CAMBRIDGE SYSTEMATICS

NGSIM U.S. 101 Data Analysis (8:05 a.m. to 8:20 a.m.)

summary report

prepared for

Federal Highway Administration

prepared by

Cambridge Systematics, Inc.

December 2005

www.camsys.com

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Introduction

This report summarizes a data collection and processing effort undertaken to provide a dataset of vehicle trajectory data completed as part of the Federal Highway Administration's (FHWA) Next Generation Simulation (NGSIM) project, and provides a detailed analysis of a subset of the data. The data analyzed in this report represent vehicle trajectories on a segment of U.S. Highway 101 (Hollywood Freeway) in Los Angeles, California collected between 8:05 a.m. and 8:20 a.m. on June 15, 2005. Aggregate summaries of flow and speed of the vehicles, number of lane changes, headway and gap analysis, and an input-output analysis of flows are provided. The results are aggregated by time, distance (100 feet), and lane.

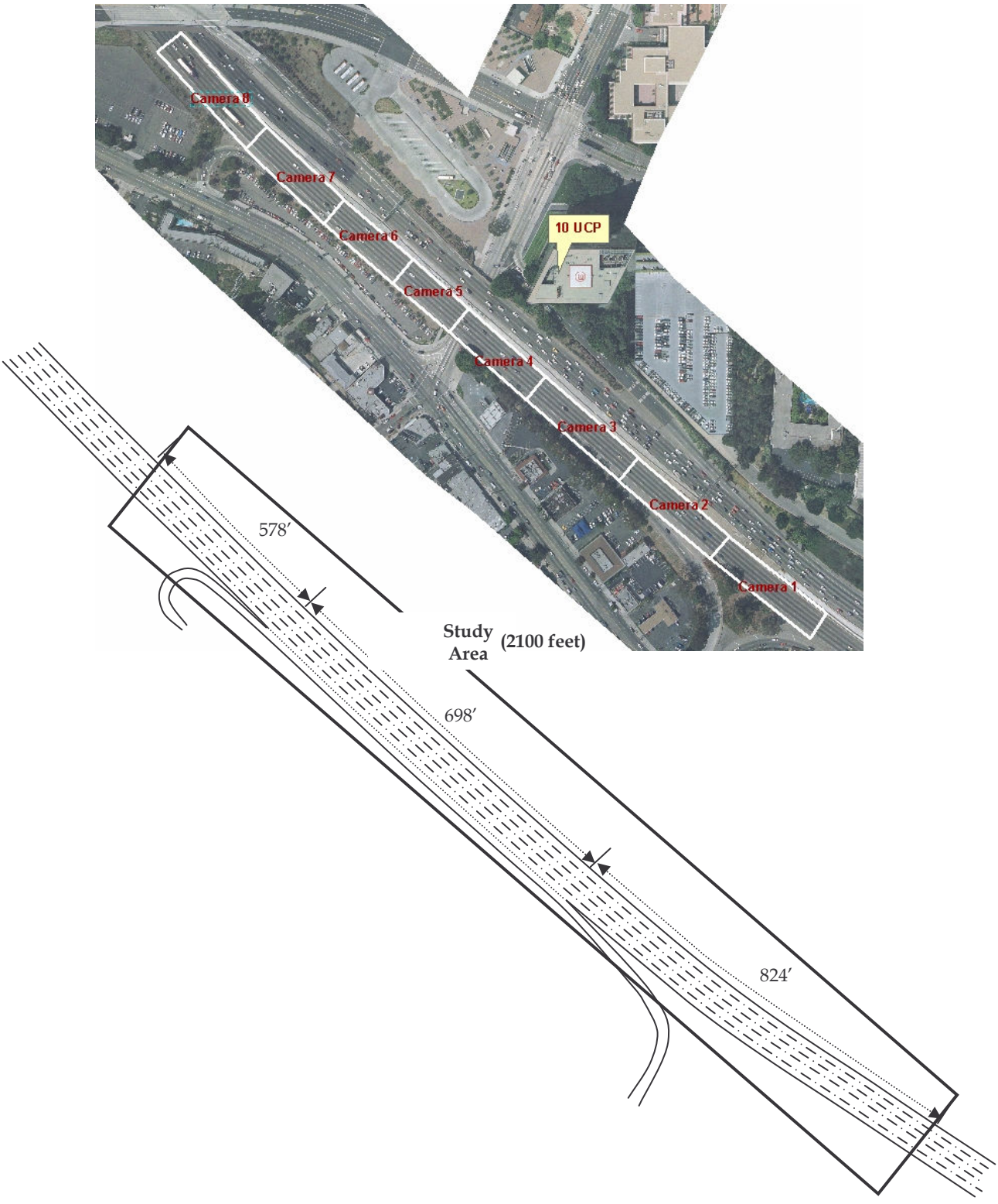
Study Area Description

Data presented in this report represent travel on the southbound direction of U.S. Highway 101 (Hollywood Freeway) in Los Angeles, California. This data was collected using video cameras mounted on a 36-story building, 10 Universal City Plaza, which is located adjacent to the U.S. Highway 101 and Lankershim Boulevard interchange in the Universal City neighborhood.

Figure 1 provides a schematic illustration of the location for the vehicle trajectory dataset. The site was approximately 2,100 feet in length, with five mainline lanes throughout the section. An auxiliary lane is present through a portion of the corridor between the on-ramp at Ventura Boulevard and the off-ramp at Cahuenga Boulevard. Lane numbering is incremented from the left-most lane.

Video data were collected using eight video cameras, cameras 1 through 8, with camera 1 recording the southernmost, and camera 8 recording the northernmost section of the study area, as shown in Figure 1. Digital video images were collected over an approximate nine-hour period from 7:00 a.m. to 12:00 p.m. and from 3:00 p.m. to 7:00 p.m. on June 15, 2005. Complete vehicle trajectories were transcribed at a resolution of 10 frames per second.

Figure 1. Study Area Schematic and Camera Coverage

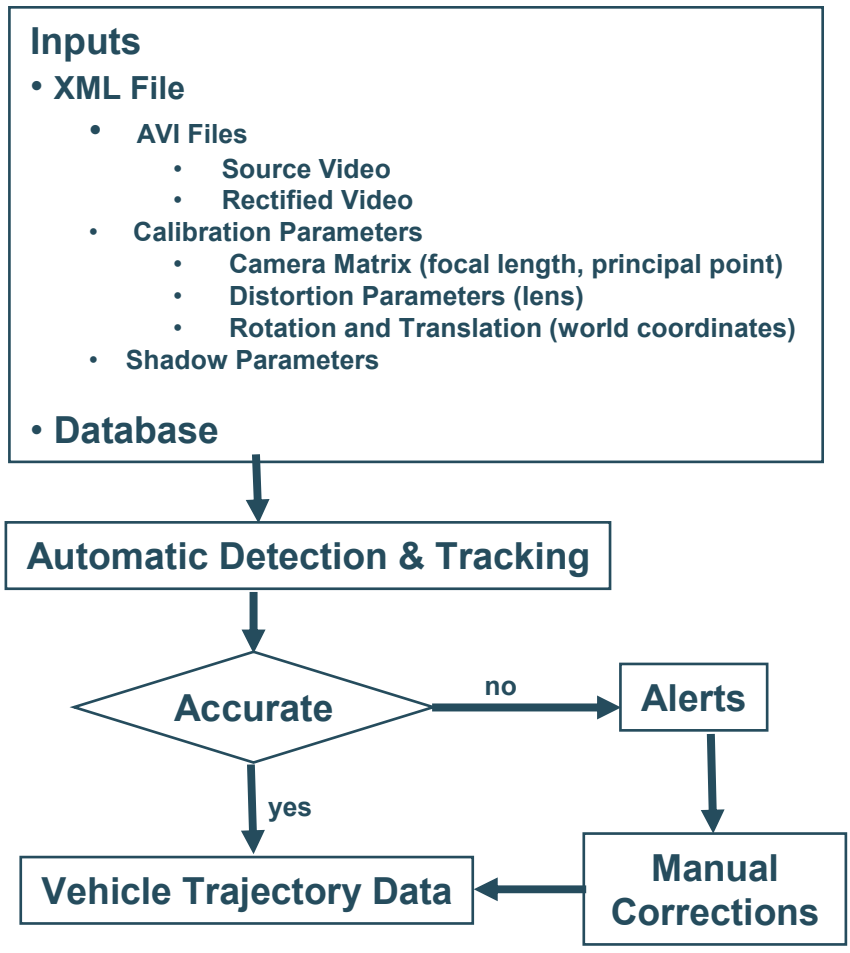


Vehicle Detection and Tracking

Vehicle trajectory data were transcribed from the video data using a customized software application developed for NGSIM. This program automatically detects and tracks most vehicles from video images and transcribes the trajectory data to a database.

The flow process for the vehicle transcription is shown in Figure 2. The software detects vehicles in a user-defined detection zone, which is usually set in the camera that is looking straight down from the building, and then tracks vehicles both upstream and downstream from the point of detection. Hence, vehicle tracking progress was divided into two major parts: a) forward (cameras 5, 4, 3, 2, and 1); and b) reverse (cameras 5, 6, 7, and 8).

Figure 2. Vehicle Detection and Tracking Process



Forward tracking was first performed for the data from 8:05 a.m. to 8:20 a.m. Immediately after 8:20 a.m., vehicle detection was stopped; however, to account for full vehicle trajectories, tracking continued to allow the vehicles which were already detected to be tracked completely to the end of the study area (camera 1). For reverse tracking, vehicle informa-

tion was retrieved from the database generated by the forward tracking. Thus, reverse tracking started from 8:20 a.m. and traced back to 8:05 a.m. Similar as in forward tracking, vehicles which have entered into the tracking system were tracked completely to the beginning of the study area (camera 8). Therefore, for the vehicle trajectory data of 8:05 a.m. to 8:20 a.m., the actual tracking time is from 8:04:02 a.m. to 8:20:43 a.m.

A total of 45 minutes vehicle trajectories are being processed from the video data collected on June 15, 2005. These data represent the periods from 7:50 a.m. to 8:05 a.m. (representing a transitional traffic period in the build up to congestion) and from 8:05 a.m. to 8:35 a.m. (representing primarily congested conditions). The data was divided into three 15-minute periods for processing and analysis.

Subsequent sections of this report provide analysis of the transcribed data. This report provides data analysis for the period from 8:05 a.m. to 8:20 a.m. Separate reports are available providing the same performance statistics for the remaining periods.

Data Analysis

Description

Flows and Time Mean Speed (TMS) are calculated at the midpoint of each study section (stretch of roadway), while Space Mean Speed (SMS) is calculated by dividing the sum of trajectory lengths traversed in a section by all the vehicles by the sum of time taken to transverse these section. Temporal variation of traffic flows during the 15-minute period is shown in Figure 3, while Figure 4 presents the variation in TMS and SMS.

$$TMS(t,s) = \frac{\sum_i v(t,s)_i}{n(t,s)} \qquad SMS(t,s) = \frac{\sum_i d(t,s)_i}{\sum_i tt(t,s)_i}$$

$TMS(t,s)$ – Time Mean Speed in section s during time period t measured at midsection;

$SMS(t,s)$ – Space Mean Speed in section s during time period t;

$v(t,s)_i$ – Instantaneous speed of a vehicle i in section s during time period t measured at midsection;

$n(t,s)$ – Number of vehicles traversing section s during time period t;

$d(t,s)_i$ – Distance traveled by vehicle i in section s during time period t; and

$tt(t,s)_i$ - Travel time of vehicle i in section s during time period t.

Figure 3. Flow by Time Period

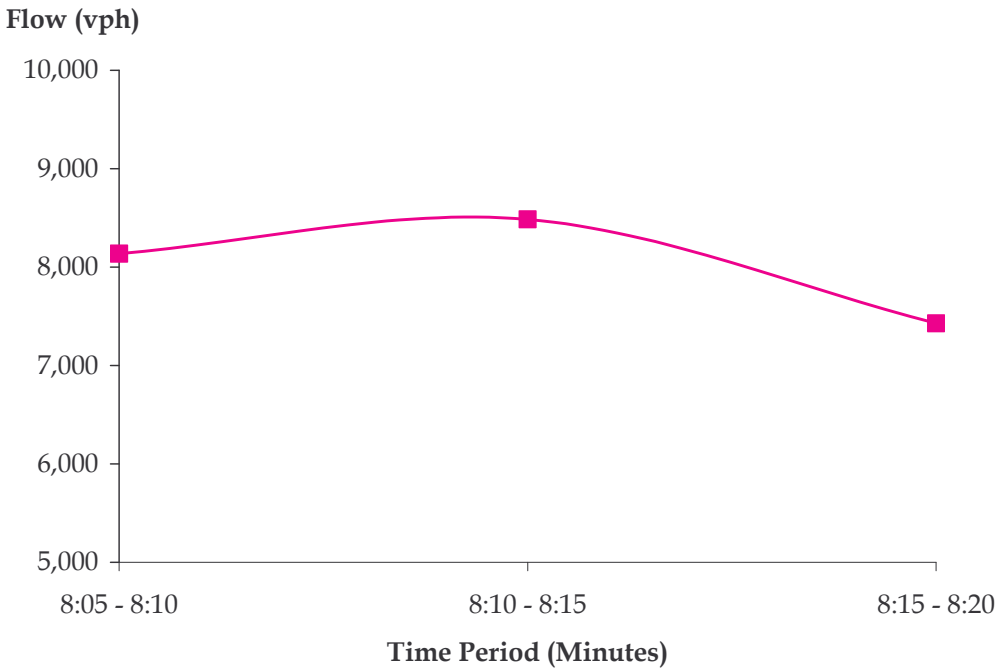
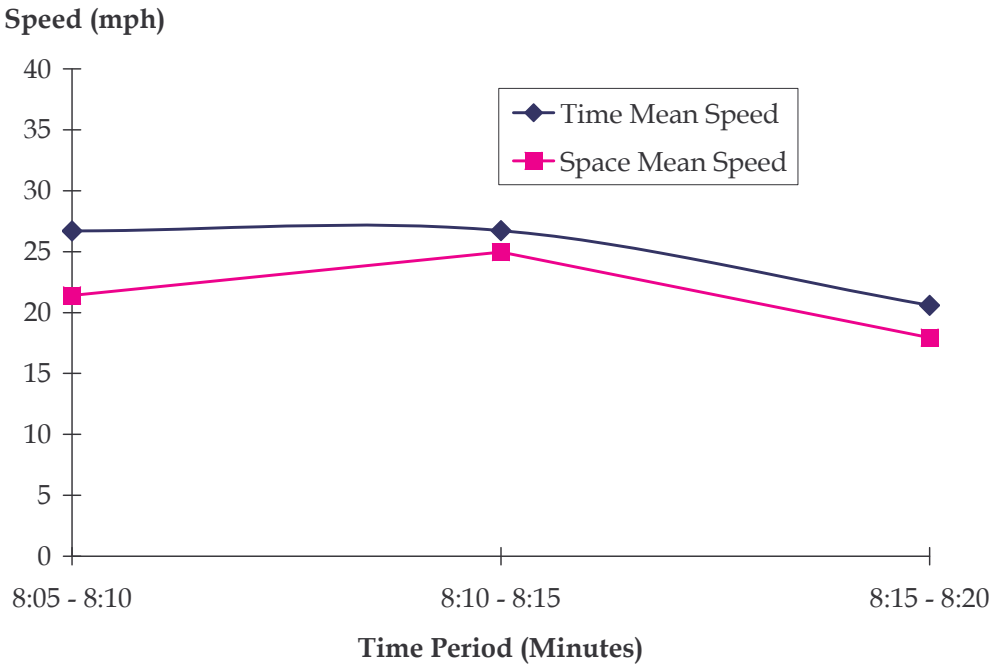


Figure 4. Time Mean Speed and Space Mean Speed by Time Period



Vehicle Type

Vehicles are classified into three categories: (1) motorcycle, (2) automobile, and (3) truck and buses. The distribution of vehicle types is shown in Table 1.

Table 1. Vehicle Type

Vehicle Type	Vehicles	Percentage
Motorcycle	10	0.5%
Automobile	1,963	97.3%
Truck and Buses	44	2.2%
Sum	**2,017**	**100.0%**

Aggregation by Time

Aggregation results by time for flow and speed are provided in Table 2.

Table 2. Aggregate Results Summary for the Entire Section

Time Period	Flow (vph)	Time Mean Speed		Space Mean Speed	
		fps	mph	fps	mph
8:05 a.m. – 8:10 a.m.	8,136	39.16	26.70	31.40	21.41
8:10 a.m. – 8:15 a.m.	8,484	39.21	26.73	36.62	24.97
8:15 a.m. – 8:20 a.m.	7,428	30.21	20.60	26.31	17.94
Average	**8,016**	**36.41**	**24.83**	**31.67**	**21.59**

Aggregation by Lane

Aggregation of flow and speeds were conducted for each lane as shown in Table 3.

Table 3. Aggregate Flow and Speed for Each Lane

Lane	Flow (vph)	Time Mean Speed		Space Mean Speed	
		fps	mph	fps	mph
1	1,474	34.63	23.61	32.03	21.84
2	1,574	34.31	23.39	30.62	20.88
3	1,474	34.80	23.73	30.65	20.90
4	1,518	35.76	24.38	31.08	21.19
5	1,512	37.30	25.43	34.05	23.22
Auxiliary Lane	464	54.00	36.82	50.62	34.51
Average	**8,016**	**36.44**	**24.85**	**32.78**	**22.35**

Figure 5. Flow by Lane

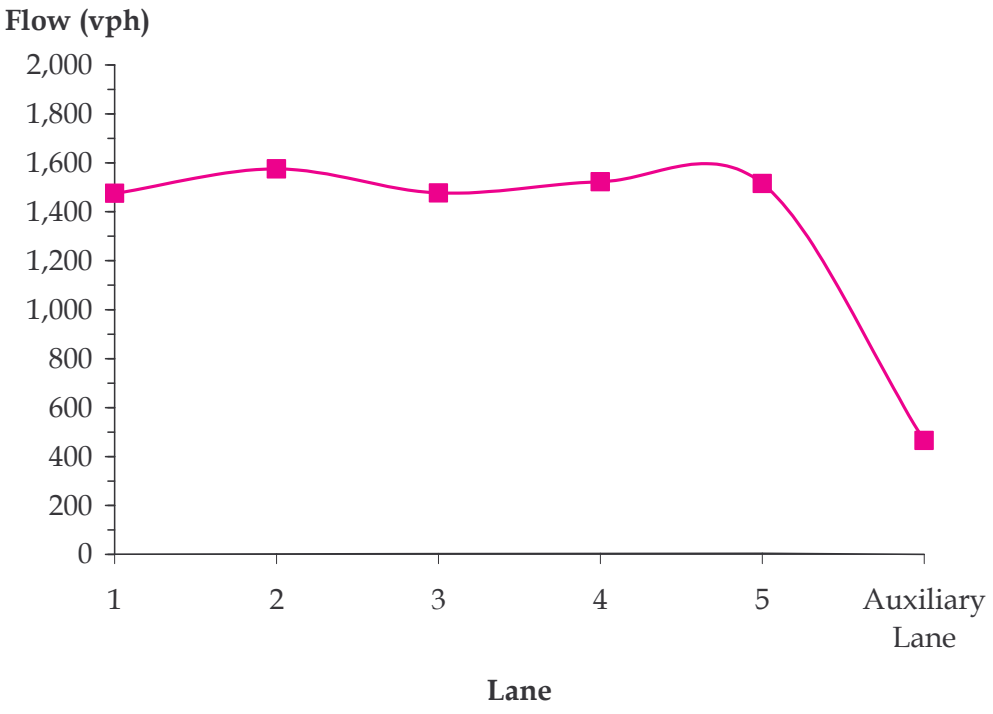
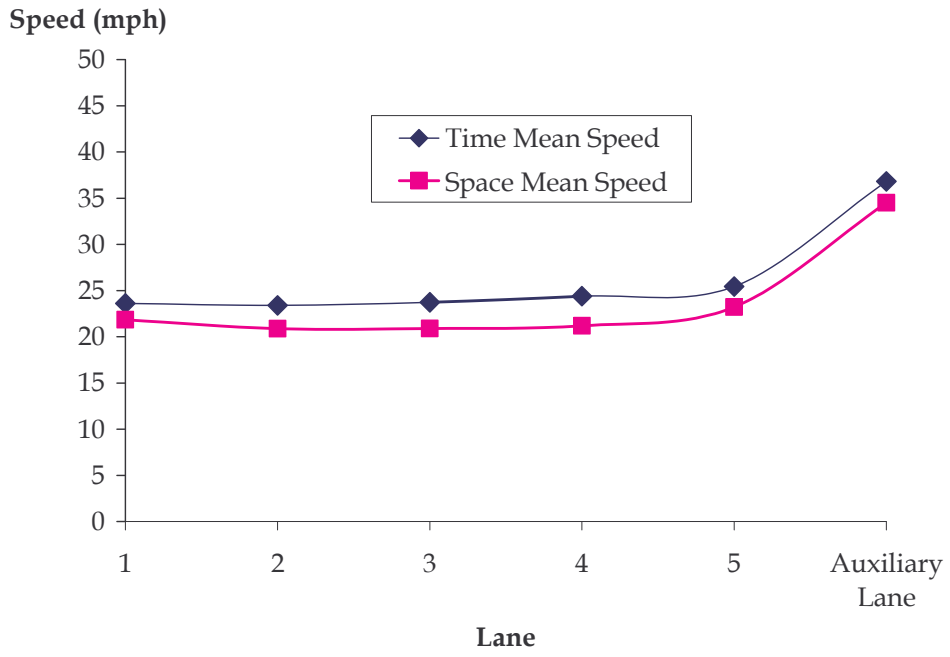


Figure 6. Speed by Lane



Input-Output Analysis

The following section summarizes the input-output analysis conducted on the section as shown in the tables below.

Table 4. Input-Output Analysis

	Time Period (p.m.)						
	8:04:02 – 8:05	8:05 - 8:10	8:10 - 8:15	8:15 - 8:20	8:20 - 8:20:43	Sum	Volume (Vehicles)
On-Ramp Flow (vehicles)	0	45	44	41	0	**130**	
Entering – Freeway Lanes (vehicles)	36	652	652	547	0	**1,887**	**2,017**
Exiting – Freeway Lanes (vehicles)	0	646	721	620	30	**2,017**	**2,017**
Entering Vehicles	36	697	696	588	0		**2,017**
Exiting Vehicles	0	-646	-721	-620	-30		**-2,017**

Table 5. Input-Output Analysis by Lane and Time Period

		Time Period (p.m.)					Sum (Vehicles)
		8:04:02 – 8:05	8:05 - 8:10	8:10 - 8:15	8:15 - 8:20	8:20 - 8:20:43	
Vehicles Entering (Vehicles)	Lane 1	8	123	127	109	0	**367**
	Lane 2	8	132	139	112	0	**391**
	Lane 3	8	130	127	104	0	**369**
	Lane 4	6	134	130	111	0	**381**
	Lane 5	6	133	129	111	0	**379**
	On-Ramp	0	45	44	41	0	**130**
	Sum	**36**	**697**	**696**	**588**	**0**	**2,017**
Vehicles Exiting (Vehicles)	Lane 1	0	115	137	114	6	**372**
	Lane 2	0	123	144	121	4	**392**
	Lane 3	0	122	140	115	5	**382**
	Lane 4	0	129	136	119	6	**390**
	Lane 5	0	121	139	120	7	**387**
	Off-Ramp	0	36	25	31	2	**94**
	Sum	**0**	**646**	**721**	**620**	**30**	**2,017**

Lane Change Analysis

An analysis of lane changes occurring in the study area is provided here as shown in Figures 7 and 8 below.

Figure 7. Lane Change Analysis

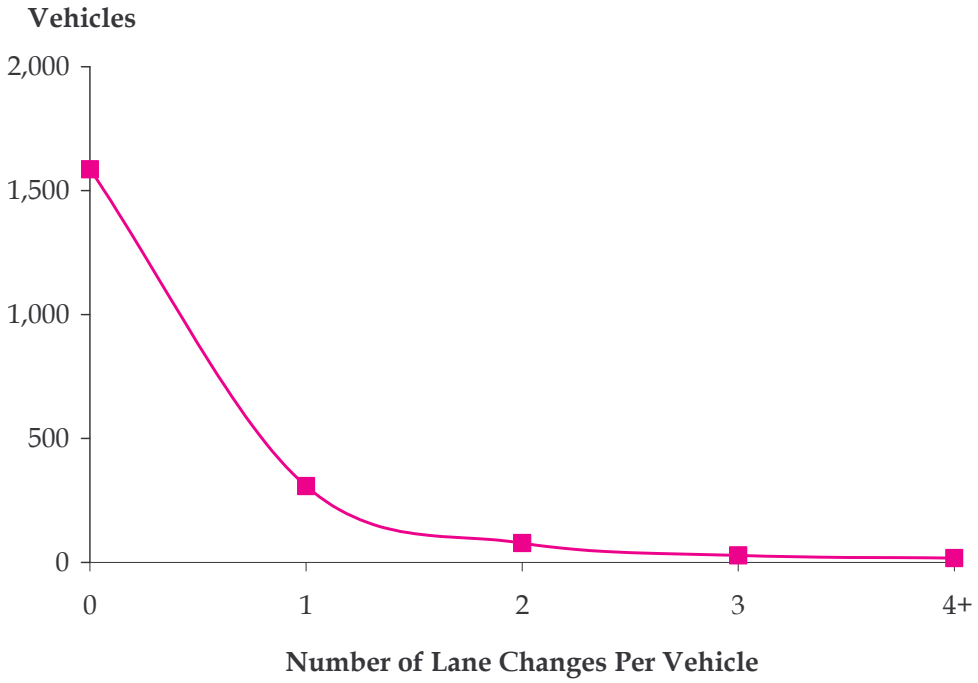
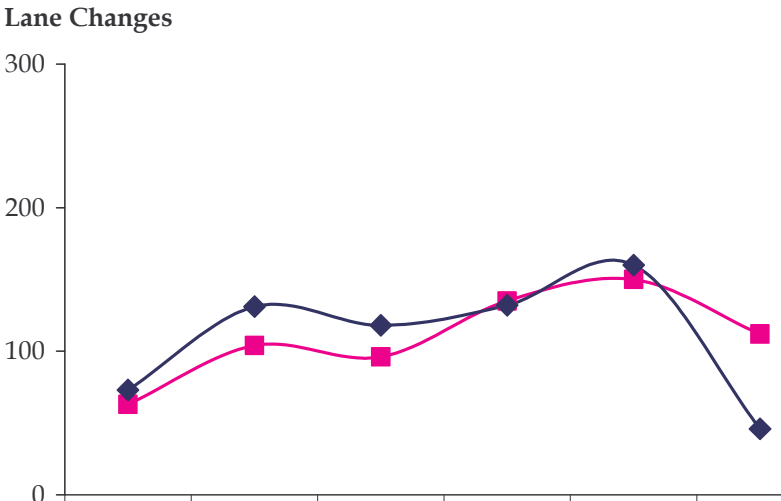


Figure 8. Number of Lane Changes by Lane



Lane	1	2	3	4	5	Auxiliary Lane
Lane Changes From	63	104	96	135	150	112
Lane Changes To	73	131	118	132	160	46

Sectional Analysis

The data collection effort tracked vehicles over a length of 2,100 feet. Data analysis was conducted every 100 feet on the 21 sections (0'-100', 100'-200', … 1,900'-2,000', and >2,000') in the study area and is provided in Table 6. The analysis for each section was conducted at its midpoint.

Table 6. Time Mean Speed and Space Mean Speed by Section

Id	Section	Flow (vph)	TMS		SMS	
			fps	mph	fps	mph
1	0-100'	7,456	30.65	20.90	24.10	16.43
2	100'-200'	7,508	29.16	19.88	24.43	16.66
3	200'-300'	7,508	30.39	20.72	25.21	17.19
4	300'-400'	7,508	31.13	21.23	26.58	18.12
5	400'-500'	7,528	31.39	21.40	26.41	18.01
6	500'-600'	8,016	32.90	22.43	26.51	18.08
7	600'-700'	8,016	34.15	23.28	27.32	18.63
8	700'-800'	8,016	34.61	23.60	27.30	18.61
9	800'-900'	8,016	37.35	25.47	28.53	19.45
10	900'-1,000'	8,016	34.55	23.56	27.30	18.61
11	1,000'-1,100'	8,016	37.57	25.62	29.46	20.09
12	1,100'-1,200'	8,016	37.08	25.28	29.74	20.28
13	1,200'-1,300'	8,016	37.19	25.36	30.41	20.73
14	1,300'-1,400'	8,016	38.49	26.24	31.25	21.31
15	1,400'-1,500'	8,016	39.06	26.63	31.18	21.26
16	1,500'-1,600'	7,754	38.10	25.98	31.53	21.50
17	1,600'-1,700'	7,702	36.99	25.22	31.07	21.18
18	1,700'-1,800'	7,702	37.10	25.30	30.45	20.76
19	1,800'-1,900'	7,702	37.50	25.57	30.89	21.06
20	1,900'-2,000'	7,702	37.40	25.50	31.77	21.66
21	>2,000'	7,702	36.96	25.20	30.23	20.61

Figure 9. Flow by Section

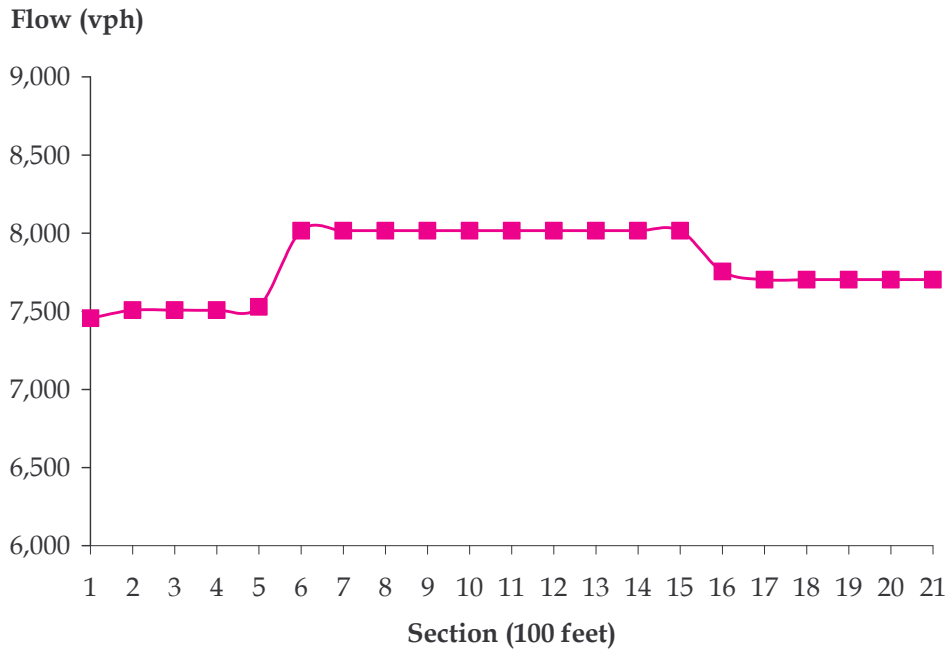
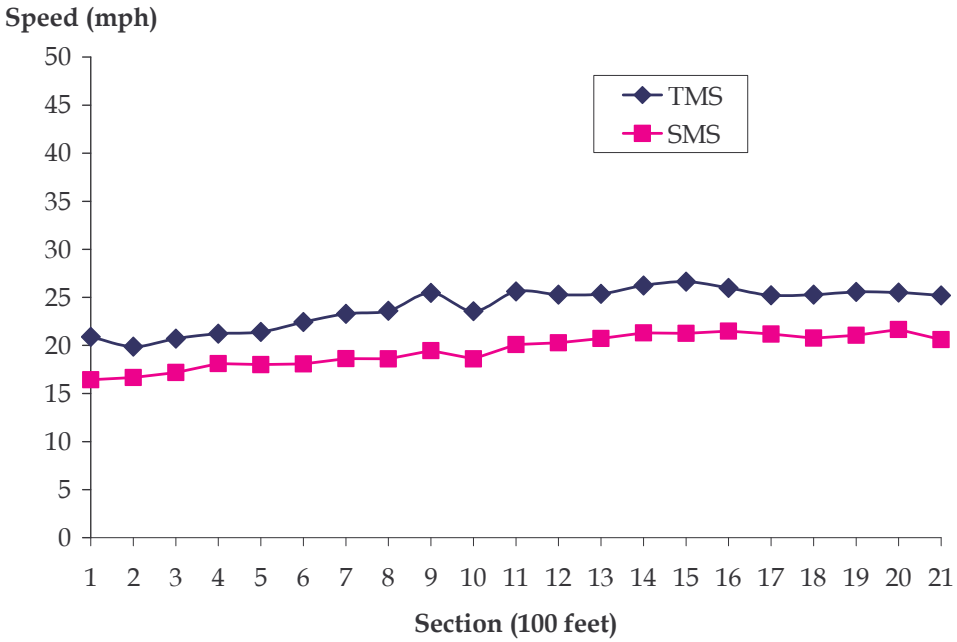


Figure 10. Time Mean Speed and Space Mean Speed by Section



Analysis by Section and Time Period

Additional analysis by 100-foot sections of the study area for each five-minute period is provided below.

Table 7. Time Mean Speed by Section and Time Period (Feet Per Second)

	Time Period (p.m.)			
Section	**8:05 - 8:10**	**8:10 - 8:15**	**8:15 - 8:20**	**Average**
0-100’	30.39	36.27	30.84	**32.50**
100’-200’	31.12	30.87	25.59	**29.19**
200’-300’	32.36	31.77	26.93	**30.35**
300’-400’	32.83	32.76	27.34	**30.98**
400’-500’	32.46	33.43	27.58	**31.16**
500’-600’	34.15	34.74	29.18	**32.69**
600’-700’	36.29	35.49	30.08	**33.95**
700’-800’	36.96	35.99	30.46	**34.47**
800’-900’	39.82	39.25	32.53	**37.20**
900’-1,000’	37.00	37.08	28.92	**34.33**
1,000’-1,100’	40.58	40.48	30.92	**37.33**
1,100’-1,200’	39.86	39.65	31.17	**36.89**
1,200’-1,300’	39.63	40.07	31.33	**37.01**
1,300’-1,400’	40.55	41.58	32.74	**38.29**
1,400’-1,500’	41.33	42.10	33.18	**38.87**
1,500’-1,600’	39.77	41.44	32.48	**37.90**
1,600’-1,700’	38.15	40.60	31.77	**36.84**
1,700’-1,800’	37.67	41.43	31.99	**37.03**
1,800’-1,900’	37.01	42.50	32.67	**37.39**
1,900’-2,000’	36.13	42.82	32.80	**37.25**
>2,000’	34.60	42.32	33.23	**36.72**
Average	**36.60**	**38.22**	**30.65**	**35.16**

Table 8. Space Mean Speed by Section and Time Period (Feet Per Second)

Section	Time Period (p.m.) 8:05 - 8:10	8:10 - 8:15	8:15 - 8:20	Average
0-100’	30.12	26.91	19.67	**25.57**
100’-200’	30.24	26.59	20.08	**25.64**
200’-300’	31.20	26.66	21.19	**26.35**
300’-400’	32.56	29.02	22.10	**27.89**
400’-500’	32.42	29.95	22.29	**28.22**
500’-600’	33.33	31.95	22.57	**29.28**
600’-700’	35.07	34.79	23.29	**31.05**
700’-800’	34.10	35.70	23.11	**30.97**
800’-900’	33.21	38.81	24.24	**32.09**
900’-1,000’	32.04	38.85	21.99	**30.96**
1,000’-1,100’	33.67	40.83	23.72	**32.74**
1,100’-1,200’	33.31	39.94	25.39	**32.88**
1,200’-1,300’	33.87	41.08	26.57	**33.84**
1,300’-1,400’	34.59	42.44	30.03	**35.69**
1,400’-1,500’	33.08	42.11	31.09	**35.43**
1,500’-1,600’	31.26	42.00	32.21	**35.16**
1,600’-1,700’	29.40	41.26	34.17	**34.94**
1,700’-1,800’	27.76	42.48	34.12	**34.79**
1,800’-1,900’	27.08	42.76	34.27	**34.70**
1,900’-2,000’	27.68	42.34	34.84	**34.95**
>2,000’	25.78	39.33	33.33	**32.81**
Average	**31.51**	**36.94**	**26.68**	**31.71**

Table 9. Lane Changes by Section and Time Period

Section	Time Period (p.m.) 8:04:02 – 8:05	8:05 - 8:10	8:10 - 8:15	8:15 - 8:20	8:20 - 8:20:43	Sum
0-100’	1	3	3	2	0	**9**
100’-200’	0	5	3	5	0	**13**
200’-300’	0	7	7	4	0	**18**
300’-400’	0	4	3	5	0	**12**
400’-500’	0	5	7	5	0	**17**
500’-600’	0	8	5	4	0	**17**
600’-700’	0	15	11	11	0	**37**
700’-800’	0	23	32	18	0	**73**
800’-900’	1	17	17	22	0	**57**
900’-1,000’	0	12	15	19	0	**46**
1,000’-1,100’	0	11	12	8	2	**33**
1,100’-1,200’	0	19	16	16	0	**51**
1,200’-1,300’	0	13	13	14	0	**40**
1,300’-1,400’	0	16	15	14	0	**45**
1,400’-1,500’	0	11	10	10	0	**31**
1,500’-1,600’	0	4	5	11	0	**20**
1,600’-1,700’	0	9	6	9	0	**24**
1,700’-1,800’	0	7	11	6	0	**24**
1,800’-1,900’	0	11	8	4	0	**23**
1,900’-2,000’	0	11	6	9	0	**26**
>2,000’	0	22	10	12	0	**44**
Sum	**2**	**233**	**215**	**208**	**2**	**660**

Analysis by Starting Lane

The tables in this section provide number of lane changes by the starting lane of the vehicle. The starting lane of a vehicle is the lane in which the vehicle was first tracked in the northernmost section of the study area.

Table 10. Number of Vehicles by Starting Lane

	Starting Lane						
Time	**1**	**2**	**3**	**4**	**5**	**On-Ramp**	**Sum**
8:04:02 – 8:05	8	8	8	6	6	0	**36**
8:05 - 8:10	123	132	130	134	133	45	**697**
8:10 - 8:15	127	139	127	130	129	44	**696**
8:15 - 8:20	109	112	104	111	111	41	**588**
8:20 - 8:20:43	0	0	0	0	0	0	**0**
Sum	**367**	**391**	**369**	**381**	**379**	**130**	**2,017**

Table 11. Number of Lane Changes by Starting Lane

	Starting Lane						
Time	**1**	**2**	**3**	**4**	**5**	**On-Ramp**	**Sum**
8:04:02 – 8:05	0	0	0	1	1	0	**2**
8:05 - 8:10	30	43	27	38	44	51	**233**
8:10 - 8:15	20	19	32	38	43	63	**215**
8:15 - 8:20	38	21	13	38	32	66	**208**
8:20 - 8:20:43	0	0	0	0	1	1	**2**
Sum	**88**	**83**	**72**	**115**	**121**	**181**	**660**

Table 12. Average Lane Changes by Starting Lane

	Starting Lane						
Time	**1**	**2**	**3**	**4**	**5**	**On-Ramp**	**Sum**
8:04:02 – 8:05	0.00	0.00	0.00	0.17	0.17	0.00	**0.06**
8:05 - 8:10	0.24	0.33	0.21	0.28	0.33	1.13	**0.42**
8:10 - 8:15	0.16	0.14	0.25	0.29	0.33	1.43	**0.43**
8:15 - 8:20	0.35	0.19	0.13	0.34	0.29	1.61	**0.48**
8:20 - 8:20:43	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Sum	**0.24**	**0.21**	**0.20**	**0.30**	**0.32**	**1.39**	**0.33**

* Average lane changes are calculated by dividing the number of lane changes (Table 11) by the number of vehicles (Table 10).

Table 13. End Lane Distribution by Starting Lane (in Vehicles)

	Ending Lane						
Starting Lane	**1**	**2**	**3**	**4**	**5**	**Off-Ramp**	**Total**
1	343	25	2	0	0	1	**371**
2	29	328	21	2	1	1	**382**
3	4	37	303	15	4	0	**363**
4	3	11	41	307	21	4	**387**
5	0	3	8	30	275	71	**387**
On-Ramp	2	5	10	30	78	2	**127**
Total	**381**	**409**	**385**	**384**	**379**	**79**	**2,017**

* End lane is the lane in which the vehicle is last tracked in the southernmost section of the study area.

Table 14. Percent End Lane Distribution by Starting Lane

	Ending Lane						
Starting Lane	**1**	**2**	**3**	**4**	**5**	**Off-Ramp**	**Total**
1	92.45%	6.74%	0.54%	0.00%	0.00%	0.27%	**100%**
2	7.59%	85.86%	5.50%	0.52%	0.26%	0.26%	**100%**
3	1.10%	10.19%	83.47%	4.13%	1.10%	0.00%	**100%**
4	0.78%	2.84%	10.59%	79.33%	5.43%	1.03%	**100%**
5	0.00%	0.78%	2.07%	7.75%	71.06%	18.35%	**100%**
On-Ramp	1.57%	3.94%	7.87%	23.62%	61.42%	1.57%	**100%**

Headway and Gap Analysis

Table 15 provides average headways of the vehicles in the section during the study period. Tables 16 and 17 present the accepted lead and lag gaps by vehicles during lane-changing. The results are presented by lane and for each time period, respectively.

Table 15. Average Headway by Time Period and Lane (in Seconds)

	Lane						
Time Period (Minutes)	**1**	**2**	**3**	**4**	**5**	**Auxiliary Lane**	**Weighted Average**
8:04:02 – 8:05	6.20	2.40	2.27	2.69	3.05	N/A	**3.45**
8:05 - 8:10	3.87	3.74	3.47	2.62	2.65	3.20	**3.31**
8:10 - 8:15	3.04	2.24	2.91	2.53	2.74	3.84	**2.70**
8:15 - 8:20	3.39	3.70	3.67	3.52	3.48	4.36	**3.56**
8:20 - 8:20:43	2.22	2.40	2.29	2.11	1.81	2.04	**2.13**
Weighted Average	**3.46**	**3.26**	**3.35**	**2.91**	**2.99**	**3.78**	**3.20**

Table 16. Average Accepted Lead and Lag Gaps During Lane Changes

From Lane	To Lane	Lead Gap (Feet)	Lag Gap (Feet)
1	2	50.74	35.72
2	1	50.88	43.68
2	3	48.98	54.43
3	2	43.55	58.11
3	4	28.25	53.79
4	3	38.75	57.52
4	5	45.76	74.72
5	4	43.96	63.41
5	Auxiliary Lane	100.79	104.21
Auxiliary Lane	5	50.57	53.20
Weighted Average		**46.64**	**56.58**

Table 17. Average Accepted Lead and Lag Gaps During Lane Changes by Time Period

	Time Period (Minutes)					
	8:04:02 – 8:05	8:05 - 8:10	8:10 - 8:15	8:15 - 8:20	8:20 - 8:20:43	Average
Lead Gap	25.27	49.02	50.65	39.47	N/A	**46.64**
Lag Gap	28.86	63.01	58.47	47.32	N/A	**56.58**