

Final Technical Report
WSDOT Field Order No. F923805
Video Survey of Traffic Flow per the Attached Specifications (in Field Order)

**AUTOMATED VIDEO-BASED SURVEY
OF TRAVEL TIMES IN HOV VS.
GENERAL PURPOSE LANES**

by

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16. ABSTRACT <p>Transformation Systems, Inc. was hired to perform automated video-based travel time surveys for the high occupancy vehicle (HOV) and the adjacent general purpose (GP) traffic lane on two freeway corridors in the Seattle area. The purpose of the project was to demonstrate and test the use of machine-vision technology for travel time data collection. Evaluating techniques for determining travel times and speeds is necessary for the WSDOT to determine whether its HOV lane performance criteria are being met. The project used hi-8 video cameras to collect very-high quality video tapes of vehicle license plates. The video tapes were then processed at Computer Recognition Systems, Inc. in Cambridge, Massachusetts, with a specialized computer programmed to convert the video images into computer data files. The report details the video survey methodology; the data acquired through license plate recognition, including date, time, location, and direction of travel; and the comparison data used to determine respective travel times for HOV and GP traffic lanes.</p> <p>The field data were collected from Monday, June 19, 1995, through Thursday, June 22, 1995, for each four-hour morning peak period (6:00-10:00 AM) on westbound SR 520 and for each four-hour evening peak period (3:00-7:00 PM) on northbound I-5. In all, over 90,000 license plates were analyzed, representing approximately 75 percent of the traffic volume. The license plate data were used to "match" vehicles between camera stations and to compute travel times on more than 200 vehicles per hour in high volume traffic conditions.</p> <p>Results on northbound I-5 indicate that the evening peak period commute away from downtown Seattle in the GP lane can be 2.0 to 2.7 times longer than the same commute using the HOV facilities for the 5.75 kilometers (3.57 miles) of freeway monitored (between NE 117th and NE 185th Street). Results averaged over the four weekdays for the entire four-hour evening period indicate approximately 60 percent longer commute times in the GP lanes compared to HOV lanes (the I-5 inside HOV lane has a two-person minimum occupancy requirement).</p> <p>Similar results on westbound SR 520 could not be statistically verified for the morning peak period because of the relatively low number of vehicles observed during the survey period (transit buses were not counted and the SR 520 outside HOV lane has a three-person minimum occupancy requirement). However, there was evidence of approximately 50 percent longer commute times in the GP traffic lanes between 7:30-8:00 AM than the vehicles observed in the HOV lane on SR 520 for the 1.75 kilometers (1.09 miles) of freeway monitored (between 92nd Ave. NE and 76th Ave. NE).</p>			
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**Washington State DOT; Traffic Office; Field Order No. F923805
"Automated Video-based Survey of Travel Times
in HOV vs. General Purpose Lanes"**

Final Report

EXECUTIVE SUMMARY

This report documents the video-based traffic data collection procedures, results obtained from using a proprietary automatic license plate reader, and conclusions drawn about travel times from a survey completed for the Washington State Department of Transportation as part of an effort to evaluate the differences in travel times of HOV lanes that run parallel to general purpose traffic lanes for westbound SR-520 (in-bound rush hour) and northbound I-5 (out-bound rush hour) near the downtown Seattle area.

Traffic surveys were performed using automatic video-based systems which have been developed by *Transformation Systems, Inc. (Transfo)* and Computer Recognition Systems, Inc. (CRS) in conjunction with the U.S. Department of Transportation (Volpe Center). Non-intrusive roadside travel time surveys were conducted from Monday, June 19th, 1995 through Thursday, June 22nd, 1995 for each morning peak period of four hours (6:00 - 10:00 AM) and each evening peak period of four hours (3:00 - 7:00 PM).

Transfo and CRS collected and analyzed over 90,000 license plates, approximately 75% of the traffic volume as calculated by the number of vehicle license plate "triggers" obtained using a machine vision system. These data were used to "match" vehicles between camera stations and compute travel times on more than 200 vehicles per hour in high volume traffic conditions.

Results indicate the evening peak period commute home from downtown Seattle on northbound I-5 can be 2.0 to 2.7 times longer on a given day than the same commute using the HOV facilities for the ~3 ½ miles of freeway monitored. Results averaged over the four weekdays for the entire four hour evening period indicate approximately 60% longer commute times in the general purpose lanes versus HOV lanes.

Similar results could not be statistically verified for the morning peak period on westbound SR-520 due to the relatively low number of vehicles observed using the HOV facilities during the survey period. However, there was evidence of approximately 50% longer commute times in the general purpose traffic lanes between 7:30 - 8:00 AM than the vehicles observed in the HOV lane on SR-520 for the ~1 mile of freeway monitored.

Average speeds of traffic flow ranged from a high of 66 mph during non-congested periods to as low as 19 mph during periods of heavy congestion with stop-and-go traffic. A few vehicles were calculated to have reached average speeds in excess of 80 mph.

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Final Report

1.0 INTRODUCTION

License plates have long been used by transportation engineers and planners as a source of data for origin-destination, travel time, and other traffic studies. Typically, these studies have required large numbers of field and office personnel with associated high manpower costs. Manual operations have often also been characterized by unacceptably high rates of error in data collection and processing, especially when large amounts of data are collected and analyzed in a short period of time.

Many of the shortcomings associated with the manual collection and processing of vehicle license plates can be overcome through the use of video camcorders and machine vision license plate readers. Modern video camcorders are capable of capturing very clear images on license plates on vehicles operating in high-speed, high-volume traffic.

These images can be converted to computer files by license plate readers with high levels of speed and accuracy. It takes a human operator ten hours or longer to read and transcribe one hour of video tape into a computer file; a plate reader can accomplish this task in less than one hour, which is ten times faster than an experienced human operator. Also, the automatic plate reader can continue, without fatigue, to process tapes at this rate continuously hour after hour after hour.

This report documents the data collection procedures, results obtained, and conclusions drawn from a travel time survey completed for the Washington State Department of Transportation as part of an effort to evaluate the differences in journey times of HOV lanes that run parallel to general purpose traffic lanes for westbound SR-520 (in-bound rush hour) and northbound I-5 (out-bound rush hour) near downtown the Seattle area.

2.0 BACKGROUND

Traditional versus Automated Video-based O-D Survey Techniques

In the past, several alternative techniques have been used to perform O-D surveys. This section discusses these techniques along with their advantages and disadvantages as well as cost comparison against automatic license plate reading and traffic flow analysis using machine recognition systems.

Laptop Computers

Using this technique, individuals are put out into the field, usually one per lane, to manually enter license plates. A simple routine can be written to attach the time when a person inputs a plate string. The input typically consists of the first four characters [often only for cars (not trucks) of a given syntax]. As an example, for a license 123 ABC, the person inputs 123A. This supposedly allows a person to keep up with the traffic flow and avoids bad entries due to the difficulty of getting all 6 (or 7) characters correct. However, in tests performed, the match rate for this technique is not adequate. Results typically indicate only 5-10 percent of the vehicles are input, and a match rate of 1-3 percent are usually obtained for the survey sample.

Advantage

- Can be used for small amounts of data and very slow traffic

Disadvantages

- Only partial data exists therefore Department of Motor Vehicles databases cannot be used
- No permanent record of the traffic flows exist
- Very poor match rate (typically one to three percent)
- Human error in data entry, particularly with traffic moving at speeds above 30 mph

Cost Comparison

- Equal Number of People
- Similar Equipment Cost (laptops versus video cameras)
- Lower Processing Costs (but much less data)

Manual Review of Video Tape

Using this technique, video tapes of traffic are recorded and then reviewed by people. The license plate numbers are entered into a database along with the time. Using this method of analysis requires between ten to twenty hours for an individual to review one hour of videotape. The difficulty comes from the need to jog and shuttle the tape (fast forward or reverse or to play and stop the tape) when a vehicle appears. For high speed traffic, a vehicle may appear on a tape for only one-quarter second or less. In this case, it becomes very difficult to stop the tape player with the vehicle in the field of view.

Advantages

- Permanent record exists with videotape
- Can do DMV database mailings

Disadvantages

- Costs associated with tremendous amount of man hours
- Manual data entry accuracy degrades with time
- Extended length of time to obtain results

Cost Comparison

- Equal amount of equipment (video cameras instead of laptops)
- More expensive than automatic processing (rate charges from \$25.00 to \$50.00 per hour). At the rate of more than ten man hours to one hour of tape, this is equivalent to \$250.00 to \$500.00 per hour of tape processing.

Automatic License Plate Reading and Traffic Flow Analysis

Using this technique, each lane of traffic is videotaped. The tapes are collected and processed through an automatic license plate reading system. This system generates data files that include the time, license plate, date, location, lane number and direction of traffic flow. A software program creates matches, origin- destinations and travel times. This information may then be used to perform other functions based on DMV databases. This approach often yields match rates in the twenty-five percent to fifty percent range.

An additional camera can be placed over the roadway looking across three to six lanes of traffic. This tape is fed into a second machine vision system. This system, called a traffic analysis system (TAS), provides data on a lane by lane basis of the number, class (three types: car, medium sized vehicles such as trucks and vans, and large vehicle such as tractor trailers), speed, density of the traffic flow and roadway occupancy. This traffic flow information can then be used to compare travel times to road conditions. The result of the automatic analysis is a very thorough, fast and dense traffic survey.

Advantages

- Large amounts of accurate data
- Very fast survey turnaround time
- Allows DMV mailings (depending on DMV permission to access their databases-varies from state to state)
- Provides additional traffic flow statistics
- Provides permanent traffic record

Disadvantages

- Some inaccuracy in plate reading may cause minor mailing errors of survey post cards

Cost Comparison

- Equal amount of equipment
- Equal or lower amount of personnel
- Lower tape processing costs than manual approaches
- Lowest cost per match approach

3.0 SCOPE OF WORK

Overall Scope of Work

Automated video-based travel time surveys were completed for the high occupancy vehicle (HOV) and adjacent general purpose (GP) traffic lanes on I-5 northbound during the afternoon peak, and the HOV and GP traffic lanes on SR-520 westbound during the morning peak for four (4) week days. In addition to the video surveys taken in the field, the following tasks were also completed to ensure safe and efficient collection of traffic data:

- Consultation on the development of safe and efficient survey procedures and site locations with the Washington State Department of Transportation, various local authorities and the State Highway Safety Department.
- Processing video tape for license plate matching was performed automatically.
- Motor vehicle license plates were matched and travel times were computed to show comparisons between the HOV and GP traffic lanes during peak times.
- Preparation of summary data for each survey site and the final summary report for "Automated Video-Based Survey of Travel Times in HOV vs. GP Lanes".

Survey Procedures

Transfo used survey procedures related to video-based surveying methods developed in conjunction with the U.S. Department of Transportation (Volpe Center). Dr. Paul Shuldiner has extensive experience in this area, and has worked with the Volpe National Transportation Research Center on developing video-based survey methodologies for origin-destination and travel times. Significant field work was completed in the Seattle area during this prior developmental work with the Puget Sound Regional Council and the Washington State Department of Transportation.

Transfo conducted travel time surveys for four (4) consecutive weekdays (4 hours during morning peak and 4 hours during afternoon peak) at four selected locations along I-5 and SR-520 in Seattle, WA. The survey sites selected by Washington State DOT include NE 117th and NE 185th along I-5 (3.57 miles apart), and 92nd Avenue NE and 76th Avenue NE along SR-520 (1.09 miles apart). Hi-8 video cameras were mounted on highway overpasses and directed downward over one (1) HOV lane and one (1) GP lane of freeway traffic passing underneath using one (1) camera per lane. The camera operators took video tape images of the rear license plates of traffic moving away.

Important Note: Thanks to the Washington State DOT for being responsible for site permits, traffic control, and police assistance as was required by local authorities.

Schedule of Activities

- **Sunday:**
Arrival, review of survey sites, site permits, and safety operations.

- **Monday-Thursday AM:**
Conducted video surveys during the morning peak period on the following four (4) camera locations (refer to Figure 1) from 6:00 AM until 10:00 AM:
 1. Westbound SR-520 General Purpose lane at 92nd Avenue NE overpass.
 2. Westbound SR-520 HOV lane at 92nd Avenue NE overpass.
 3. Westbound SR-520 General Purpose lane at 76th Avenue NE overpass.
 4. Westbound SR-520 HOV lane at 76th Avenue NE overpass.

- **Monday-Thursday PM:**
Conducted video surveys during the evening peak period on the following four (4) camera locations (refer to Figure 2) from 3:00 PM until 7:00 PM:
 1. Northbound I-5 General Purpose lane at NE 117th Street overpass.
 2. Northbound I-5 HOV lane at NE 117th Street overpass.
 3. Northbound I-5 General Purpose lane at NE 185th Street overpass.
 4. Northbound I-5 HOV lane at NE 185th Street overpass.

Processing Video Tape

Tapes collected from the automated video surveys (refer to Table 1) were processed by CRS to match license plates to a specific location and time. The processing consisted of playing the tapes through a proprietary license plate reading system. The end results of this process was a database consisting of license plate numbers and the time and location at which they were observed. This provided a database listing approximately 75% of the license plates of all vehicles traveling by the station at a particular date and time.

Travel times were computed by matching the observed license plate numbers from one camera station located upstream with the corresponding camera station located downstream of the traffic flow. This task was completed using an automatic license plate matching algorithm which provides averages and statistics for every 15 minute interval.

Figure 1. Location of Field Camera Stations for Morning Peak Period.

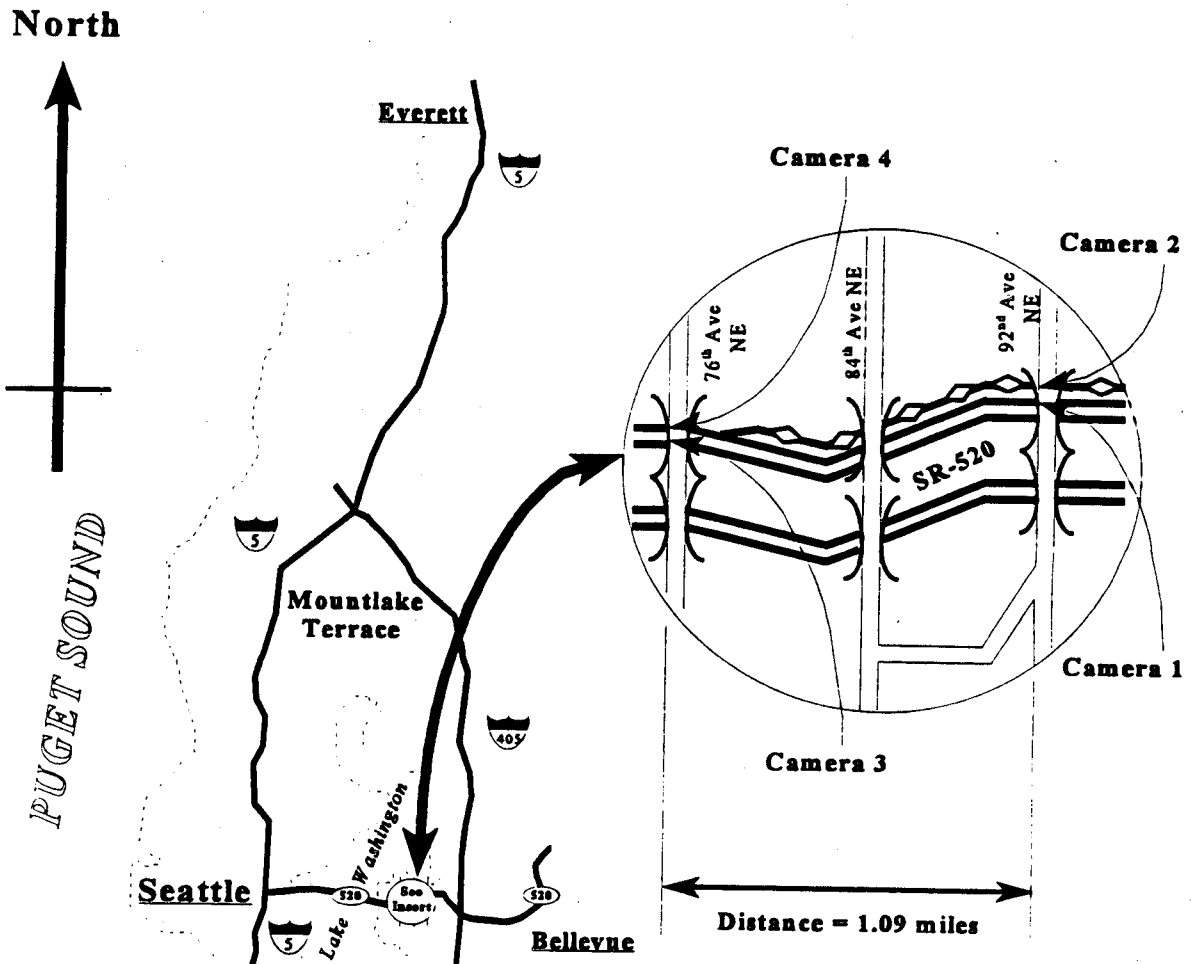


Figure 2. Location of Field Camera Stations for Evening Peak Period.

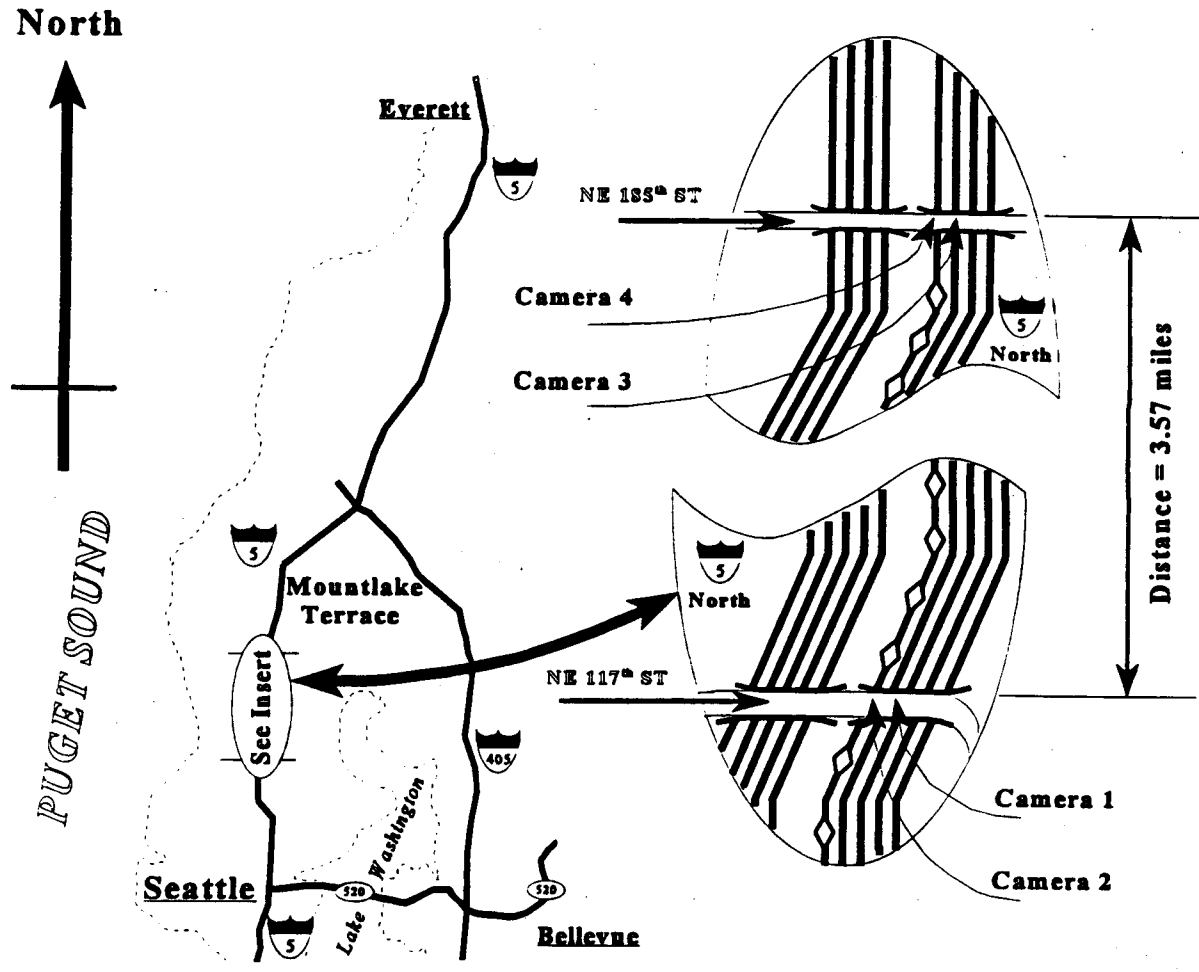


Table 1. Field Camera Stations, Tape Number, Directions, and Time of Day

Field Camera Stations, Directions, and Time of Day									
Tape No.	Date	Cam No.	Tape No.	Start Time	Adjusted Start Time	R - L L - R B - T	Operator	Location	Direction
1	6/19/95	1	1	6:00:10	6:00:20	B - T	Eldon	SR 520 @ 92 nd	GP Lane - w/b
2	6/19/95	1	2	8:01:00		B - T	Eldon	SR 520 @ 92 nd	GP Lane - w/b
3	6/19/95	1	3	2:57:00		B - T	Eldon	I-5 @ 117 th	GP Lane - n/b
4	6/19/95	1	4	4:57:45		B - T	Eldon	I-5 @ 117 th	GP Lane - n/b
5	6/19/95	2	1	6:00:50		B - T	Perk	SR 520 @ 92 nd	HOV Lane - w/b
6	6/19/95	2	2	8:00:30		B - T	Perk	SR 520 @ 92 nd	HOV Lane - w/b
7	6/19/95	2	3	2:57:30		B - T	Perk	I-5 @ 117 th	HOV Lane - n/b
8	6/19/95	2	4	4:58:15		B - T	Perk	I-5 @ 117 th	HOV Lane - n/b
9	6/19/95	3	1	6:07:30		B - T	Pedro	SR 520 @ 76 th	GP Lane - w/b
10	6/19/95	3	2	8:00:00		B - T	Pedro	SR 520 @ 76 th	GP Lane - w/b
11	6/19/95	3	3	3:03:00		B - T	Pedro	I-5 @ 185 th	GP Lane - n/b
12	6/19/95	3	4	5:00:30		B - T	Pedro	I-5 @ 185 th	GP Lane - n/b
13	6/19/95	4	1	6:02:00		B - T	Jeff	SR 520 @ 76 th	HOV Lane - w/b
14	6/19/95	4	2	7:58:00		B - T	Jeff	SR 520 @ 76 th	HOV Lane - w/b
15	6/19/95	4	3	3:00:00		B - T	Jeff	I-5 @ 185 th	HOV Lane - n/b
16	6/19/95	4	4	5:00:00		B - T	Jeff	I-5 @ 185 th	HOV Lane - n/b
17	6/20/95	1	1	6:00:00		B - T	Eldon	SR 520 @ 92 nd	GP Lane - w/b
18	6/20/95	1	2	8:01:00		B - T	Eldon	SR 520 @ 92 nd	GP Lane - w/b
19	6/20/95	1	3	2:59:30		B - T	Eldon	I-5 @ 117 th	GP Lane - n/b
20	6/20/95	1	4	5:00:00		B - T	Eldon	I-5 @ 117 th	GP Lane - n/b
21	6/20/95	2	1	6:00:50		B - T	Perk	SR 520 @ 92 nd	HOV Lane - w/b
22	6/8/95	2	2	8:01:30	8:18:30	B - T	Perk	SR 520 @ 92 nd	HOV Lane - w/b
23	6/20/95	2	3	3:00:30		B - T	Perk	I-5 @ 117 th	HOV Lane - n/b
24	6/20/95	2	4	5:01:30		B - T	Perk	I-5 @ 117 th	HOV Lane - n/b
25	6/20/95	3	1	6:04:00		B - T	Pedro	SR 520 @ 76 th	GP Lane - w/b
26	6/20/95	3	2	8:04:00		B - T	Pedro	SR 520 @ 76 th	GP Lane - w/b
27	6/20/95	3	3	3:03:00		B - T	Pedro	I-5 @ 185 th	GP Lane - n/b

Field Camera Stations, Directions, and Time of Day

Tape No.	Date	Cam No.	Tape No.	Start Time	Adjusted Start Time	R - L L - R B - T	Operator	Location	Direction
28	6/20/95	3	4	5:03:00		B - T	Pedro	I-5 @ 185 th	GP Lane - n/b
29	6/20/95	4	1	6:03:00		B - T	Jeff	SR 520 @ 76 th	HOV Lane - w/b
30	6/30/95	4	2	8:01:00		B - T	Jeff	SR 520 @ 76 th	HOV Lane - w/b
31	6/20/95	4	3	3:00:00		B - T	Jeff	I-5 @ 185 th	HOV Lane - n/b
32	6/20/95	4	4	5:00:00		B - T	Jeff	I-5 @ 185 th	HOV Lane - n/b
33	6/21/95	1	1	6:00:30		B - T	Eldon	SR 520 @ 92 nd	GP Lane - w/b
34	6/21/95	1	2	8:00:45		B - T	Eldon	SR 520 @ 92 nd	GP Lane - w/b
35	6/21/95	1	3	2:57:00		B - T	Eldon	I-5 @ 117 th	GP Lane - n/b
36	6/21/95	1	4	4:58:00		B - T	Eldon	I-5 @ 117 th	GP Lane - n/b
37	6/21/95	2	1	6:01:30		B - T	Perk	SR 520 @ 92 nd	HOV Lane - w/b
38	6/21/95	2	2	8:02:15		B - T	Perk	SR 520 @ 92 nd	HOV Lane - w/b
39	6/21/95	2	3	2:56:00		B - T	Perk	I-5 @ 117 th	HOV Lane - n/b
40	6/21/95	2	4	5:00:00		B - T	Perk	I-5 @ 117 th	HOV Lane - n/b
41	6/21/95	3	1	6:00:00		B - T	Pedro	SR 520 @ 76 th	GP Lane - w/b
42	6/21/95	3	2	8:00:20		B - T	Pedro	SR 520 @ 76 th	GP Lane - w/b
43	6/21/95	3	3	3:00:30		B - T	Pedro	I-5 @ 185 th	GP Lane - n/b
44	6/21/95	3	4	5:04:00		B - T	Pedro	I-5 @ 185 th	GP Lane - n/b
45	6/21/95	4	1	6:00:30		B - T	Jeff	SR 520 @ 76 th	HOV Lane - w/b
46	6/21/95	4	2	8:02:30		B - T	Jeff	SR 520 @ 76 th	HOV Lane - w/b
47	6/21/95	4	3	3:00:00		B - T	Jeff	I-5 @ 185 th	HOV Lane - n/b
48	6/21/95	4	4	5:03:30		B - T	Jeff	I-5 @ 185 th	HOV Lane - n/b
49	6/22/95	1	1	5:58:45		B - T	Paul	SR 520 @ 92 nd	GP Lane - w/b
50	6/22/95	1	2	8:00:00		B - T	Paul	SR 520 @ 92 nd	GP Lane - w/b
51	6/22/95	1	3	2:58:00		B - T	Paul	I-5 @ 117 th	GP Lane - n/b
52	6/22/95	1	4	4:59:00		B - T	Paul	I-5 @ 117 th	GP Lane - n/b
53	6/22/95	2	1	6:00:30		B - T	Perk	SR 520 @ 92 nd	HOV Lane - w/b
54	6/22/95	2	2	8:01:00		B - T	Perk	SR 520 @ 92 nd	HOV Lane - w/b
55	6/22/95	2	3	3:00:00		B - T	Perk	I-5 @ 117 th	HOV Lane - n/b
56	6/22/95	2	4	5:01:00		B - T	Perk	I-5 @ 117 th	HOV Lane - n/b

Field Camera Stations, Directions, and Time of Day

Tape No.	Date	Cam No.	Tape No.	Start Time	Adjusted Start Time	R - L L - R B - T	Operator	Location	Direction
57	6/22/95	3	1	6:01:30		B - T	Pedro	SR 520 @ 76 th	GP Lane - w/b
58	6/22/95	3	2	8:03:00		B - T	Pedro	SR 520 @ 76 th	GP Lane - w/b
59	6/22/95	3	3	3:00:00		B - T	Pedro	I-5 @ 185 th	GP Lane - n/b
60	6/22/95	3	4	5:01:00		B - T	Pedro	I-5 @ 185 th	GP Lane - n/b
61	6/22/95	4	1	6:02:30		B - T	Jeff	SR 520 @ 76 th	HOV Lane - w/b
62	6/22/95	4	2	8:02:30		B - T	Jeff	SR 520 @ 76 th	HOV Lane - w/b
63	6/22/95	4	3	3:00:00		B - T	Jeff	I-5 @ 185 th	HOV Lane - n/b
64	6/22/95	4	4	5:00:00		B - T	Jeff	I-5 @ 185 th	HOV Lane - n/b

4.0 DISCUSSION OF RESULTS

Tape Processing Procedures

Processing the camcorder tapes involved transferring the license plate images recorded on videotape at each camera station into a computer file along with the instant of time at which each license plate image was recorded. Each separate station file was then matched against a logically related file to obtain the number of vehicles traveling from one station to another and the interval for time required by each vehicle to accomplish this movement. Thus, for example, the license plates observed at Station 1 (GP lane upstream) were matched against the plates observed at Station 3 (GP lane downstream). Likewise, the license plates observed at Station 2 (HOV lane upstream) were matched against the plates observed at Station 4 (HOV lane downstream). The difference between the instant at which a given license was observed at the upstream station and the instant at which that same plate was observed at the downstream station is the travel time between those two stations for the vehicle carrying that license plate.

The percentage of the license plates passing a given camera location that can be successfully transferred from videotape images to a computer file depends on the quality of the videotape recording and the method used to effect that transfer. If the videotape license plate images are of very high quality, then processing by means of an automatic plate reader results in a relatively high percentage of these images being transferred directly to a computer file for subsequent analysis.

If, as was the case with about five percent of the videotapes in the present study, license plate images are in poor focus, or too dark (or bright), or are otherwise ill-suited for automatic reading, then other means of "reading" these images were employed. Wherever possible, the license plate images were automatically "captured" from the more comprehensive image of the vehicle and transferred to a separate view from which they could be read by a human operator and entered into a computer file. For those videotapes, or portions of tapes, for which the license plate images were unsuited for automatic "capture", human operators read license plates directly from the original tapes.

Analysis of Results

Observed Traffic Volume

The volume of traffic observed passing by each camera station was estimated by counting the number of vehicle plates which were obtained by processing the video tapes with a machine vision system. This system triggers whenever it "sees" a license plate. These data are presented in Table 2 on the following page.

Mean travel times from the originating stations to their respective destination station are presented in Tables 3 - 10 on the following pages. Statistical data on standard deviations and coefficients of variations can be found in Tables 3A - 10A in the Appendix. The number of observed and matched license plates are summed over the entire four day period in Tables 11 and 12, along with the "averaged" mean travel times and speeds. Travel times vary generally with the ebb and flow of traffic volumes over the morning and evening peak periods of observation. A good example of this is seen in Table 8 (northbound I-5 traffic becoming congested around 5:00 PM), where travel time averages 200 seconds (corresponding to average speed of 64 mph) at 3:00 PM, rises to 940 seconds (dropping average speed to 14 mph) by 4:30 PM and remains high until 6:00 PM, and then drops to 230 seconds (increasing average speed back to 55 mph) by 7:00 PM.

Travel Time Results

Observed License Plates Using Machine Vision				
Time of Day	Cam No.	Location	Direction	Number of Plates Read
6 - 10 (AM Peak)	1	SR-520 @ 92 nd	GP Lane - w/b	12,141
	2	SR-520 @ 92 nd	HOV Lane - w/b	534
	3	SR-520 @ 76 th	GP Lane - w/b	16,822
	4	SR-520 @ 76 th	HOV Lane - w/b	10,168
Morning Total for SR-520 (in-bound)				
39,665				
2 - 6 (PM Peak)	1	I-5 @ 117 th	GP Lane - n/b	15,978
	2	I-5 @ 117 th	HOV Lane - n/b	10,020
	3	I-5 @ 185 th	GP Lane - n/b	15,254
	4	I-5 @ 185 th	HOV Lane - n/b	10,152
Evening Total for I-5 (out-bound)				
51,404				
Project Total for License Plate Reads				
91,069				

Table 2. Observed License Plates Using Machine Vision Technology.

In most instances, both the mean travel times and the coefficients of variation appear to be quite reasonable. The coefficients of variation associated with the various travel time estimates generally support the conclusion that these estimates accurately reflect the true value of mean travel time for each time period. Of the 206 calculated coefficients of variation (C.V.) only 6 are above 20 percent, and most C.V.'s are in the single digit range.

**Table 3. Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Westbound SR-520
June 19, 1995 - 6:00 AM to 10:00 AM**

MORNING PEAK Time of Day A. M.	HOV LANE *				GENERAL PURPOSE LANE				TRAVEL TIME DIFFERENCES	
	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	Seconds $t_{GP} - t_{HOV}$	Ratio t_{GP}/t_{HOV}
6:00 - 6:15	3	0			76	4	62.8	62.5		
6:15 - 6:30	7	1	52.0	75.5	192	23	66.6	58.9	14.6	1.3
6:30 - 6:45	8	4	53.5	73.3	209	21	66.5	59.0	13.0	1.2
6:45 - 7:00	8	1	51.0	76.9	215	19	67.2	58.4	16.2	1.3
7:00 - 7:15	16	2	46.0	85.3	237	16	70.9	55.3	24.9	1.5
7:15 - 7:30	17	8	49.3	79.6	268	31	73.3	53.5	24.0	1.5
7:30 - 7:45	24	5	46.6	84.2	251	33	86.2	45.5	39.6	1.9
7:45 - 8:00	24	2	44.5	88.2	200	29	77.1	50.9	32.6	1.7
8:00 - 8:15	2	1	73.0	53.8	211	22	73.3	53.5	0.3	1.0
8:15 - 8:30	2	1	74.0	53.0	212	17	70.0	56.1	-4.0	0.9
8:30 - 8:45	3	1	72.0	54.5	195	8	68.0	57.7	-4.0	0.9
8:45 - 9:00	2	1	74.0	53.0	201	15	66.3	59.2	-7.7	0.9
9:00 - 9:15	4	1	68.0	57.7	205	22	65.1	60.3	-2.9	1.0
9:15 - 9:30	3	1	67.0	58.6	179	14	66.6	58.9	-0.4	1.0
9:30 - 9:45	0	0			239	30	70.2	55.9		
9:45 - 10:00	0	0			194	14	66.4	59.1		

* Excluding Transit Buses

**Table 4. Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Westbound SR-520
June 20, 1995 - 6:00 AM to 10:00 AM**

MORNING PEAK Time of Day A. M.	HOV LANE *				GENERAL PURPOSE LANE				TRAVEL TIME DIFFERENCES	
	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	Seconds $t_{GP} - t_{HOV}$	Ratio t_{GP}/t_{HOV}
6:00 - 6:15	0	0			171	16	62.2	63.1		
6:15 - 6:30	3	1	75.0	52.3	191	24	65.5	59.9	-9.5	0.9
6:30 - 6:45	4	1	73.0	53.8	227	13	66.8	58.7	-6.2	0.9
6:45 - 7:00	6	1	86.0	45.6	204	26	66.3	59.2	-19.7	0.8
7:00 - 7:15	0	0			235	24	68.3	57.5		
7:15 - 7:30	0	0			253	20	73.4	53.5		
7:30 - 7:45	0	0			268	29	116.3	33.7		
7:45 - 8:00	0	0			211	14	133.1	29.5		
8:00 - 8:15	0	0			27	2	115.0	34.1		
8:15 - 8:30	10	1	85.0	46.2	42	1	225.0	17.4	140.0	2.6
8:30 - 8:45	13	2	93.0	42.2	29	2	236.0	16.6	143.0	2.5
8:45 - 9:00	10	1	96.0	40.9	35	1	158.0	24.8	62.0	1.6
9:00 - 9:15	10	1	91.0	43.1	29	1	81.0	48.4	-10.0	0.9
9:15 - 9:30	0	0			32	1	72.0	54.5		
9:30 - 9:45	0	0			26	2	64.5	60.8		
9:45 - 10:00	0	0			29	2	70.0	56.1		

* Excluding Transit Buses

Table 5. Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Westbound SR-520
 June 21, 1995 - 6:00 AM to 10:00 AM

MORNING PEAK Time of Day	HOV LANE *					GENERAL PURPOSE LANE					TRAVEL TIME DIFFERENCES	
	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	Seconds $t_{GP} - t_{HOV}$	Ratio t_{GP}/t_{HOV}		
6:00 - 6:15	0	0			147	4	62.3	63.0				
6:15 - 6:30	2	1	77.0	51.0	190	4	69.3	56.6	-7.7	0.9		
6:30 - 6:45	9	1	86.0	45.6	232	3	71.3	55.0	-14.7	0.8		
6:45 - 7:00	12	1	78.0	50.3	215	8	69.0	56.9	-9.0	0.9		
7:00 - 7:15	7	1	77.0	51.0	234	3	70.7	55.5	-6.3	0.9		
7:15 - 7:30	15	1	77.0	51.0	246	8	76.0	51.6	-1.0	1.0		
7:30 - 7:45	15	1	83.0	47.3	277	9	94.7	41.4	11.7	1.1		
7:45 - 8:00	15	1	93.0	42.2	207	12	118.1	33.2	25.1	1.3		
8:00 - 8:15	6	1	90.0	43.6	205	11	91.9	42.7	1.9	1.0		
8:15 - 8:30	4	1	77.0	51.0	218	4	72.8	53.9	-4.2	0.9		
8:30 - 8:45	0	0			210	2	70.5	55.7				
8:45 - 9:00	0	0			201	5	70.2	55.9				
9:00 - 9:15	0	0			207	4	67.3	58.3				
9:15 - 9:30	0	0			218	5	69.2	56.7				
9:30 - 9:45	0	0			213	5	71.8	54.7				
9:45 - 10:00	0	0			233	5	68.8	57.0				

* Excluding Transit Buses

Table 6. Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Westbound SR-520
 June 22, 1995 - 6:00 AM to 10:00 AM

MORNING PEAK	Time of Day	HOV LANE *							GENERAL PURPOSE LANE			TRAVEL TIME DIFFERENCES
		# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	Seconds t _g -t _{hov}	Ratio t _g /t _{hov}	
	6:00 - 6:15	3	0	174	70.5	2	70.5	55.7				
	6:15 - 6:30	1	1	54.0	72.7	180	68.5	57.3	14.5	1.3		
	6:30 - 6:45	15	3	62.7	62.6	227	70.1	56.0	7.4	1.1		
	6:45 - 7:00	11	2	71.5	54.9	228	68.5	57.3	-3.0	1.0		
	7:00 - 7:15	12	2	67.5	58.1	232	72.9	53.8	5.4	1.1		
	7:15 - 7:30	22	2	72.5	54.1	252	93.2	42.1	20.7	1.3		
	7:30 - 7:45	13	4	61.5	63.8	248	94.6	41.5	33.1	1.5		
	7:45 - 8:00	18	3	48.3	81.2	187	74.3	52.8	26.0	1.5		
	8:00 - 8:15	14	7	73.7	53.2	214	74.9	52.4	1.2	1.0		
	8:15 - 8:30	9	3	93.3	42.1	191	76.3	51.4	-17.0	0.8		
	8:30 - 8:45	12	4	70.8	55.4	224	70.4	55.7	-0.4	1.0		
	8:45 - 9:00	11	5	75.0	52.3	190	68.8	57.0	-6.2	0.9		
	9:00 - 9:15	16	8	71.1	55.2	189	70.1	56.0	-1.0	1.0		
	9:15 - 9:30	12	5	70.2	55.9	214	69.3	56.6	-0.9	1.0		
	9:30 - 9:45	13	6	66.7	58.8	216	69.8	56.2	3.1	1.0		
	9:45 - 10:00	17	10	63.6	61.7	205	69.5	56.5	5.9	1.1		

* Excluding Transit Buses

**Table 7. Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Northbound I-5
June 19, 1995 - 3:00 PM to 7:00 PM**

EVENING PEAK Time of Day P. M.	HOV LANE*				GENERAL PURPOSE LANE				TRAVEL TIME DIFFERENCES	
	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	Seconds $t_{GP} - t_{HOV}$	Ratio t_{GP}/t_{HOV}
3:00 - 3:15	111	55	200.2	64.2	280	78	221.7	58.0	21.5	1.1
3:15 - 3:30	156	71	204.8	62.8	339	111	224.8	57.2	20.0	1.1
3:30 - 3:45	149	68	213.5	60.2	318	98	246.0	52.2	32.5	1.2
3:45 - 4:00	149	67	223.7	57.5	194	66	281.5	45.7	57.8	1.3
4:00 - 4:15	137	60	215.6	59.6	116	35	240.1	53.5	24.5	1.1
4:15 - 4:30	170	80	227.3	56.5	249	77	266.9	48.2	39.6	1.2
4:30 - 4:45	166	71	249.9	51.4	238	61	352.6	36.4	102.7	1.4
4:45 - 5:00	189	63	264.8	48.5	158	30	381.2	33.7	116.4	1.4
5:00 - 5:15	264	13	255.6	50.3	131	24	441.4	29.1	185.8	1.7
5:15 - 5:30	305	19	252.4	50.9	141	26	385.3	33.4	132.9	1.5
5:30 - 5:45	243	22	240.2	53.5	127	27	334.8	38.4	94.6	1.4
5:45 - 6:00	145	9	208.4	61.7	91	15	308.5	41.7	100.1	1.5
6:00 - 6:15	116	1	185.0	69.5	117	23	224.5	57.2	39.5	1.2
6:15 - 6:30	138	5	184.8	69.5	164	32	223.9	57.4	39.1	1.2
6:30 - 6:45	101	4	179.5	71.6	106	10	221.1	58.1	41.6	1.2
6:45 - 7:00	73	5	175.8	73.1	95	2	212.0	60.6	36.2	1.2

* Excluding Transit Buses

**Table 8. Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Northbound I-5
June 20, 1995 - 3:00 PM to 7:00 PM**

EVENING PEAK Time of Day P. M.	HOV LANE*				GENERAL PURPOSE LANE				TRAVEL TIME DIFFERENCES	
	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	Seconds $t_{GP} - t_{HOV}$	Ratio t_{GP}/t_{HOV}
3:00 - 3:15	147	4	200.0	64.3	244	67	203.5	63.2	3.5	1.0
3:15 - 3:30	161	7	216.9	59.3	258	56	237.5	54.1	20.6	1.1
3:30 - 3:45	159	6	247.3	52.0	246	57	411.4	31.2	164.1	1.7
3:45 - 4:00	207	9	277.0	46.4	266	71	585.1	22.0	308.1	2.1
4:00 - 4:15	200	14	283.4	45.3	259	69	708.2	18.1	424.8	2.5
4:15 - 4:30	247	22	337.9	38.0	270	77	788.2	16.3	450.3	2.3
4:30 - 4:45	230	13	354.9	36.2	256	70	940.6	13.7	585.7	2.7
4:45 - 5:00	313	1	465.0	27.6	230	2	960.0	13.4	495.0	2.1
5:00 - 5:15	239	96	494.0	26.0	326	68	938.4	13.7	444.4	1.9
5:15 - 5:30	313	137	524.3	24.5	339	83	981.3	13.1	457.0	1.9
5:30 - 5:45	275	107	524.5	24.5	351	81	953.6	13.5	429.1	1.8
5:45 - 6:00	283	102	485.4	26.5	369	76	1007.6	12.8	522.2	2.1
6:00 - 6:15	216	73	478.8	26.8	334	77	936.8	13.7	458.0	2.0
6:15 - 6:30	214	93	271.9	47.3	336	66	692.4	18.6	420.5	2.5
6:30 - 6:45	80	35	203.7	63.1	282	29	382.2	33.6	178.5	1.9
6:45 - 7:00	76	17	172.2	74.6	269	50	229.7	56.0	57.5	1.3

* Excluding Transit Buses

**Table 9. Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Northbound I-5
June 21, 1995 - 3:00 PM to 7:00 PM**

EVENING PEAK Time of Day P. M.	HOV LANE*				GENERAL PURPOSE LANE				TRAVEL TIME DIFFERENCES	
	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	Seconds $t_{GP} - t_{HOV}$	Ratio t_{GP}/t_{HOV}
3:00 - 3:15	49	10	208.1	61.8	226	11	207.9	61.8	-0.2	1.0
3:15 - 3:30	57	14	210.1	61.2	284	16	221.3	58.1	11.2	1.1
3:30 - 3:45	66	17	234.3	54.9	282	15	345.9	37.2	111.6	1.5
3:45 - 4:00	77	19	272.0	47.3	290	13	493.8	26.0	221.8	1.8
4:00 - 4:15	76	16	305.3	42.1	235	7	497.8	25.8	192.5	1.6
4:15 - 4:30	103	22	327.5	39.2	274	16	640.4	20.1	312.9	2.0
4:30 - 4:45	83	20	371.7	34.6	275	7	719.1	17.9	347.4	1.9
4:45 - 5:00	60	6	408.3	31.5	41	12	714.2	18.0	305.9	1.7
5:00 - 5:15	89	7	378.1	34.0	271	56	703.3	18.3	325.2	1.9
5:15 - 5:30	81	10	318.1	40.4	283	71	711.3	18.1	393.2	2.2
5:30 - 5:45	85	10	323.3	39.8	251	65	617.6	20.8	294.3	1.9
5:45 - 6:00	49	5	295.4	43.5	267	46	558.7	23.0	263.3	1.9
6:00 - 6:15	48	2	273.0	47.1	243	23	332.6	38.6	59.6	1.2
6:15 - 6:30	37	2	267.5	48.0	223	40	341.8	37.6	74.3	1.3
6:30 - 6:45	24	4	229.0	56.1	212	43	393.7	32.6	164.7	1.7
6:45 - 7:00	28	2	224.0	57.4	193	18	229.4	56.0	5.4	1.0

* Excluding Transit Buses

**Table 10. Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Northbound I-5
June 22, 1995 - 3:00 PM to 7:00 PM**

EVENING PEAK Time of Day P. M.	HOV LANE*				GENERAL PURPOSE LANE				TRAVEL TIME DIFFERENCES	
	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	Seconds $t_{GP} - t_{HOV}$	Ratio t_{GP}/t_{HOV}
3:00 - 3:15	128	53	205.4	62.6	263	77	213.8	60.1	8.4	1.0
3:15 - 3:30	156	62	220.3	58.3	271	69	247.4	51.9	27.1	1.1
3:30 - 3:45	185	90	245.7	52.3	277	73	353.9	36.3	108.2	1.4
3:45 - 4:00	201	74	272.2	47.2	294	81	484.9	26.5	212.7	1.8
4:00 - 4:15	211	85	318.8	40.3	259	69	650.4	19.8	331.6	2.0
4:15 - 4:30	229	85	307.5	41.8	265	58	638.6	20.1	331.1	2.1
4:30 - 4:45	220	87	333.2	38.6	270	66	607.3	21.2	274.1	1.8
4:45 - 5:00	272	52	363.7	35.3	218	24	566.5	22.7	202.8	1.6
5:00 - 5:15	195	67	392.7	32.7	312	76	612.6	21.0	219.9	1.6
5:15 - 5:30	251	77	362.4	35.5	346	68	671.1	19.2	308.7	1.9
5:30 - 5:45	188	48	330.9	38.8	312	55	686.2	18.7	355.3	2.1
5:45 - 6:00	190	57	284.9	45.1	333	60	526.1	24.4	241.2	1.8
6:00 - 6:15	167	42	286.7	44.8	297	48	473.3	27.2	186.6	1.7
6:15 - 6:30	144	38	230.3	55.8	317	52	294.9	43.6	64.6	1.3
6:30 - 6:45	107	39	199.9	64.3	292	69	207.9	61.8	8.0	1.0
6:45 - 7:00	91	22	203.2	63.2	233	53	209.2	61.4	6.0	1.0

* Excluding Transit Buses

**Table 11. Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Westbound SR-520
June 19 Through June 22, 1995 - 6:00 AM to 10:00 AM**

MORNING PEAK Time of Day A.M.	HOV LANE*				GENERAL PURPOSE LANE				TRAVEL TIME DIFFERENCES	
	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	Avg. Seconds $t_{GP} - t_{HOV}$	Avg. Ratio t_{GP}/t_{HOV}
6:00 - 6:15	6	0			568	26	64.5	60.8		
6:15 - 6:30	13	4	65.0	60.4	753	53	67.5	58.1	2.5	1.0
6:30 - 6:45	36	9	68.8	57.0	895	47	68.7	57.1	-0.1	1.0
6:45 - 7:00	37	5	71.6	54.8	862	75	67.8	57.9	-3.8	0.9
7:00 - 7:15	35	4	63.5	61.8	938	67	69.8	56.2	6.3	1.1
7:15 - 7:30	54	11	66.3	59.2	1,019	79	78.9	49.7	12.6	1.2
7:30 - 7:45	52	10	63.7	61.6	1,044	97	97.9	40.1	34.2	1.5
7:45 - 8:00	57	6	61.9	63.4	805	76	100.7	39.0	38.8	1.6
8:00 - 8:15	22	9	78.9	49.7	657	57	88.8	44.2	9.9	1.1
8:15 - 8:30	25	6	82.3	47.7	663	43	111.0	35.4	28.7	1.3
8:30 - 8:45	28	7	78.6	49.9	658	39	111.2	35.3	32.6	1.4
8:45 - 9:00	23	7	81.7	48.0	627	48	90.8	43.2	9.1	1.1
9:00 - 9:15	30	10	76.7	51.2	630	42	70.9	55.3	-5.8	0.9
9:15 - 9:30	15	6	68.6	57.2	643	46	69.3	56.6	0.7	1.0
9:30 - 9:45	13	6	66.7	58.8	694	61	69.1	56.8	2.4	1.0
9:45 - 10:00	17	10	63.6	61.7	661	41	68.7	57.1	5.1	1.1

* Excluding Transit Buses

Table 12. Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Northbound I-5 June 19 thru June 22, 1995 - 3:00 PM to 7:00 PM

Time of Day P.M.	HOV LANE*					GENERAL PURPOSE LANE					TRAVEL TIME DIFFERENCES
	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Average Speed (mph)	Avg. Seconds Gr-Hov	Avg. Ratio Gr-Hov	
3:00 - 3:15	435	122	203.4	63.2	1,013	233	211.7	60.7	8.3	1.0	
3:15 - 3:30	530	154	213.0	60.3	1,152	252	232.3	55.3	19.3	1.1	
3:30 - 3:45	559	101	235.2	54.6	1,123	243	339.3	37.9	104.1	1.4	
3:45 - 4:00	634	169	261.2	49.2	1,044	231	461.3	27.9	200.1	1.8	
4:00 - 4:15	624	175	280.8	45.8	869	180	524.1	24.5	243.3	1.9	
4:15 - 4:30	749	209	300.1	42.8	1,058	228	583.5	22.0	283.4	1.9	
4:30 - 4:45	699	191	347.7	37.0	1,039	204	654.9	19.6	307.2	1.9	
4:45 - 5:00	834	122	375.5	34.2	647	122	655.5	19.6	280.0	1.7	
5:00 - 5:15	787	183	380.1	33.8	1,040	224	673.9	19.1	293.8	1.8	
5:15 - 5:30	950	243	364.3	35.3	1,109	248	687.2	18.7	322.9	1.9	
5:30 - 5:45	791	178	354.7	36.2	1,041	228	648.1	19.8	293.4	1.8	
5:45 - 6:00	667	173	318.5	40.4	1,060	197	600.2	21.4	281.7	1.9	
6:00 - 6:15	547	118	305.9	42.0	991	171	491.8	26.1	185.9	1.6	
6:15 - 6:30	533	138	238.6	53.9	1,040	190	388.3	33.1	149.7	1.6	
6:30 - 6:45	312	82	203.0	63.3	892	151	301.2	42.7	98.2	1.5	
6:45 - 7:00	268	46	193.8	66.3	790	123	220.1	58.4	26.3	1.1	

* Excluding Transit Buses

5.0 CONCLUSIONS

Results indicate the evening peak period commute home from downtown Seattle on northbound I-5 can be 2.0 to 2.7 times longer in high volume traffic conditions than the same commute using the HOV facilities for the ~3 ½ miles of freeway monitored. Results averaged over the four weekdays for the entire four hour evening period indicate approximately 60% longer commute times in the general purpose versus HOV lanes.

Similar results could not be statistically verified for the morning peak period on westbound SR-520 due to the relatively low number of vehicles observed using the HOV facilities during the survey period. However, there was evidence of approximately 50% longer commute times in the general purpose traffic lanes between 7:30 - 8:00 AM than the vehicles observed in the HOV lane on SR-520 for the ~1 mile of freeway monitored.

Average speeds of traffic flow in the general purpose lane ranged from a high of 60 mph during non-congested periods to as low as 19 mph during periods of heavy congestion with stop-and-go traffic. Average speeds of traffic flow in the HOV lane ranged from a high of 66 mph to a low of 34 mph.

Automatic video-based license plate reading techniques were successful in determining travel time data for both peak traffic periods at separate study locations by collecting and analyzing over 90,000 vehicle license plates (approximately 75% of traffic flow) using a machine vision system which operated on video tapes of vehicles passing by each of four (4) camera stations located strategically along the travel corridor during peak hours. This license plate data was used to "match" vehicles between camera stations and compute travel times on more than 200 vehicles per hour in high volume traffic conditions.

6.0 APPENDIX

List of Tables Summarizing Mean Travel Times and Statistical Variations

List of Tables Summarizing Travel Time Matching Data Between Camera Stations

List of Tables Summarizing License Plate Numbers Matched to Station and Time

**Table 3A. Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - State Route 520
June 19, 1995 - 6:00 AM to 10:00 AM**

MORNING PEAK Time of Day A.M.	HOV LANE *					GENERAL PURPOSE LANE					TRAVEL TIME DIFFERENCES	
	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Std. Deviation (sec)	C.V. of Variance (%)	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Std. Deviation (sec)	C.V. of Variance (%)	Seconds $t_g - t_h$	Ratio t_g/t_h
6:00 - 6:15	3	0				76	4	62.8	4.1	6.5		
6:15 - 6:30	7	1	52.0			192	23	66.6	3.4	5.1	14.6	1.3
6:30 - 6:45	8	4	53.5	2.4	4.5	209	21	66.5	3.3	5.0	13.0	1.2
6:45 - 7:00	8	1	51.0			215	19	67.2	4.0	6.0	16.2	1.3
7:00 - 7:15	16	2	46.0	4.2	9.1	237	16	70.9	3.9	5.5	24.9	1.5
7:15 - 7:30	17	8	49.3	6.8	13.8	268	31	73.3	4.0	5.5	24.0	1.5
7:30 - 7:45	24	5	46.6	4.8	10.3	251	33	86.2	15.8	18.3	39.6	1.8
7:45 - 8:00	24	2	44.5	4.9	11.0	200	29	77.1	13.4	17.4	32.6	1.7
8:00 - 8:15	2	1	73.0			211	22	73.3	5.4	7.4	0.3	1.0
8:15 - 8:30	2	1	74.0			212	17	70.0	4.0	5.5	-4.0	0.95
8:30 - 8:45	3	1	72.0			195	8	68.0	1.9	2.8	-4.0	0.94
8:45 - 9:00	2	1	74.0			201	15	66.3	4.2	6.3	-7.7	0.90
9:00 - 9:15	4	1	68.0			205	22	65.1	3.8	5.8	-2.9	0.96
9:15 - 9:30	3	1	67.0			179	14	66.6	3.3	5.0	-0.4	0.99
9:30 - 9:45						239	30	70.2	4.3	6.1		
9:45 - 10:00						194	14	66.4	3.3	5.0		

* Excluding Transit Buses

Table 4A. Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - State Route 520
 June 20, 1995 - 6:00 AM to 10:00 AM

MORNING PEAK Time of Day A.M.	HOV LANE *												GENERAL PURPOSE LANE		TRAVEL TIME DIFFERENCES
	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Sid. Deviation (sec)	C.V. of Variance (%)	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Sid. Deviation (sec)	C.V. of Variance (%)	Seconds t _p	Ratio t _p			
6:00 - 6:15	0	0				171	16	62.2	2.6	4.2%					
6:15 - 6:30	3	1	75.0			191	24	65.5	3.7	5.6%	-9.5	0.87			
6:30 - 6:45	4	1	73.0			227	13	66.8	3.2	4.8%	-6.2	0.92			
6:45 - 7:00	6	1	86.0			204	26	66.3	3.6	5.4%	-19.7	0.77			
7:00 - 7:15	0	0				235	24	68.3	4.3	6.3%					
7:15 - 7:30	0	0				253	20	73.4	4.8	6.5%					
7:30 - 7:45	0	0				268	29	116.3	22.2	19.1%					
7:45 - 8:00	0	0				211	14	133.1	18.2	13.7%					
8:00 - 8:15	0	0				27	2	115.0	4.2	3.7%					
8:15 - 8:30	10	1	85.0			42	1	225.0			140.0	2.6			
8:30 - 8:45	13	2	93.0	2.8		29	2	236.0	35.4	15.0%	143.0	2.5			
8:45 - 9:00	10	1	196.0			35	1	158.0			-38.0	0.81			
9:00 - 9:15	10	1	91.0			29	1	81.0			-10.0	0.89			
9:15 - 9:30	0	0				32	1	72.0							
9:30 - 9:45	0	0				26	2	64.5	0.7	1.1%					
9:45 - 10:00	0	0				29	2	70.0	4.2	6.0%					

* Excluding Transit Buses

Table SA. Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - State Route 520
 June 21, 1995 - 6:00 AM to 10:00 AM

Time of Day	HOV LANE *											GENERAL PURPOSE LANE				TRAVEL TIME DIFFERENCES	
	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Std Deviation (sec)	C.V. of Variance (%)	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Std Deviation (sec)	C.V. of Variance (%)	Seconds t ₂ -t ₁	Ratio t ₂ /t ₁					
MORNING PEAK																	
6:00 - 6:15	0	0				147	4	62.3	3.2	5.1%							
6:15 - 6:30	2	1	77.0			190	4	69.3	0.5	0.7%	-7.7	0.90					
6:30 - 6:45	9	1	86.0			232	3	71.3	1.5	2.1%	-14.7	0.83					
6:45 - 7:00	12	1	78.0			215	8	69.0	4.2	6.1%	-9.0	0.88					
7:00 - 7:15	7	1	77.0			234	3	70.7	1.5	2.1%	-6.3	0.92					
7:15 - 7:30	15	1	77.0			246	8	76.0	1.3	1.7%	-1.0	0.99					
7:30 - 7:45	15	1	83.0			277	9	94.7	15.9	16.8%	11.7	1.1					
7:45 - 8:00	15	1	93.0			207	12	118.1	12.5	10.6%	25.1	1.3					
8:00 - 8:15	6	1	90.0			205	11	91.9	21.4	23.3%	1.9	1.0					
8:15 - 8:30	4	1	77.0			218	4	72.8	4.1	5.6%	-4.2	0.95					
8:30 - 8:45	0	0				210	2	70.5	3.5	5.0%							
8:45 - 9:00	0	0				201	5	70.2	1.5	2.1%							
9:00 - 9:15	0	0				207	4	67.3	4.1	6.1%							
9:15 - 9:30	0	0				218	5	69.2	2.6	3.8%							
9:30 - 9:45	0	0				213	5	71.8	1.6	2.2%							
9:45 - 10:00	0	0				233	5	68.8	1.9	2.8%							

* Excluding Transit Buses

Table 6A. Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - State Route 520
 June 22, 1995 - 6:00 AM to 10:00 AM

MORNING PEAK Time of Day A.M.	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Std. Deviation (sec)	C.V. of Variance (%)	GENERAL PURPOSE LANE						Ratio t _g /t _h
						# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Std. Deviation (sec)	C.V. of Variance (%)	Seconds t _g	
6:00 - 6:15	3	0		174	2	70.5	9.2	13.1%				
6:15 - 6:30	1	1	54.0			180	2	68.5	3.5	5.1%	14.5	1.3
6:30 - 6:45	15	3	62.7	2.5	4.0%	227	10	70.1	3.3	4.7%	7.4	1.1
6:45 - 7:00	11	2	71.5	12.0	16.8%	228	22	68.5	4.4	6.4%	-3.0	0.96
7:00 - 7:15	12	2	67.5	0.7	1.0%	232	21	72.9	6.3	8.6%	5.4	1.1
7:15 - 7:30	22	2	72.5	30.4	41.9%	252	20	93.2	15.5	16.6%	20.7	1.3
7:30 - 7:45	13	4	61.5	3.5	5.7%	248	26	94.6	13.5	14.3%	33.1	1.5
7:45 - 8:00	18	3	48.3	0.6	1.2%	187	21	74.3	7.6	10.2%	26.0	1.5
8:00 - 8:15	14	7	73.7	5.9	8.0%	214	22	74.9	5.8	7.7%	1.2	1.0
8:15 - 8:30	9	3	93.3	8.1	8.7%	191	21	76.3	8.8	11.5%	-17.0	0.82
8:30 - 8:45	12	4	70.8	2.1	3.0%	224	27	70.4	3.8	5.4%	0.4	0.99
8:45 - 9:00	11	5	75.0	4.3	5.7%	190	26	68.8	4.5	6.5%	-6.2	0.92
9:00 - 9:15	16	8	71.1	3.4	4.8%	189	15	70.1	4.8	6.8%	-1.0	0.99
9:15 - 9:30	12	5	70.2	5.1	7.3%	214	26	69.3	4.5	6.5%	-0.9	0.99
9:30 - 9:45	13	6	66.7	2.0	3.0%	216	24	69.8	3.7	5.3%	3.1	1.0
9:45 - 10:00	17	10	63.6	4.2	6.6%	205	20	69.5	3.9	5.6%	5.9	1.1

* Excluding Transit Buses

Transit Systems, Inc.

Table 7A. Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Interstate 5
 June 19, 1995 - 3:00 PM to 7:00 PM

TRAVEL TIME DIFFERENCES	HOV LANE*						GENERAL PURPOSE LANE					
	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Std. Deviation (sec)	C.V. of Variance (%)	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Std. Deviation (sec)	C.V. of Variance (%)	Seconds $t_2 - t_1$	Ratio t_2/t_1
Time of Day PEAK	EVENING											
3:00 - 3:15	111	55	200.2	7.6	3.8%	280	78	221.7	6.6	3.0%	21.5	1.1
3:15 - 3:30	156	71	204.8	6.8	3.3%	339	111	224.8	7.9	3.5%	20.0	1.1
3:30 - 3:45	149	68	213.5	8.0	3.7%	318	98	246.0	16.0	6.5%	32.5	1.2
3:45 - 4:00	149	67	223.7	7.1	3.2%	194	66	281.5	19.2	6.8%	57.8	1.3
4:00 - 4:15	137	60	215.6	6.7	3.1%	116	35	240.1	5.4	2.2%	24.5	1.1
4:15 - 4:30	170	80	227.3	10.5	4.6%	249	77	266.9	20.7	7.8%	39.6	1.2
4:30 - 4:45	166	71	249.9	11.5	4.6%	238	61	352.6	21.8	6.2%	102.7	1.4
4:45 - 5:00	189	63	264.8	13.7	5.2%	158	30	381.2	17.8	4.7%	116.4	1.4
5:00 - 5:15	264	13	255.6	21.5	8.4%	131	24	441.4	15.0	3.4%	185.8	1.7
5:15 - 5:30	305	19	252.4	20.8	8.2%	141	26	385.3	16.1	4.2%	132.9	1.5
5:30 - 5:45	243	22	240.2	27.2	11.3%	127	27	334.8	23.3	7.0%	94.6	1.4
5:45 - 6:00	145	9	208.4	7.3	3.5%	91	15	308.5	25.5	8.3%	100.1	1.5
6:00 - 6:15	116	1	185.0		0.0%	117	23	224.5	6.6	2.9%	39.5	1.2
6:15 - 6:30	138	5	184.8	5.1	2.8%	164	32	223.9	6.8	3.0%	39.1	1.2
6:30 - 6:45	101	4	179.5	4.5	2.5%	106	10	221.1	7.0	3.2%	41.6	1.2
6:45 - 7:00	73	5	175.8	10.9	6.2%	95	2	212.0	1.4	0.7%	36.2	1.2

* Excluding Transit Buses

Table 8A. Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Interstate 5 June 20, 1995 - 3:00 PM to 7:00 PM

EVENING PEAK Time of Day P.M.	HOV LANE*					GENERAL PURPOSE LANE					TRAVEL TIME DIFFERENCES	
	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Std. Deviation (sec)	C.V. of Variance (%)	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Std. Deviation (sec)	C.V. of Variance (%)	Seconds	Ratio
3:00 - 3:15	147	4	200.0	12.3	6.2%	244	67	203.5	6.4	3.1%	3.5	1.0
3:15 - 3:30	161	7	216.9	8.4	3.9%	258	56	237.5	25.5	10.7%	20.6	1.1
3:30 - 3:45	159	6	247.3	17.7	7.2%	246	57	411.4	55.5	13.5%	164.1	1.7
3:45 - 4:00	207	9	277.0	20.6	7.4%	266	71	585.1	77.0	13.2%	308.1	2.1
4:00 - 4:15	200	14	283.4	9.2	3.2%	259	69	708.2	41.8	5.9%	424.8	2.5
4:15 - 4:30	247	22	337.9	17.7	5.2%	270	77	788.2	60.8	7.7%	450.3	2.3
4:30 - 4:45	230	13	354.9	33.5	9.4%	256	70	940.6	43.7	4.6%	585.7	2.7
4:45 - 5:00	313	1	465.0			230	2	960.0	2.1	0.2%	495.0	2.1
5:00 - 5:15	239	96	494.0	48.2	9.8%	326	68	938.4	50.0	5.3%	444.4	1.9
5:15 - 5:30	313	137	524.3	40.0	7.6%	339	83	981.3	22.3	2.3%	457.0	1.9
5:30 - 5:45	275	107	524.5	40.6	7.7%	351	81	953.6	72.6	7.6%	429.1	1.8
5:45 - 6:00	283	102	485.4	32.8	6.8%	369	76	1007.6	57.1	5.7%	522.2	2.1
6:00 - 6:15	216	73	478.8	91.2	19.0%	334	77	936.8	63.6	6.8%	458.0	2.0
6:15 - 6:30	214	93	271.9	41.4	15.2%	336	66	692.4	86.3	12.5%	420.5	2.5
6:30 - 6:45	80	35	203.7	16.3	8.0%	282	29	382.2	87.7	22.9%	178.5	1.9
6:45 - 7:00	76	17	172.2	6.6	3.8%	269	50	229.7	21.8	9.5%	57.5	1.3

* Excluding Transit Buses

**Table 9A. Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Interstate 5
June 21, 1995 - 3:00 PM to 7:00 PM**

EVENING PEAK Time of Day P.M.	HOV LANE*					GENERAL PURPOSE LANE					TRAVEL TIME DIFFERENCES	
	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Std. Deviation (sec)	C.V. of Variance (%)	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Std. Deviation (sec)	C.V. of Variance (%)	Seconds $t_g - t_h$	Ratio t_g/t_h
3:00 - 3:15	49	10	208.1	6.3	3.0%	226	11	207.9	7.0	3.4%	- 0.2	1.0
3:15 - 3:30	57	14	210.1	6.5	3.1%	284	16	221.3	11.6	5.2%	11.2	1.1
3:30 - 3:45	66	17	234.3	13.7	5.8%	282	15	345.9	64.4	18.6%	111.6	1.5
3:45 - 4:00	77	19	272.0	35.8	13.2%	290	13	493.8	73.3	14.8%	221.8	1.8
4:00 - 4:15	76	16	305.3	45.6	14.9%	235	7	497.8	46.7	9.4%	192.5	1.6
4:15 - 4:30	103	22	327.5	15.4	4.7%	274	16	640.4	55.3	8.6%	312.9	2.0
4:30 - 4:45	83	20	371.7	11.6	3.1%	275	7	719.1	37.5	5.2%	347.4	1.9
4:45 - 5:00	60	6	408.3	12.3	3.0%	41	12	714.2	7.6	1.1%	305.9	1.7
5:00 - 5:15	89	7	378.1	31.3	8.3%	271	56	703.3	36.3	5.2%	325.2	1.9
5:15 - 5:30	81	10	318.1	25.8	8.1%	283	71	711.3	78.5	11.0%	393.2	2.2
5:30 - 5:45	85	10	323.3	39.8	12.3%	251	65	617.6	34.5	5.6%	294.3	1.9
5:45 - 6:00	49	5	295.4	33.2	11.2%	267	46	558.7	85.9	15.4%	263.3	1.9
6:00 - 6:15	48	2	273.0	30.0	11.0%	243	23	332.6	65.1	19.6%	59.6	1.2
6:15 - 6:30	37	2	267.5	85.6	32.0%	223	40	341.8	97.4	28.5%	74.3	1.3
6:30 - 6:45	24	4	229.0	3.2	1.4%	212	43	393.7	58.4	14.8%	164.7	1.7
6:45 - 7:00	28	2	224.0	5.7	2.5%	193	18	229.4	43.7	19.1%	5.4	1.0

* Excluding Transit Buses

**Table 10A. Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Interstate 5
June 22, 1995 - 3:00 PM to 7:00 PM**

EVENING PEAK Time of Day P.M.	HOV LANE*					GENERAL PURPOSE LANE					TRAVEL TIME DIFFERENCES	
	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Std. Deviation (sec)	C.V. of Variance (%)	# of License Plates	# of Matched Pairs	Mean Travel Time (sec)	Std. Deviation (sec)	C.V. of Variance (%)	Seconds $t_g - t_h$	Ratio t_g/t_h
3:00 - 3:15	128	53	205.4	9.0	4.4%	263	77	213.8	6.2	2.9%	8.4	1.0
3:15 - 3:30	156	62	220.3	17.6	8.0%	271	69	247.4	34.1	13.8%	27.1	1.1
3:30 - 3:45	185	90	245.7	11.0	4.5%	277	73	353.9	37.6	10.6%	108.2	1.4
3:45 - 4:00	201	74	272.2	13.1	4.8%	294	81	484.9	43.9	9.1%	212.7	1.8
4:00 - 4:15	211	85	318.8	26.2	8.2%	259	69	650.4	60.8	9.3%	331.6	2.0
4:15 - 4:30	229	85	307.5	45.9	14.9%	265	58	638.6	41.9	6.6%	331.1	2.1
4:30 - 4:45	220	87	333.2	24.8	7.4%	270	66	607.3	40.7	6.7%	274.1	1.8
4:45 - 5:00	272	52	363.7	13.7	3.8%	218	24	566.5	25.5	4.5%	202.8	1.6
5:00 - 5:15	195	67	392.7	29.7	7.6%	312	76	612.6	19.4	3.2%	219.9	1.6
5:15 - 5:30	251	77	362.4	34.6	9.5%	346	68	671.1	47.9	7.1%	308.7	1.9
5:30 - 5:45	188	48	330.9	17.9	5.4%	312	55	686.2	40.3	5.9%	355.3	2.1
5:45 - 6:00	190	57	284.9	18.3	6.4%	333	60	526.1	45.8	8.7%	241.2	1.8
6:00 - 6:15	167	42	286.7	19.4	6.8%	297	48	473.3	36.6	7.7%	186.6	1.7
6:15 - 6:30	144	38	230.3	22.7	9.9%	317	52	294.9	71.4	24.2%	64.9	1.3
6:30 - 6:45	107	39	199.9	6.4	3.2%	292	69	207.9	6.6	3.2%	8.0	1.0
6:45 - 7:00	91	22	203.2	7.9	3.9%	233	53	209.2	7.4	3.5%	6.0	1.0

* Excluding Transit Buses

- PRESS RELEASE -

"The ITS Division of Huntingdon Engineering & Environmental in Houston (TX) and the transportation business of Computer Recognition Systems (CRS) in Cambridge (MA) have formed a new company, Transformation Systems, Inc. to develop and market automated traffic surveillance and survey systems. Transformation Systems has acquired exclusive rights to Huntingdon's current and future ITS contracts."

"Jeffrey Woodson, formerly Vice President of Huntingdon's ITS Division, has been appointed president of Transformation Systems, Inc. which is based in Houston. Salvatore D'Agostino retains his position as president of CRS, which continues to pursue other markets, but also serves as a director at Transformation Systems, Inc. Symonds Travers Morgan Limited (formerly known as Huntingdon Travers Morgan) in the U.K. will also have an interest in the new corporation."

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(617) 491-7665

Transformation **Systems, Inc.**

Intelligent Transportation Systems (ITS) Services

Automated Video-Based Computer Systems

- Traffic monitoring and vehicle classification systems (TAS2) developed by Computer Recognition Systems to automatically count and classify vehicles using CCTV cameras and machine vision technology
- Origin-destination and journey time surveys to automatically perform travel surveys for determining traffic patterns, trip times, congestion delays, and performance of HOV facilities using portable Hi-8 video cameras and license plate recognition. Where DMV records are available, a database is created for use in mailouts and other survey information.
- SVDD (Speed Violation Detection/Deterrent) is a video-based system used to measure vehicle speed and identify violators using license plate recognition
- HOVER (High Occupancy Vehicle lane Enforcement and Review) is used to remotely monitor HOV lanes and identify violators using cameras and computers
- Security cordon and border crossing surveillance using CCTV cameras and automatic license plate recognition to identify and monitor frequent or recurring threats and incidents involving vehicles

Transformation Systems, Inc., 2537 South Gessner, Suite 212, Houston, Texas 77063

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