CAMBRIDGE SYSTEMATICS

NGSIM I-80 Data Analysis (5:00 p.m. to 5:15 p.m.)

summary report

prepared for

Federal Highway Administration

prepared by

Cambridge Systematics, Inc.

September 2005

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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 Interstate 80 in Emeryville (San Francisco), California collected between 5:00 p.m. and 5:15 p.m. on April 13, 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 northbound direction of Interstate 80 in Emeryville, California. This data was collected using video cameras mounted on a 30-story building, Pacific Park Plaza, which is located in 6363 Christie Avenue and is adjacent to the interstate freeway I-80. The University of California at Berkeley maintains traffic surveillance capabilities at the building and the segment is known as the Berkeley Highway Laboratory (BHL) site.

Figure 1 provides a schematic illustration of the location for the vehicle trajectory dataset. The site was approximately 1,650 feet in length, with an on-ramp at Powell Street. The off-ramp at Ashby Avenue is just downstream of the study area. Lane numbering is incremented from the left-most lane (the high-occupancy vehicle (HOV) lane).

Video data were collected using seven video cameras, cameras 1 through 7, with camera 1 recording the southernmost, while camera 7 recording the northernmost section of the study area, as shown in Figure 1. Digital video images were collected over an approximate 5-hour period from 2:00 p.m. to 7:00 p.m. on April 13, 2005. Complete vehicle trajectories were transcribed at a resolution of 10 frames per second.

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 4, 5, 6, and 7); and b) reverse (cameras 4, 3, 2, and 1). Forward

Figure 1. Study Area Schematic and Camera Coverage

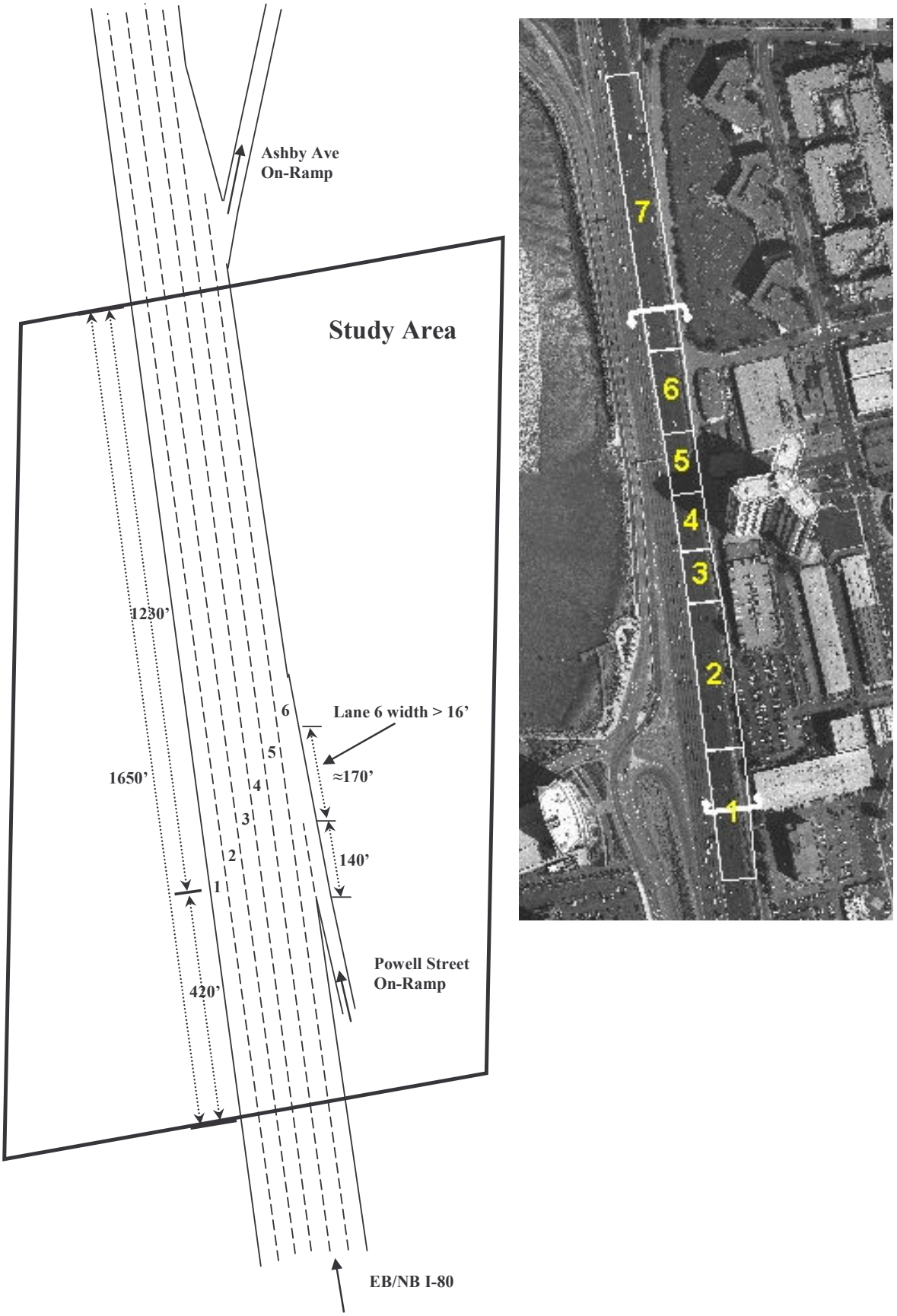
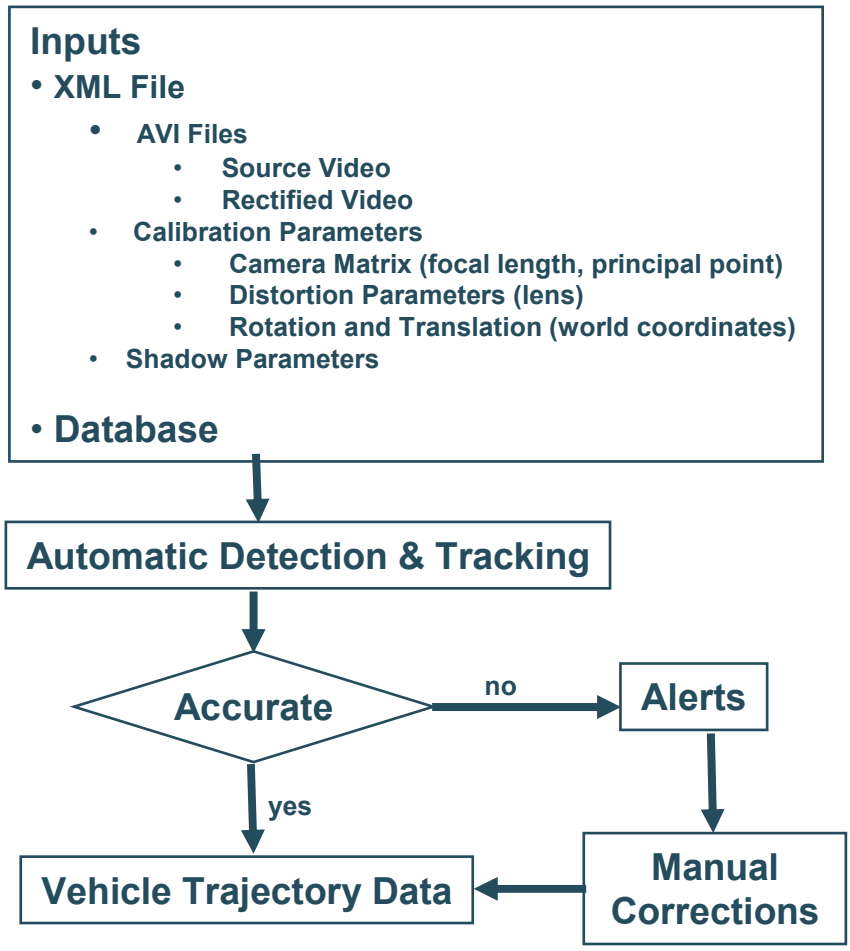


Figure 2. Vehicle Detection and Tracking Process



tracking was first performed for the data from 5:00 p.m. to 5:15 p.m. Immediately after 5:15 p.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 7). For reverse tracking, vehicle information was retrieved from the database generated by the forward tracking. Thus, reverse tracking started from 5:15 p.m. and traced back to 5:00 p.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 1). Therefore, for the vehicle trajectory data of 5:00 p.m. to 5:15 p.m., the actual tracking time is from 4:59:27 p.m. to 5:15:47 p.m.

A total of 45 minutes vehicle trajectories were processed from the video data collected on April 13, 2005. These data represent the periods from 4:00 p.m. to 4:15 p.m. (representing a transitional traffic period in the build up to congestion) and from 5:00 p.m. to 5:30 p.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 5:00 p.m. to 5:15 p.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.

Aggregation by Time

Aggregation results by time for flow and speed are provided in Table 1.

Table 1. Aggregate Results Summary for the Entire Section

Time Period	Flow (vph)	Time Mean Speed		Space Mean Speed	
		fps	mph	fps	mph
5:00 p.m. – 5:05 p.m.	7,488	30.49	20.79	25.06	17.09
5:05 p.m. – 5:10 p.m.	7,608	28.00	19.09	21.16	14.43
5:10 p.m. – 5:15 p.m.	6,276	22.66	15.45	13.77	9.39
Average	**7,124**	**27.30**	**18.62**	**20.36**	**13.88**

Figure 3. Flow by Time Period

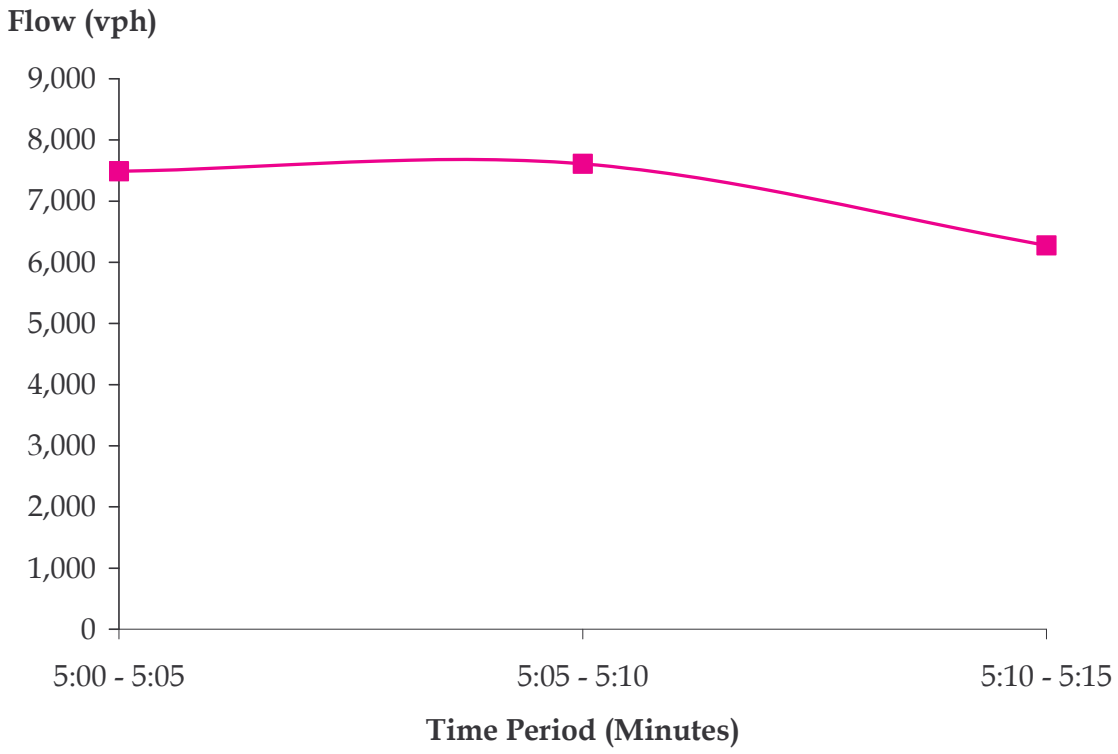
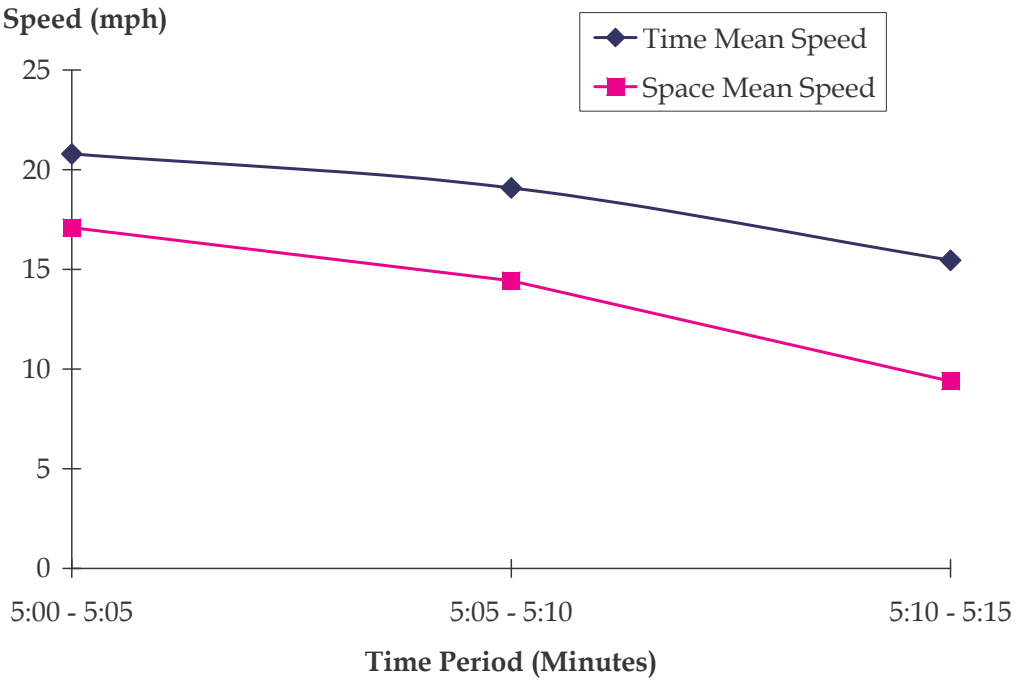


Figure 4. Time Mean Speed and Space Mean Speed by Time Period



Aggregation by Lane

Aggregation of flow and speeds were conducted for each lane as shown in Table 2.

Table 2. Aggregate Flow and Speed for Each Lane

Lane	Flow (vph)	Time Mean Speed		Space Mean Speed	
		fps	mph	fps	mph
1	1,556	47.36	32.29	34.48	23.51
2	1,168	23.75	16.19	16.54	11.28
3	932	19.72	13.45	14.75	10.06
4	1,009	21.29	14.52	15.44	10.53
5	1,055	22.36	15.25	16.49	11.24
6	1,405	21.95	14.97	15.85	10.81
Average	**7,124**	**27.47**	**18.73**	**19.92**	**13.58**

Figure 5. Flow by Lane

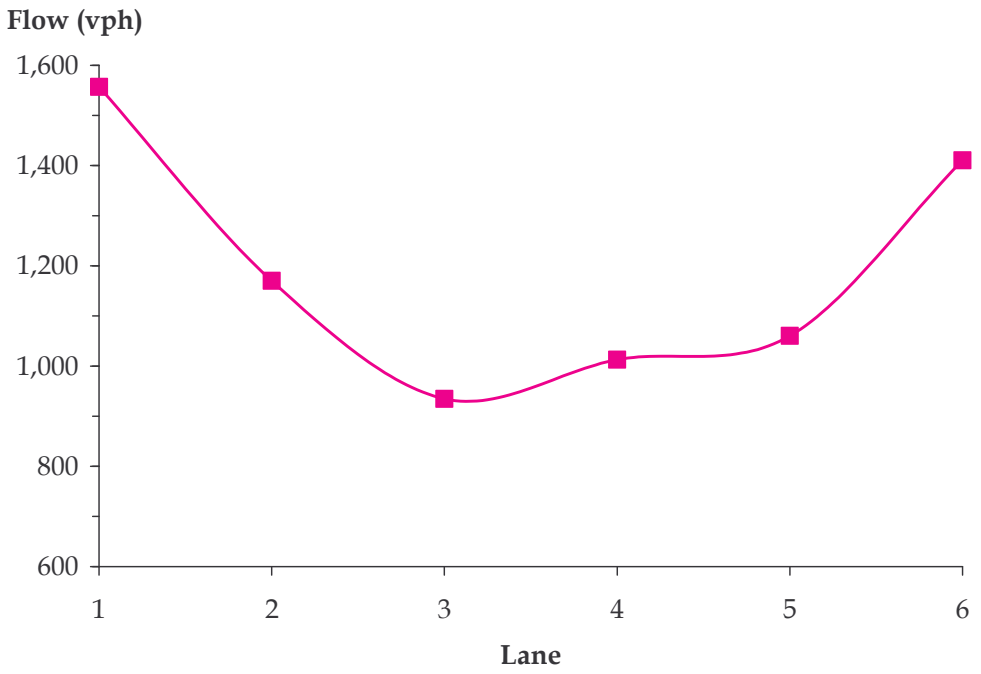
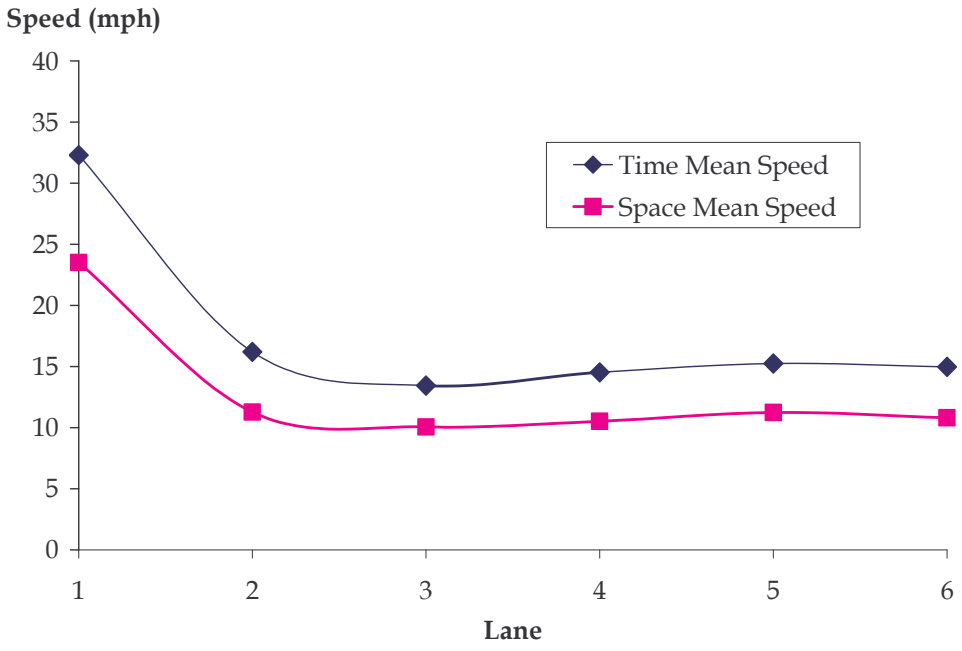


Figure 6. Speed by Lane



Input-Output Analysis

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

Table 3. Input-Output Analysis

	Time Period (p.m.)						
	4:59:27 – 5:00	5:00 – 5:05	5:05 – 5:10	5:10 – 5:15	5:15 – 5:15:47	Sum	Volume (Vehicles)
On-Ramp Flow (vehicles)	0	81	71	53	0	**205**	**1,836**
Entering – Freeway Lanes (vehicles)	47	617	577	390	0	**1,631**	
Exiting – Freeway Lanes (vehicles)	0	614	644	508	70	**1,836**	**1,836**
Entering Vehicles	47	698	648	443	0		**1,836**
Exiting Vehicles	0	-614	-644	-508	-70		**-1,836**

Table 4. Input-Output Analysis by Lane and Time Period

		Time Period (p.m.)					
		4:59:27 – 5:00	5:00 – 5:05	5:05 – 5:10	5:10 – 5:15	5:15 – 5:15:47	Sum (Vehicles)
Vehicles Entering (Vehicles)	Lane 1	6	121	139	122	0	**388**
	Lane 2	9	112	104	69	0	**294**
	Lane 3	9	96	81	48	0	**234**
	Lane 4	8	99	93	51	0	**251**
	Lane 5	8	104	88	51	0	**251**
	Lane 6	7	85	72	49	0	**213**
	On-Ramp	0	81	71	53	0	**205**
	Sum	**47**	**698**	**648**	**443**	**0**	**1,836**
Vehicles Exiting (Vehicles)	Lane 1	0	122	142	132	9	**405**
	Lane 2	0	108	118	78	16	**320**
	Lane 3	0	91	92	65	11	**259**
	Lane 4	0	89	101	63	15	**268**
	Lane 5	0	98	79	62	9	**248**
	Lane 6	0	106	112	108	10	**336**
	Sum	**0**	**614**	**644**	**508**	**70**	**1,836**

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

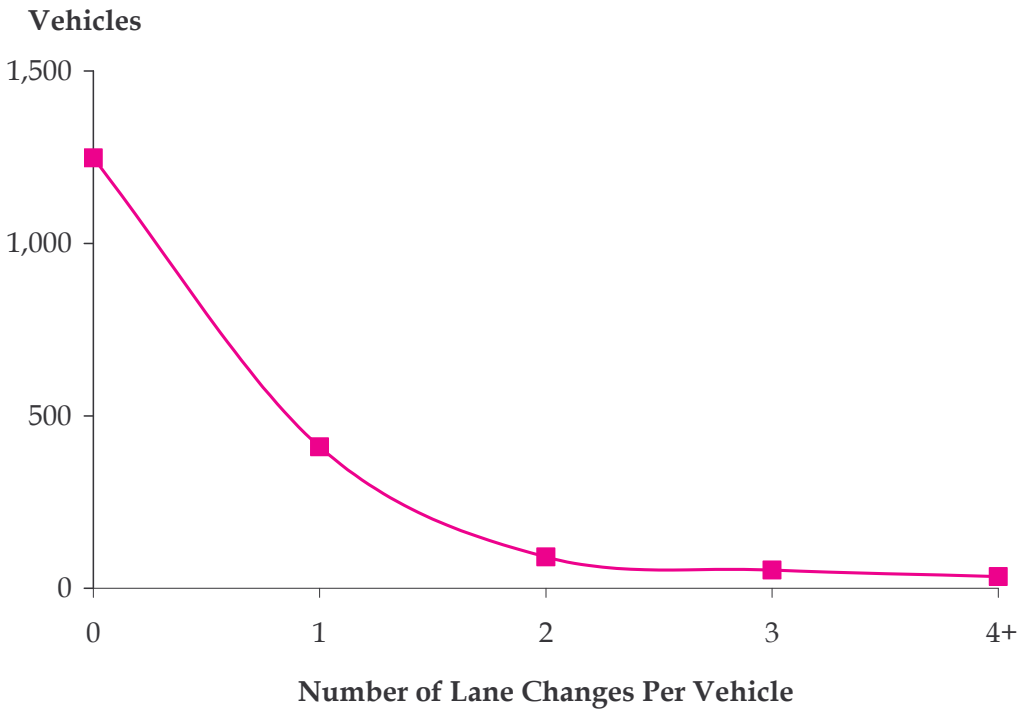
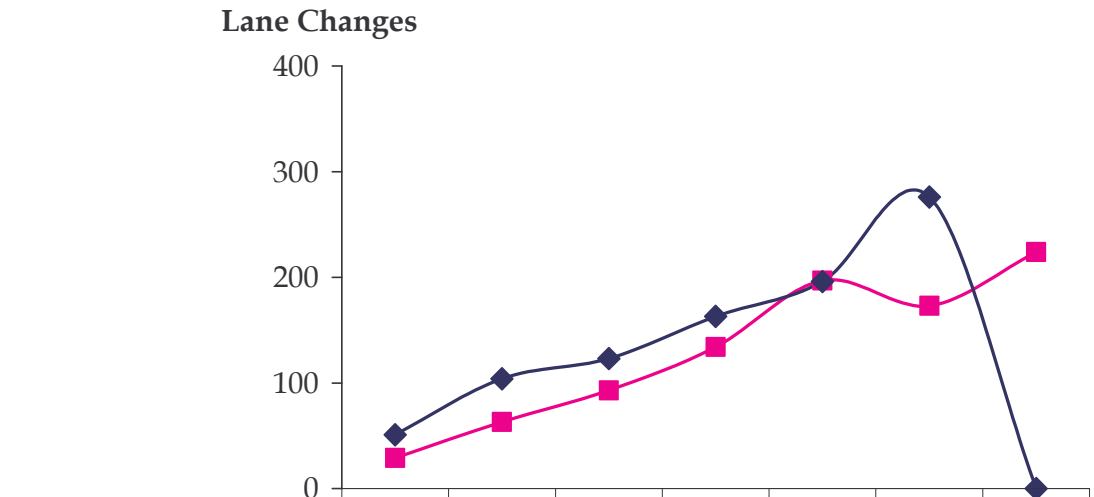


Figure 8. Number of Lane Changes by Lane



Lane	1	2	3	4	5	6	Powell On
Lane Changes From	29	63	93	134	197	173	224
Lane Changes To	51	104	123	163	196	276	0

Sectional Analysis

The data collection effort tracked vehicles over a length of 1,650 feet. Data analysis was conducted every 100 feet on the 17 sections (0'-100', 100'-200', … 1,500'-1,600', and >1,600') in the study area is provided in Table 5. The analysis for each section was conducted at its midpoint.

Table 5. Time Mean Speed and Space Mean Speed by Section

Id	Section	Flow (vph)	TMS		SMS	
			fps	mph	fps	mph
1	0-100’	6,247	24.11	16.44	19.43	13.25
2	100’-200’	6,325	28.66	19.54	19.59	13.36
3	200’-300’	6,360	29.33	20.00	19.36	13.20
4	300’-400’	7,124	25.74	17.55	17.50	11.93
5	400’-500’	7,124	24.86	16.95	16.70	11.39
6	500’-600’	7,124	23.95	16.33	16.30	11.11
7	600’-700’	7,124	24.84	16.94	17.23	11.75
8	700’-800’	7,124	25.94	17.69	18.39	12.54
9	800’-900’	7,124	27.46	18.72	18.84	12.85
10	900’-1,000’	7,124	26.45	18.03	18.24	12.44
11	1,000’-1,100’	7,124	28.07	19.14	19.15	13.06
12	1,100’-1,200’	7,124	28.12	19.17	18.94	12.91
13	1,200’-1,300’	7,124	29.64	20.21	19.97	13.62
14	1,300’-1,400’	7,124	28.51	19.44	19.19	13.08
15	1,400’-1,500’	7,124	28.30	19.30	19.28	13.15
16	1,500’-1,600’	7,124	30.14	20.55	20.15	13.74
17	>1,600’	7,124	27.45	18.72	18.98	12.94

Figure 9. Flow by Section

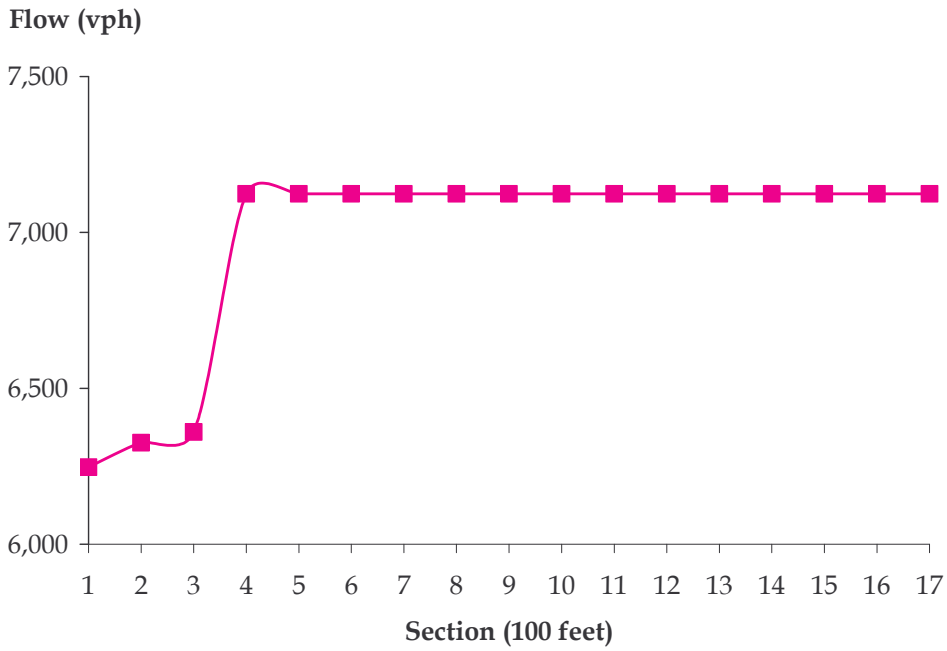
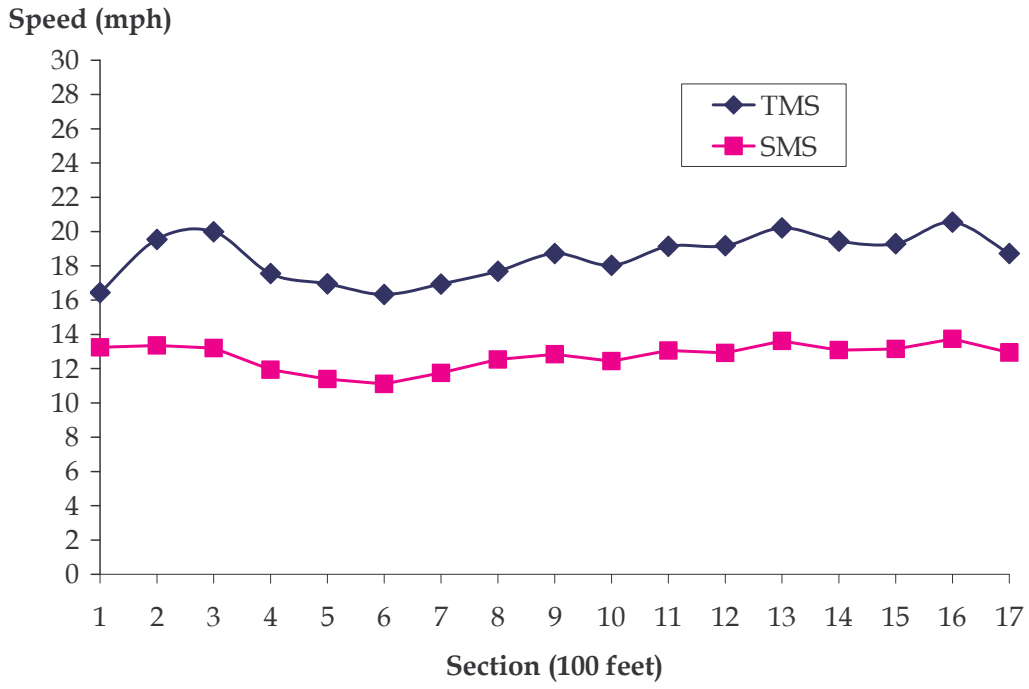


Figure 10. Time Mean Speed and Space Mean Speed by Section



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 6. Time Mean Speed by Section and Time Period
Feet Per Second

	Time Period (p.m.)			
Section	**5:00 – 5:05**	**5:05 – 5:10**	**5:10 – 5:15**	**Average**
0-100’	28.19	23.88	20.54	**24.20**
100’-200’	33.76	25.77	23.29	**27.61**
200’-300’	34.79	26.85	23.19	**28.28**
300’-400’	30.36	24.29	19.65	**24.77**
400’-500’	28.93	23.57	19.53	**24.01**
500’-600’	27.10	23.32	19.36	**23.26**
600’-700’	28.03	24.83	19.66	**24.17**
700’-800’	29.37	26.39	20.40	**25.39**
800’-900’	30.49	28.00	22.66	**27.05**
900’-1,000’	29.20	27.17	21.92	**26.10**
1,000’-1,100’	30.62	28.78	24.05	**27.82**
1,100’-1,200’	30.96	28.69	24.00	**27.88**
1,200’-1,300’	32.78	30.28	25.38	**29.48**
1,300’-1,400’	31.61	29.08	24.64	**28.44**
1,400’-1,500’	31.46	29.08	24.02	**28.19**
1,500’-1,600’	32.27	32.23	25.26	**29.92**
>1,600’	29.58	29.38	22.81	**27.26**
Average	**30.56**	**27.15**	**22.37**	**26.70**

Table 7. Space Mean Speed by Section and Time Period

Feet Per Second

Section	Time Period (p.m.)			Average
	5:00 – 5:05	5:05 – 5:10	5:10 – 5:15	
0-100’	29.80	19.40	15.07	**21.42**
100’-200’	29.68	19.48	15.40	**21.52**
200’-300’	28.03	19.83	14.68	**20.85**
300’-400’	24.87	18.59	10.98	**18.15**
400’-500’	22.79	17.23	9.96	**16.66**
500’-600’	21.11	17.32	9.71	**16.05**
600’-700’	22.68	19.26	10.24	**17.39**
700’-800’	25.31	21.86	11.38	**19.52**
800’-900’	25.84	22.78	12.23	**20.28**
900’-1,000’	25.01	21.56	13.12	**19.90**
1,000’-1,100’	25.82	22.78	15.02	**21.21**
1,100’-1,200’	24.75	22.14	16.23	**21.04**
1,200’-1,300’	26.24	23.18	18.48	**22.63**
1,300’-1,400’	25.41	22.56	18.01	**21.99**
1,400’-1,500’	24.83	23.57	18.40	**22.27**
1,500’-1,600’	23.77	25.63	19.31	**22.90**
>1,600’	22.03	24.11	17.73	**21.29**
Average	**25.17**	**21.25**	**14.47**	**20.30**

Table 8. Lane Changes by Section and Time Period

	Time Period (p.m.)					
Section	**4:59:27 – 5:00**	**5:00 – 5:05**	**5:05 – 5:10**	**5:10 – 5:15**	**5:15 – 5:15:47**	**Sum**
0-100’	0	5	7	1	0	**13**
100’-200’	3	23	26	9	0	**61**
200’-300’	0	23	16	7	0	**46**
300’-400’	0	25	19	10	0	**54**
400’-500’	1	24	19	14	0	**58**
500’-600’	0	28	23	14	0	**65**
600’-700’	0	91	78	67	0	**236**
700’-800’	1	14	16	8	0	**39**
800’-900’	0	19	29	27	0	**75**
900’-1,000’	0	10	12	9	0	**31**
1,000’-1,100’	0	14	22	19	0	**55**
1,100’-1,200’	0	19	15	8	0	**42**
1,200’-1,300’	0	8	9	9	0	**26**
1,300’-1,400’	0	13	17	6	2	**38**
1,400’-1,500’	0	9	10	5	0	**24**
1,500’-1,600’	0	7	11	10	1	**29**
>1,600’	0	6	7	7	1	**21**
Sum	**5**	**338**	**336**	**230**	**4**	**913**

*On-ramp merge traffic starts here.

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 southernmost section of the study area.

Table 9. Number of Vehicles by Starting Lane

	Starting Lane							
Time	**1**	**2**	**3**	**4**	**5**	**6**	**Powell On**	**Sum**
4:59:27 – 5:00	6	9	9	8	8	7	0	**47**
5:00 – 5:05	121	112	96	99	104	85	81	**698**
5:05 – 5:10	139	104	81	93	88	72	71	**648**
5:10 – 5:15	122	69	48	51	51	49	53	**443**
5:15 – 5:15:47	0	0	0	0	0	0	0	**0**
Sum	**388**	**294**	**234**	**251**	**251**	**213**	**205**	**1,836**

Table 10. Number of Lane Changes by Starting Lane

	Starting Lane							
Time	**1**	**2**	**3**	**4**	**5**	**6**	**Powell On**	**Sum**
4:59:27 – 5:00	0	0	1	2	0	2	0	**5**
5:00 – 5:05	27	10	31	40	58	44	128	**338**
5:05 – 5:10	7	20	28	40	50	47	144	**336**
5:10 – 5:15	7	4	22	24	39	35	99	**230**
5:15 – 5:15:47	0	0	0	2	1	0	1	**4**
Sum	**41**	**34**	**82**	**108**	**148**	**128**	**372**	**913**

Table 11. Average Lane Changes by Starting Lane

	Starting Lane							
Time	**1**	**2**	**3**	**4**	**5**	**6**	**Powell On**	**Average**
4:59:27 – 5:00	0.00	0.00	0.11	0.25	0.00	0.29	0.00	**0.09**
5:00 – 5:05	0.22	0.09	0.32	0.40	0.56	0.52	1.58	**0.53**
5:05 – 5:10	0.05	0.19	0.35	0.43	0.57	0.65	2.03	**0.61**
5:10 – 5:15	0.06	0.06	0.46	0.47	0.76	0.71	1.87	**0.63**
5:15 – 5:15:47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Average	**0.11**	**0.12**	**0.35**	**0.43**	**0.59**	**0.60**	**1.81**	**0.50**

* Average lane changes are calculated by dividing the number of lane changes (Table 10) by the number of vehicles (Table 9).

Table 12. End Lane Distribution by Starting Lane (in Vehicles)

Starting Lane	Ending Lane						
	1	**2**	**3**	**4**	**5**	**6**	**Total**
1	375	8	0	1	0	0	**384**
2	13	261	5	1	0	0	**280**
3	11	32	179	6	0	4	**232**
4	3	11	57	162	2	5	**240**
5	1	6	10	62	141	26	**246**
6	1	0	3	13	68	163	**248**
Powell On	2	3	8	24	34	135	**206**
Total	**406**	**321**	**262**	**269**	**245**	**333**	**1,836**

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

Table 13. Percent End Lane Distribution by Starting Lane

	Ending Lane						
Starting Lane	**1**	**2**	**3**	**4**	**5**	**6**	**Total**
1	97.66%	2.08%	0.00%	0.26%	0.00%	0.00%	**100%**
2	4.64%	93.21%	1.79%	0.36%	0.00%	0.00%	**100%**
3	4.74%	13.79%	77.16%	2.59%	0.00%	1.72%	**100%**
4	1.25%	4.58%	23.75%	67.50%	0.83%	2.08%	**100%**
5	0.41%	2.44%	4.07%	25.20%	57.32%	10.57%	**100%**
6	0.40%	0.00%	1.21%	5.24%	27.42%	65.73%	**100%**
Powell On	0.97%	1.46%	3.88%	11.65%	16.50%	65.53%	**100%**

Headway and Gap Analysis

Table 14 provides average headways of the vehicles in the section during the study period. Tables 15 and 16 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 14. Average Headway by Time Period and Lane (in Seconds)

Time Period (Minutes)	Lane						**Weighted Average**
	1	**2**	**3**	**4**	**5**	**6**	
4:59:27 – 5:00	2.54	2.34	2.34	2.53	2.76	2.67	**2.49**
5:00 – 5:05	2.39	3.05	3.82	5.15	3.09	3.49	**3.60**
5:05 – 5:10	2.13	3.73	3.93	4.15	4.03	3.76	**3.75**
5:10 – 5:15	2.30	7.41	6.45	10.09	8.04	4.75	**6.96**
5:15 – 5:15:47	1.87	3.96	3.73	2.88	3.32	2.45	**3.29**
Weighted Average	**2.27**	**4.83**	**4.73**	**6.60**	**5.41**	**4.03**	**4.87**

Table 15. Average Accepted Lead and Lag Gaps During Lane Changes

From Lane	To Lane	Lead Gap (feet)	Lag Gap (feet)
1	2	32.21	19.34
2	1	31.86	70.29
2	3	43.09	31.45
3	2	23.14	34.27
3	4	26.65	37.00
4	3	30.05	44.11
4	5	32.26	44.77
5	4	26.94	33.79
5	6	30.78	39.81
6	5	31.36	42.67
Powell On	6	14.70	21.30
Weighted Average		**25.84**	**35.93**

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

	Time Period (Minutes)					
	4:59:27 – 5:00	5:00 – 5:05	5:05 – 5:10	5:10 – 5:15	5:15 – 5:15:47	Average
Lead Gap (feet)	34.19	34.57	24.40	16.55	15.13	**25.84**
Lag Gap (feet)	29.14	44.57	33.40	27.14	21.88	**35.93**