t-statistic[a]
	Floating Car	License Plate	Floating Car	License Plate	
Bel-Red Road Eastbound PM	590	590	5	27	0
148th Avenue Southbound PM	453	487	3	45	-0.44
NE Eighth Eastbound PM	242	264	6	11	-0.40
148th Avenue Southbound AM	247	257	5	38	-0.27

Source: adapted from reference (10).

Not [a] The Student's t-statistic is used here to compare the mean travel times of two travel time distributions. All t-values are within the critical t-value at the level of alpha=0.005, and the associated degrees of freedom for each test. This indicates that there is no statistical difference between the two travel time methodologies.

Rickman et al. also experimented with ways to reduce spurious or incorrect matches. Several of the techniques that were recommended include:

- establishing a minimum and maximum travel time expected during the study and eliminating matches outside these limits;
- using graphs to recognize unrealistic outliers;
- using smaller time intervals for license plate matching (e.g., 15 minutes vs. one hour); and
- recording more digits of the license plate.

Other important information gathered from Rickman et al.'s study includes:

- A good typist can collect about 900 four-character license plates per hour (provided adequate volume), with as many as 100 matches for a freeway section with one to two exits;
- Even with complex networks, between 11 and 40 valid travel times per hour were obtained using license plate matching; and
- Collecting four characters from the license plates provides the best combination of ease of data entry and a low level of spurious matches.

Seattle--Use of Voice Recognition on Portable Computers

Washburn and Nihan (11) have experimented with using voice recognition on portable computers as a means to input license plates. The tests indicated that entry accuracy rates as high as 95 percent can be obtained with voice recognition. In their tests, Washburn and Nihan used commercially-available IBM voice recognition engines and two different portable computers, representing a lower and upper-end processing speed:

- Low-speed processor: 80486 processor at 50 MHZ, 8 MB of RAM; and
- High-speed processor: Pentium processor at 120 MHZ, 32 MB of RAM.

High-quality microphones and sound card/speaker systems were added to the portable computers, which were then tested at an arterial street and freeway site. The results of the tests at the arterial street site are shown in Table 4-7. The authors arrived at the following conclusions from the study:

- Voice recognition can provide entry accuracy rates in excess of 95 percent;

- Use of the military alphabet (e.g., A=alpha, B=bravo, etc.) in enunciating license plate characters provides a higher rate of recognition, as does the use of a high-quality microphone; and

- Voice recognition enables a single observer at some sites that may have required two observers (e.g., where one must use binoculars, other enters license plates).

Table 4-7. Summary of Voice Recognition Performance on Arterial Streets

Arterial Test	Time Period (minutes)	Flow Rate (vphpl)	Voice Recognition		Keyboard Entry	
			Sample Rate	Accuracy Rate	Sample Rate	Accuracy Rate
Test 1	27	618	56.8%	90.8%	n/a	n/a
Test 2	26	771	60.1%	96.3%	55.6%	94.0%
Test 3	12	720	73.0%	97.0%	73.0%	89.8%

Source: adapted from reference (11).
Note: Test 1 used the lower quality microphone and the slower processing speed computer. Tests 2 and 3 used the higher quality microphone and the faster processing speed computer.

Chicago Area Transportation Study (CATS)

The Chicago Area Transportation Study (CATS) used portable computer-based license plate matching for travel time data collection on Chicago area arterial streets (12,13). The study included 394 km (245 miles) of the strategic regional arterial system, which was divided into 68 individual roadway segments. The estimated cost of the study was $75,000, amounting to approximately $305 per mile of roadway. Travel time data were collected for three time intervals:

- morning peak (6:30 to 8:30 a.m.);
- mid-day (11:30 a.m. to 1:30 p.m.); and
- evening peak (3:30 to 6:30 p.m.).

Other relevant information about CAT's experience with license plate matching include:

- Computer programs, "SPEEDRUN" and "MATCH", were developed in the BASIC programming language to collect and match the license plates;

- Field observers collected the last four characters of the license plate;

- It was theorized that field observers were able to collect license plates from about 50 to 65 percent of the vehicles that passed on the arterial street;

- Field observers sampled as many plates as possible from all lanes;

- The target sample size for number of matches was 26. Actual number of matches obtained in the field ranged from 5 to 143 for a 20-minute interval; and

- Spurious matches were reduced by 1) eliminating matches with speeds less than 8 km/h (5 mph) and greater than 160 km/h (100 mph), 2) eliminating matches with speeds more than two standard deviations from the mean, and 3) using graphs to visually identify outliers.

CATS has since abandoned all efforts of computerized license plate matching for travel time data collection, instead using the manual test vehicle technique. They have also been considering the use of GPS equipment.

Volpe Center Field Tests

Liu and Haines (14), of the Volpe Center, conducted field tests of several travel time data collection techniques in 1993. The techniques tested in this study included:

- license plate matching using portable computers;
- license plate matching using video cameras and character recognition;
- floating car (test vehicle);
- probe vehicle;
- automatic vehicle identification; and
- loop detectors.

The portable computer-based license matching was tested in Seattle, Washington and Lexington, Kentucky. "Palmtop" computers were used in Seattle and larger "laptop" computers were used in Lexington. Typically two field observers were used at each checkpoint, with each person reading license plates from one specific lane. The observers only collected four of the six characters from the license plate. Major findings from these field tests were:

- Selection of travel time collection methodology depends upon data needs (as they relate to sample size and sample efficiency);

- Portable computer-based method is easy to perform, very portable, requires minimal training, and is particularly well-suited for arterial street use;

- Its limitations are the degradation of observer performance over time, ineffectiveness for high speed locations, the possibility of spurious matches with partial plate (four-character) collection (which points to the need for a screening/quality control process), and the inability to collect intermediate delay data;

- Observers could collect license plates from about 60 percent of the passing vehicles, resulting in approximately 100 to 200 matches per segment per hour; and

- Equipment costs were approximately $1,800 per checkpoint and personnel costs were between $650 and $775 per route per day.

Texas Transportation Institute (TTI)

The Texas Transportation Institute (TTI) developed license plate collection and matching software as part of the National Cooperative Highway Research Program (NCHRP) Project 7-13, "Quantifying Congestion" (1). Also, Turner et al. (7) used the license plate collection and matching software to evaluate the travel time savings and reliability of HOV lanes in Houston and Dallas, Texas. Documentation of the license plate collection and matching software, "TTCOLLEC" and "TTMATCH", is contained in Appendix B.

Turner et al. (7) quantified the travel time savings and reliability of HOV lanes for two freeway corridors in Houston and Dallas, Texas using portable computer-based license plate matching. License plates were collected concurrently from vehicles in the freeway general purpose lanes and the HOV lanes during morning and evening peak periods. Observation points were separated by significant distances, ranging from 5.3 to 11.1 km (3.3 to 6.9 mi). Table 4-8 shows the results of the license plate collection and matching.

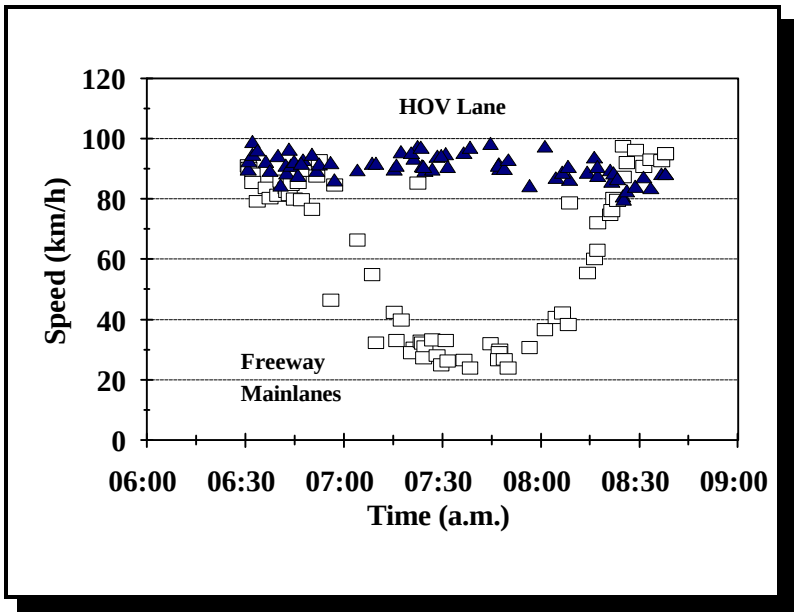
License plate observers collected only the first four characters of the plate, and were able to collect between 300 and 500 license plates per hour. Observers for the freeway lanes (three lanes total per direction) estimated that they were able to collect about 10 to 20 percent of the total number of vehicles. Observers for the HOV lane (one lane total) estimated that they were collecting about 50 percent of the total number of vehicles. Plate matching percentages on the freeway general purpose lanes ranged from 3 to 13 percent. These matching percentages were low because of the long segment lengths and high number of freeway entrance and exit ramps. Matching percentages for the HOV lanes ranged from 32 to 54 percent, and were high because of the limited number of access points to the HOV lanes.

Figures 4-4 and 4-5 show two illustrations that are easily constructed using the large sample sizes available with the license plate matching method. Figure 4-4 contains the continuum of freeway and HOV lane speeds throughout the peak period, and illustrates a significant speed reduction due to congestion. Figure 4-5 shows a speed distribution for a particular roadway segment. The speed or travel time distributions can be examined for normality by conducting statistical tests.

Table 4-8. License Plate Collection and Matching Statistics from Houston and Dallas, Texas

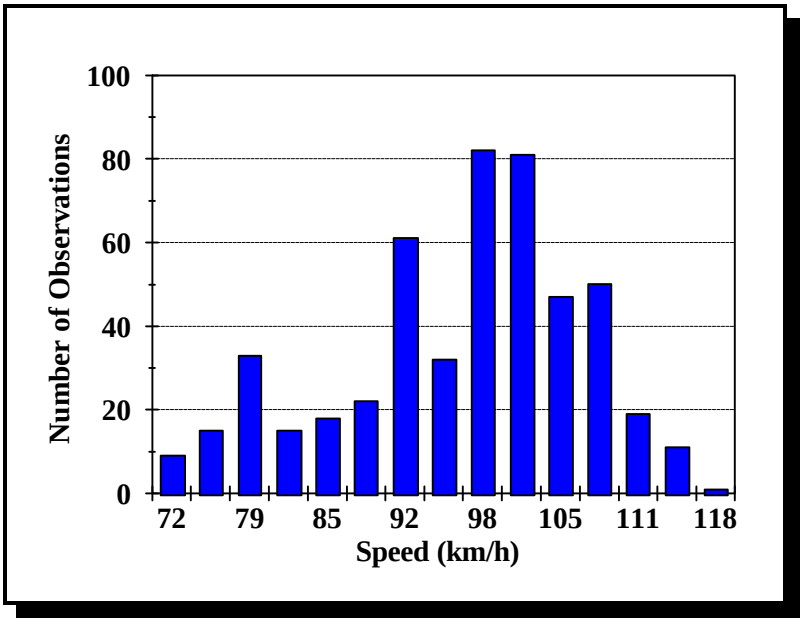
Time Period and Date	Roadway Segment	Segment Length	General Purpose Lanes		HOV Lane	
			Collected Plates	Audited Matches [a]	Collected Plates	Audited Matches [a]
6 to 9 am, July 7	IH-10 EB, SH 6 to Gessner	11.1 km (6.9 mi)	1,144 903	48 (5%)	433 590	197 (45%)
3:30 to 6:30 pm, July 7	IH-10 WB, Gessner to SH 6	11.1 km (6.9 mi)	1,018 1,167	33 (3%)	867 417	198 (47%)
6 to 9 am, July 8	IH-10 EB, Gessner to Washington	9.3 km (5.8 mi)	904 1,064	46 (5%)	543 596	175 (32%)
3:30 to 6:30 pm, July 8	IH-10 WB, Washington to Gessner	9.3 km (5.8 mi)	1,184 1,237	60 (5%)	926 1,017	436 (47%)
6 to 9 am, July 13	IH-30 WB, Jim Miller to CBD Ramp	8.4 km (5.2 mi)	1,000 875	70 (8%)	774 999	283 (37%)
4 to 7 pm, July 13	IH-30 EB, CBD Ramp to Dolphin	5.3 km (3.3 mi)	1,095 1,524	144 (13%)	857 909	4 (1%)[b]
6 to 9 am, July 13	IH-30 WB, Jim Miller to CBD Ramp	8.4 km (5.2 mi)	1,124 844	70 (8%)	806 1,066	317 (39%)
4 to 7 pm, July 13	IH-30 EB, CBD Ramp to Dolphin	5.3 km (3.3 mi)	1,422 1,292	154 (12%)	999 920	486 (53%)

Notes: [a] Number of matches after use of "speed limits" and visual inspection of data.
[b] Obvious error in recording correct plate characters.



Source: adapted from reference (7).

Figure 4-4. Peak Period Speed Profile for IH-30 Freeway and HOV Lane: Dallas, Texas



Source: adapted from reference (7).

Figure 4-5. Speed Frequency Distribution for IH-30 HOV Lane: Dallas, Texas

4.3 Video with Manual Transcription

This method of license plate matching relies on video cameras or camcorders to collect license plates in the field and human personnel to transcribe the license plates into a computer in the office after the actual time of data collection. Video collection of license plates is preferred over the manual collection (pen and paper, tape recorder) of license plates because:

- video provides a permanent record of license plates and traffic conditions;
- video permits the reading of license plates in a controlled environment in which plate characters can be closely examined;
- video provides information about traffic flow characteristics such as traffic volume and vehicle headway; and
- video can provide a time stamp for accurate determination of arrival times.

4.3.1 Advantages and Disadvantages

License plate matching using video with manual transcription has the following **advantages** (as compared to other methods of license plate matching):

- video provides a permanent, easily-review record of traffic conditions;
- accuracy may be better than manual methods; and
- able to capture a larger sample of the total number of vehicles.

Manual license plate matching has the following **disadvantage**:

- transcription of license plates is labor-intensive (typically 10 hours per hour of data collection).

4.3.2 Cost and Equipment Requirements

The cost and equipment requirements for video-based method of license plate collection are minimal. The cost of license plate transcription and matching may vary depending upon the skill level of personnel used to perform this task. Table 4-9 contains information about hardware, software, and personnel requirements and approximate costs.

Table 4-9. Estimated Costs for Video with Manual Transcription

Equipment/Personnel	Unit Cost (1998 dollars)
Hardware	
Video recorder and accessories (tripod, power supply, additional lens, carrying case) Video playback system (4-head VCR) and monitor	$1,000 to $2,500 (depends upon quality of camcorder) $750 to $1,500
Miscellaneous field supplies and equipment (stools or chairs, video or audio tapes, batteries, fuel for transportation, etc.)	$250
Personnel	
Observer/video taper (minimum of one per checkpoint)	$15 to $20 per hour
Study supervision and management	Varies
License plate transcription and matching (approx. 10 hours per hour of video tape)	$6 to $10 per hour

4.3.3 Data Collection Instructions

The following steps should be performed before license plate collection begins (see Chapter 2 and Sections 4.0.2 through 4.0.5 in this chapter):

1. Define the routes to be studied;

2. Designate the checkpoints and specific locations where observers or video recorders will be positioned;

3. Perform site reconnaissance and find best camera positions (e.g., clear away wire mesh fences if necessary and permitted);

4. Define the time period during which data will be collected;

5. Train personnel with use of cameras and practice recording two to three hours of license plates in actual roadside conditions.

Once the necessary planning and preparation have been performed, the following steps should be performed in collecting and matching license plates.

1. **Inventory and check equipment.** All equipment should be inventoried and checked before proceeding to the data collection sites. **Watches and video camera clocks should be synchronized at this time**. Ensure that each observer has a backup power supply (extra batteries).

2. **Arrive at site early.** Observers should arrive at the data collection site 20 to 30 minutes in advance of when they are scheduled to begin data collection. This ensures that observers can find the most suitable and comfortable location, and prepare the equipment. For video taping, observers may want to tape one to two minutes of video for instant playback to ensure that the camera is positioned and operating correctly. Monitors should be used to check the quality of video before starting data collection. This time can also be used to ensure that **video tapes are labeled** with the time, date, and specific location of the data collection.

3. **Begin data collection at scheduled times.** For video recording, it is possible to capture one to two lanes of traffic per camera before the license plate characters become illegible. A fast shutter speed of at least 1/1000 second or faster should be used to provide stop motion and clear, frame-by-frame resolution of license plate characters. A time stamp that includes seconds or frames should be displayed on the video to create a permanent time record. Once video taping begins, the observer(s) only need to occasionally check the camera to ensure that camera settings are still adequate and that the camera is recording to tape. If data collection lasts longer than two hours, arrangements should be made for switching video tapes. A 12-volt marine battery should be used to provide enough power for prolonged periods of data collection.

4. **Check quality of video on frequent basis.** Field personnel should check the quality of video throughout the data collection period to adjust for changing light conditions and to ensure that the proper view is still being recorded.

5. **Ensure that tapes are labeled correctly.** Once the license plate collection has been completed, ensure that the video tapes are labeled correctly with the time, date, and specific location of the data collection.

6. **Transcribe the license plates into a computer.** Transcription of the license plates from the video tapes into a computer is performed in the office. A four-head VCR provides the best results in freezing video frames for reading license plates. Some VCRs also provide advanced editing features that allow frame-by-frame advance and

review. A screen line should be chosen on the video that is nearest to the designated checkpoint, and thin dark-colored tape can be used to mark this screen line on the video monitor. When a vehicle passes this screen line on the monitor, the license plate characters and video time stamp are entered into a spreadsheet or database.

7. **Match the license plates.** License plates can be matched using special license matching software, database or statistical analysis software, or spreadsheet functions. The license plate matching should incorporate an algorithm to remove spurious matches, which occur if plate characters are incorrectly read or only four characters are recorded. For example, if only the first four characters are collected, "ATM123" could be matched with "ATM189". Several types of screening algorithms can be used to reduce spurious matches:

   - *Use of "speed limits"* - automatically delete any match that falls outside of preset speeds, typically less than 5 km/h or greater than 125 km/h.

   - *Use of standard deviations* - automatically delete any match that falls outside of three or four standard deviations for the time period.

   - *Visual inspection of travel time/speed profile* - graphs of travel time/speed can be used to visually identify and remove outlying data points.

   The results of the license matching process will be individual vehicle speeds at different times throughout the data collection time period. These speeds can be averaged for the entire time period (i.e., peak hour or peak period), or for smaller intervals of the entire time period (e.g., 15- or 30-minute summaries). Chapter 7 contains more information on reducing and summarizing data.

8. **Consider destroying all license plate records because of privacy issues.** After license plates have been matched and travel times computed, one may want to consider destroying or deleting all license plate records. This can eliminate potential problems with privacy issues or objections to the permanent storage of license plate records by public agencies.

4.4 Video with Character Recognition

The most automated form of license plate matching is accomplished using video and computerized optical character recognition. With this method, license plates are collected using high quality video (typically Super VHS or Hi-8 mm, although Hi-8 mm is preferred because of smaller tape sizes). The license plates are read and matched by a computer using hardware/software that performs optical character recognition. Several license plate recognition (LPR) systems permit manual review of "unreadable" license plates, or those plates that the computer is unable to recognize. The manual review process can be used to improve the reading rate in cases where license plates are damaged or partially illegible.

Because of their relatively high costs, automated LPR systems have primarily been used at critical automated enforcement installations, such as electronic toll plazas, weigh-in-motion stations, or remote sensing of mobile source emissions. A few consultants also use LPR systems to perform large-scale origin-destination and travel time studies.

The collection and matching of license plates using automated LPR systems in real-time has been implemented in the United Kingdom and is currently being tested by the Minnesota and Washington DOTs. In fact, the United Kingdom has planned to install nearly 3,000 video cameras over 10,000 km (6,000 mi) of British highway to provide real-time traffic information (travel times via LPR systems) (15,16,17). These real-time license plate reading and matching techniques are being utilized to provide traveler information (typically travel times) as part of ITS strategies. No recommendations or guidelines are provided in the handbook for these real-time license matching methods. However, agencies should recognize the potential opportunities that these systems offer when implemented as part of an ITS infrastructure.

4.4.1 Advantages and Disadvantages

Video with character recognition has the following **advantages** (as compared to other methods of license plate matching):

- automated license plate recognition dramatically decreases data reduction time;
- video provides a permanent record (if saved) that can be reviewed at any time; and
- video captures a large sample of the total vehicle traffic.

Video with character recognition has the following **disadvantages**:

- accuracy of license plate recognition is sensitive to ambient conditions;
- equipment is costly for small studies;
- method is technologically intensive and typically requires outsourcing; and
- LPR technology is not mature for some vendors and not standardized among vendors.

4.4.2 Cost and Equipment Requirements

Because of the high equipment costs for automated LPR systems, several options are presented here for the video with character recognition method of license plate matching:

Option 1. Outsourcing or contracting the entire data collection process, including video collection, license plate recognition and matching, and data reduction. This technique has been used by several agencies throughout the United States.

Option 2. Outsourcing or contracting **only the license plate recognition**, with video collection and data reduction performed internal to your agency. This approach may be considered if you have high quality video resources available and if a vendor/consultant is willing to provide only the license plate recognition.

Option 3. Purchasing video cameras and LPR system for extensive agency use. This approach should be considered if your agency has a considerable, ongoing need for license plate collection (e.g., automated enforcement, origin-destination, or travel time studies).

Because automated LPR systems require high quality video with specific lighting and plate size specifications, most vendors or consultants prefer to perform the video collection to ensure high plate reading rates (Option 1 above). LPR systems do require extensive training and technical knowledge, making Options 2 and 3 appear less desirable for most transportation agencies.

Table 4-10 contains approximate cost and equipment requirements for Option 1 (contract all data collection) and Option 3 (purchase equipment and perform data collection internally). Cost and equipment requirements for Option 2 can be derived from this information or directly from a consultant willing to perform the license plate matching.

CAUTION !! Significant experience is needed in collecting video and matching license plates using an automated LPR system. Approach vendor's claims with caution and ask for their previous experience in license plate matching studies.

Table 4-10. Estimated Costs for Video with Character Recognition

Equipment/Personnel	Unit Cost (1998 dollars)
Option 1--Contracting Entire Data Collection	
Video collection, license plate recognition and matching, and data reduction	$300 to $400 per lane-hour
Option 3--Purchase All Equipment and Perform Internally	
Video specialists (min. of one per checkpoint)	$15 to $25 per hour
Video camera and accessories (tripod, power supply, lenses, carrying case)	$4,000 to $6,000 per camera
Monitor for portable camcorder	$1,500 per camera
LPR hardware and software	$30,000 to $50,000 per unit
Miscellaneous field supplies and equipment (stools or chairs, video tapes, batteries, fuel for transportation, etc.)	$1,000
Training	$5,000
Study supervision and management	Varies

4.4.3 Considerations for Automated License Plate Recognition Systems

This section contains background information on automated license plate recognition (LPR) systems. This information is provided as background for study planning and discussions with LPR vendors or suppliers. A complete discussion of optical character recognition is beyond the scope of this handbook.

At least 15 vendors claim they currently offer LPR systems (4 of them are U.S.-based) (18); however, the capabilities of each system may vary. There are no industry standards at this time for performance of LPR systems, although individual vendors may have performance specifications. A typical LPR system consists of the following components (18):

- **Video-image acquisition unit** - uses video camera and external (e.g., inductance loop or laser beam) or internal (software or processor-based recognition of plate) trigger to capture images of the vehicle license plate;
- **Central processing unit** - processing part of workstation that handles image manipulation and control;
- **Character recognition engine** - hardware or software-based engine that uses neural networks and/or character templates to perform character recognition; and
- **Storage or transmission subsystem** - part of workstation that stores or transfers image records and machine-read results (text license plate, read date, and time).

The license plate character font and syntax is useful in training automated LPR systems and improving the license plate reading rate. The font refers to the particular style of lettering, whereas the syntax refers to the number and placement of characters on the plate and their sequence.

Each state in the U.S. has established rules and guidelines for license plate fonts and syntax. Most LPR systems typically use a limited number of font templates that would recognize a majority of the possible fonts encountered. The automated processing of license plates can be somewhat slower when several font templates are used, but this is only an issue when plate reading and matching is performed in real-time. For several travel time studies, analysts have chosen to disregard any out-of-state license plates, thus eliminating problems of numerous font templates. Some LPR systems can be trained (through neural networks) to recognize certain problematic characters or font styles.

The syntax of license plates also can help in increasing the accuracy and reading rate of automated LPR systems. For example, one state may distribute license plates with the following syntax: “ATM123”, where the first three characters are letters, and the last three characters are numbers. Very few states issue plates with more than seven characters (this may help to identify the origin state of the plate). Also, some states do not use numbers or characters that look similar. For example, many states do not use the letters “O” or “Q” because of the similarities to the number “0”. Also, some states have different syntaxes for different types of vehicles (e.g., commercial vs. trucks vs. passenger cars). If desired, this syntax can be used to eliminate commercial vehicles or tractor-trailer combinations that typically do not travel at speeds characteristic of the traffic flow.

The accuracy of automated LPR systems is another consideration in their use for travel time measurement. To date, no standardized tests have been performed to compare the accuracy of these

systems under various conditions. A number of factors can affect an automated LPR system's ability to correctly identify license plate characters (18):

- vehicle speed;
- volume of vehicle flow;
- ambient illumination (day, night, sun, or shadow);
- spacing between vehicles (headway) because of occlusion;
- weather (rain, snow, fog);
- vehicle type (passenger car, truck, tractor-trailer, etc.);
- plate mounting (rear only or front and rear);
- plate variety and jurisdiction;
- camera-to-plate distance;
- plate tilt, rotation, and skew;
- presence of a trailer hitch; and
- communications pathway.

When discussing performance and accuracy specifications with LPR system vendors, it is important to specify the conditions under which the accuracy is to be achieved. The license plate capture and reading rate may vary from as low as 15 to 20 percent for poor visibility or weather conditions, to as high as 85 to 90 percent for ideal conditions. The accuracy of the system also depends upon two critical functions:

- **Capturing the entire license plate within the image field-of-view** - the accuracy of this step can be affected by the external or internal trigger mechanism, but also is affected by camera field-of-view and vehicle position within or between lanes; and

- **Correctly recognizing the characters of the license plate** - this step's accuracy is based upon the character recognition engine, which is typically proprietary for each vendor.

The accuracy of automated LPR systems can be evaluated in two ways:

$$LPR\ System\ Accuracy\ (\%) = \frac{N_{LPR}}{N_{Manual}} \qquad (4\text{-}2)$$

where: N_{LPR} = number of plates correctly interpreted by LPR system
N_{Manual} = number of plates able to be read by a person using raw video signals on a monitor

or:

$$LPR\ System\ Accuracy\ (\%) = (Rate_{recognition} \times Rate_{interpretation}) \times 100 \quad (4\text{-}3)$$

where: $Rate_{recognition}$ = rate of successful plate recognition in field of view (expressed as a decimal)

$Rate_{interpretation}$ = rate of successful interpretation of entire plate content (expressed as a decimal)

If automated LPR systems are not used for measuring travel times in real-time, there are opportunities to improve the accuracy. One technique involves training the LPR system to recognize certain difficult-to-read characters. Another technique consists of a person reviewing those plates that the LPR system could not read, then simply manually entering those license plates that can be recognized by the human eye. The latter technique has been used extensively by one vendor in several fields tests in the U.S., which are discussed further in Section 4.3.5, *Previous Experiences*. There will be a small percentage of license plates (typically five to ten percent) that may not be readable, either because of mud, damaged or worn plates, or visual obstructions such as tow hitches.

4.4.4 Data Collection Instructions

Data collection instructions are provided here for collecting clear, usable video of vehicle license plates for automated LPR systems. If you will be using a vendor or consultant to perform the license plate reading only, you should contact the vendors/consultants as soon as possible to determine their video requirements and specifications for accurate character recognition.

The following steps should be performed before license plate collection begins (see Chapter 2 and Sections 4.0.2 through 4.0.5 in this chapter):

1. Define the routes to be studied;
2. Designate the checkpoints and locations where observers will be positioned;
3. Perform site survey to identify vantage points and camera positioning;
4. Define the time period during which data will be collected; and
5. Train with video camera equipment.

Once the necessary planning and preparation has been performed, the following steps should be performed in collecting license plates using video:

1. **Inventory and check equipment.** All equipment should be inventoried and checked before proceeding to the data collection sites. **Video camera clocks and wrist watches should be synchronized at this time**. Ensure that each observer has a backup power supply (12-volt marine battery).

2. **Arrive at site early.** Observers should arrive at the data collection site 60 minutes in advance of when they are scheduled to begin data collection. This ensures that observers can find the most suitable and comfortable location, and prepare the video camera for license plate collection. Video tapes labels should include:

    - study route and direction;
    - location of observer;
    - date and time (start and end time); and
    - camera identification number.

3. **Begin data collection at scheduled times.** Several general techniques have been used to make license plate collection easier and more effective. These techniques are summarized as follows:

    Straight-on, elevated camera positioning - The best position for the camera is a straight-on, elevated shot, with as little horizontal angle as possible. This prevents the excessive lateral movement of the license plate between video frames, and makes the plate image easier to automatically acquire. Typically the only place to get straight-on video is from an overpass structure, in which a zoom lens will likely be necessary for making plates legible.

    Collection of the rear license plate - Because front plates are not required by all states in the U.S., the rear license plate is commonly captured for LPR systems.

    Representative sampling of through-lanes - Studies have shown that speeds vary across lanes, so sampling of all through-lanes is necessary to collect representative speed samples. For high-volume roadways, however, sampling from all through lanes will produce a low percentage of matches. In this case, observers should concentrate on a lane that has a speed representative of the average traffic flow, but also collect a few speed samples from all through lanes. Auxiliary and turning lanes should be avoided because of the low number of matches for high percentage of turning traffic.

    Collection during clear, daylight hours - Although collection during night-time hours is possible, it complicates plate-reading and often creates safety problems.

4. **Consider destroying all license plate records because of privacy issues.** After license plates have been matched and travel times computed, you may want to consider destroying or deleting all license plate records. This can eliminate potential problems with privacy issues or objections to the permanent storage of license plate records by public agencies.

4.4.5 Previous Experience

There have been several applications of video with character recognition license plate matching in the U.S. These experiences have involved the use of a single vendor's automated LPR system for various travel time, origin-destination, and vehicle occupancy studies. This video camera and LPR system has been used in several field applications, examples of which will be summarized in this section:

- series of field trial tests for travel time collection by the Volpe Center in 1993;
- collection of traffic performance data for Hillsborough County, Florida's congestion management system; and
- collection of travel time savings and reliability data for HOV lanes in Seattle, Washington.

Other experience with automated LPR systems in the United States and Europe, in particular, have focused on enforcing electronic toll collection systems.

Volpe Center Field Tests

Liu and Haines (14), of the Volpe Center, conducted field tests of several travel time data collection techniques in 1993. The techniques tested in this study included:

- license plate matching using portable computers;
- license plate matching using video cameras and character recognition;
- floating car (test vehicle);
- probe vehicle;
- automatic vehicle identification; and
- loop detectors.

The video and character recognition-based license matching was tested in Boston, Massachusetts; Seattle, Washington; and Lexington, Kentucky. High-quality video cameras (Hi-8 mm) were used to collect video in the field, with each camera focused on a single lane. All six characters of the license plates were read automatically using a vendor's automatic license plate reading (LPR) system. The vendor's LPR system also enabled license plate characters to be extracted manually if the machine vision component was unable to automatically read the license plate characters.

Major findings from these field tests were:

- Primary advantages of automated license plate reading include the use of all license plate characters in matching for increased accuracy, ability to capture large samples of vehicles, and low labor intensity compared to other license matching techniques;

- Major limitations of automated license plate reading include constraints on camera location and positioning, limited success in less-than-ideal conditions, and the evolving machine vision technology;

- The video camera and LPR system were capable of capturing and identifying about 50 percent of the vehicle license plates in the traffic stream (manual reduction of video has been estimated to capture about 90 percent);

- The automatic LPR system was capable of processing at least 1,800 plates per hour, or about one plate per second (manual reduction has been estimated to require 10 hours for each hour of video tape); and

- Approximately 40 to 100 license plate matches were obtained during 15-minute time periods (about 160 to 400 per hour) for varying traffic volume and geometric conditions.

In another paper discussing the results of these field tests, Liu (19) presents several analytical methods that were used to screen or audit the license matches. Liu recommended that 30-minute time periods be used for plate matching and computation of average travel time and speed statistics. This length of time helps to reduce the potential for spurious matches. Initial "speed limits" were set at 24 and 137 km/h (15 and 85 mph); therefore, any plate matches with speeds below 24 km/h (15 mph) or above 137 km/h (85 mph) were removed from the valid data set. For specific locations with recurring congestion, Liu recommends that the lower speed limit of 24 km/h (15 mph) be reduced or dropped entirely. The number of plate matches with travel times outside of two standard deviations also was noted as a means to identify and screen spurious matches.

Hillsborough County, Florida Congestion Management System

The Center for Urban Transportation Research demonstrated video and character recognition-based license plate matching methods for the collection of traffic data for the Hillsborough County Congestion Management System in Florida (20). Researchers obtained travel times, origin-destination information, and average vehicle occupancies from the video that was collected. The study collected two hours of video for three consecutive morning peak periods on several freeway sites in Tampa, Florida (six hours of total tape per site). Traffic volume counts were collected concurrent with the video using pneumatic tubes.

Varying combinations of manual entry and automated license plate reading were used in the demonstration. Manual review and entry were used in cases when license plate characters could not be read accurately by the LPR system. For the three-day test, the plate capture rate (i.e., plates read divided by total license plates) ranged from 63 to 85 percent. Fifteen and thirty-minute analysis periods were used to summarize statistics such as mean travel time, standard deviation, and coefficient of variation. The researchers concluded that the video and character recognition-based method offers substantial time savings as compared to manual observation methods, with slightly higher to comparable costs per survey.

Seattle--HOV Lane Surveys

In 1995, the Washington Department of Transportation (WashDOT) contracted with the same automated LPR vendor to perform surveys of the travel times for two HOV corridors in Seattle (the Volpe field tests were performed in Seattle in 1993) (21). Four weekdays of license plate collection were performed, with each day consisting of a four-hour morning peak period and a four-hour evening peak period. As with other license plate collection efforts, one camera per lane is used to capture license plates of an adequate size for automated processing by the LPR system. The distance between camera observation points was 1.75 km (1.09 mi) and 5.75 km (3.57 mi) on SR 520 and IH-5, respectively.

Over the four-day period, approximately 90,000 license plates were read by the automated LPR system, which was estimated to be about 75 percent of the total traffic volume passing the camera observation points. About five percent of the plates were unreadable because the plates images were in poor focus, too dark or bright, or otherwise ill-suited for automated processing. A combination of automatic processing and manual entry of unreadable plates was used to improve the license plate capture rate. License plate matching results and corresponding travel time statistics were summarized for 15-minute intervals, and illustrated the travel time savings of the HOV lane versus the freeway general purpose lanes.

West Virginia

Researchers with the West Virginia University and the West Virginia DOT have documented specifications for automated LPR systems that are to be used in collecting travel time and origin-destination data (22). Their recommendations focused on transportability and set-up requirements, traffic operations and roadside safety, and the technical attributes of an LPR system (i.e., video source, light source, triggering mechanism, and image processor). Technical specifications were also provided for use by other agencies in contracting or performing work with automated LPR systems.

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