Characteristics of Freeway Bottlenecks Operating at Capacity

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1 Introduction

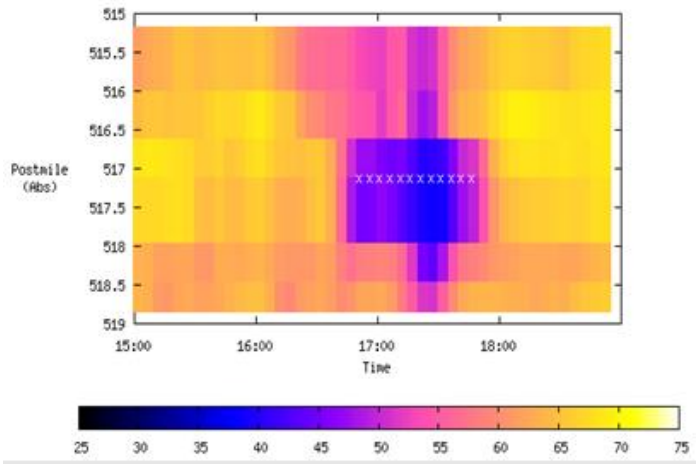
A freeway bottleneck is a point on space, active for a specific period of time, having congested flow on its upstream and free flow on its downstream [1]. Many researchers [2] and [3] have used oblique cumulative flow occupancy plots which are very effective tools for diagnosis of freeway bottlenecks. These plots detect active bottleneck at a given location when there is a simultaneous decrease in oblique flow and increase in oblique occupancy for a given duration. In the present study, two recurrent freeway bottlenecks in California were analyzed using oblique plots for studying their characteristics.

2 Data Collection

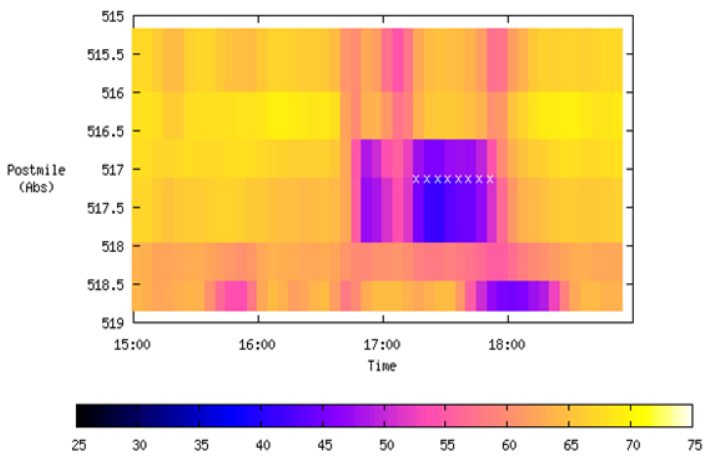
The Performance Measurement System (PeMS) of Caltrans declares a location between two detectors as an active bottleneck if the speed at the upstream detector is less than 40 mph and this speed is at least 20 mph lesser than at the speed at the detector immediately downstream sustained over periods more than 5-minutes [4]. In the present study, two locations on freeways diagnosed as bottlenecks by the PeMS were chosen. Flow and occupancy data aggregated at 30-sec for the nearest detector/s in the upstream and the downstream of the bottleneck were collected from the PeMS. Additionally, average speeds of vehicles at these locations aggregated at 5-min intervals were also collected. The spatial plots(speed contours) that helped identifying the bottlenecks for two days viz. February 2nd and 16th on State Route 99 Southbound

(SR-99 S) and February 15th and 16th, 2012 on Interstate 5 S (I-5 S) are shown in Figure 1. The detector and bottleneck details at both these locations are given in Tables 1 and 2.

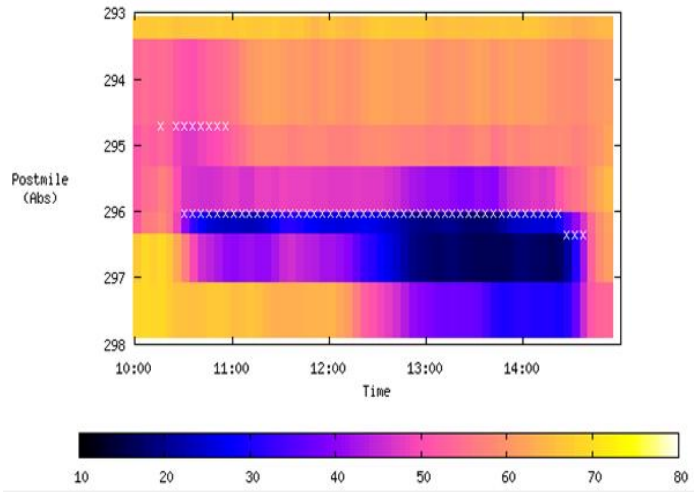
Figure 1. Spatial Plots (speed contours) showing Presence of Bottlenecks (Source: Caltrans PeMS)



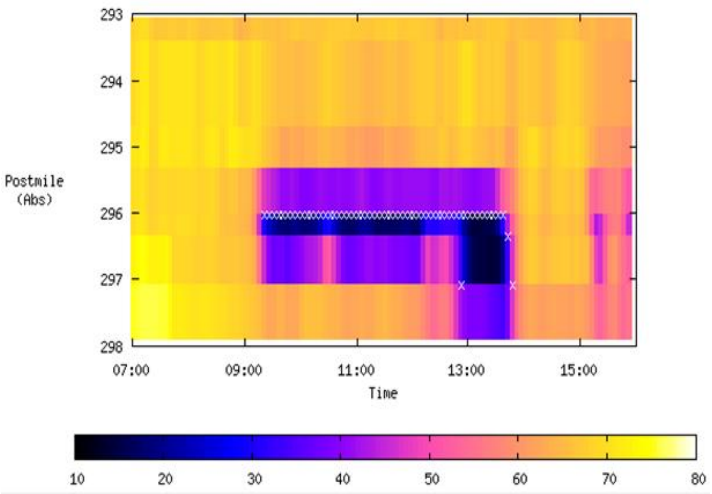
a) Vallejo Way, I-5 S, Feb 15th 2012



b) Vallejo Way, I-5 S, Feb 16th 2012



c) Fruit ridge Road, SR-99 S, Feb 2nd 2012



d) Fruit ridge Road , SR-99 S, Feb 16th 2012

Table 1 Details of Freeways Chosen for Analysis (Source: Caltrans PeMS)

Freeway	Detector	Location	Post Mile	# Lanes
SR-99 S	Fruit ridge Rd.	Upstream	296.31	3
	Martin L. King Jr	Upstream	295.98	3
	EB 47th Ave	Downstream	295.31	3
	Turn bridge Dr.	Downstream	294.67	3
	Oranage Ave	Downstream	293.39	3
I-5 S	Vallejo Way	Upstream	517.09	5
	10th Avenue	Downstream	516.59	4
	Sutterville Road	Downstream	515.98	4
	25th Avenue	Downstream	515.17	4

Table 2 Bottleneck Features on Freeways SR-99 S and I-5 S (Source: Caltrans PeMS)

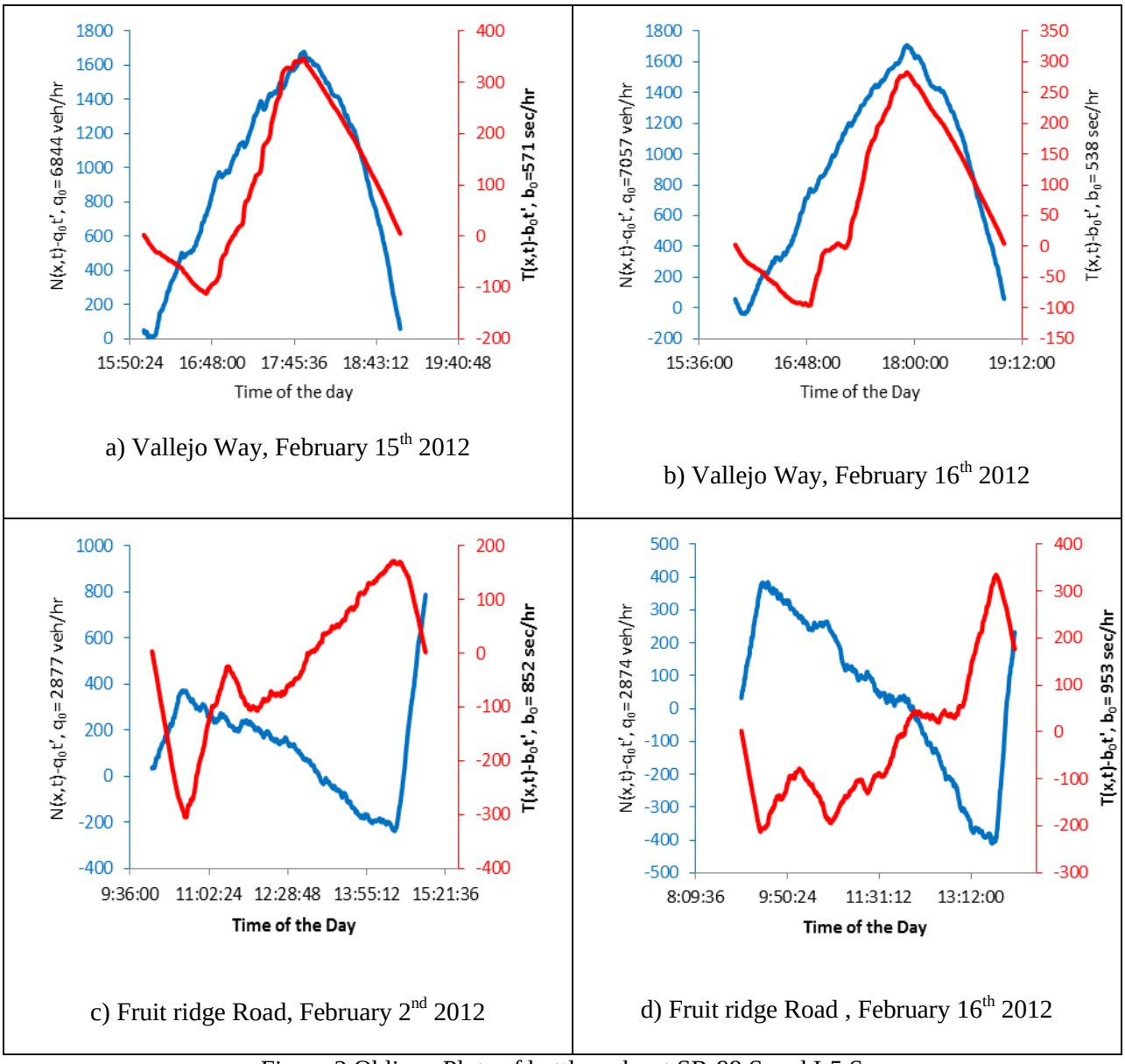
VDS	Name	Freeway	Days Active	Average Extent (Miles)	Average Duration (minutes)	Analysis Hours	Dates
318036	Martin Lr King Jr	SR 99-S	3	1.0	176.6	09:00 to 15:00	November 2011, February 2012
314843	Vallejo Way	I5-S	6	0.7	48.9	16:00 to 19:00	February 2012

3 Methodology and Discussion

Oblique cumulative flow occupancy plots for a few upstream and downstream detectors were drawn for three and six days for the bottlenecks on SR-99 S and I-5 S respectively. The sample plots for two of the days for both locations are given in Figure 2 (a, b, c and d). For all the three days analyzed, the oblique plots could detect the bottleneck at Martin Lr King Jr on SR-99 S, conforming to the PeMS spatial plots. This can be seen from Figure 2c and 2d when the occupancy and flow have an inverse relation from 10:30 to 14:30 hours on the 2nd February and 09:10 to 13:25 hours on the 16th February, 2012. But for the other bottleneck at Vallejo Way on the freeway I-5 S, the oblique plots (Figures 2a and 2b) for all the six days analyzed did not reveal the presence of any bottleneck. On the contrary, bottlenecks were evident from 16:45 to 17:50 hours on the 15th of February and 17:20 to 17:50 hours on the 16th of February, 2012 at Vallejo Way according to PeMS.

As the oblique cumulative flow occupancy curves are proportional to the flows and occupancies at the measurement location [5], flow versus occupancy relationship were plotted using the 30-sec data (Figure 3(a, b, c and d). It was found from the plots that at SR-99 S, the flows and occupancies varied

over a wide range over the congested regime (Figure 3c and 3d). But for the I-5 S, though they were in the congested regime, they varied over a narrow range. Either more than 80% (approx.) of the points were concentrated near the maximum flow or the points formed a straight line parallel to the x-axis (Figure 3a and 3b respectively). This indicates that the bottleneck is operating at its capacity with negligible temporal variation in queue discharge flows.



a) Vallejo Way, February 15th 2012

b) Vallejo Way, February 16th 2012

c) Fruit ridge Road, February 2nd 2012

d) Fruit ridge Road , February 16th 2012

Figure 2.Oblique Plots of bottlenecks at SR-99 S and I-5 S

The average speeds computed for the 5-min intervals also revealed a similar trend. The average speed on SR-99 S was around 20 mph whereas it was about 30 mph on I-5 S. The 5-min averaged speeds of vehicles in case of the former varied from 10 mph to 58 mph, whereas they ranged from 20 to 46 mph

in case of the latter. Thus in the case of SR-99 S, the speeds vary over a relatively wider range over the congested regime whereas they are centered near the critical speed (V_{cr}) for I-5 S. It should also be noted that PeMS declares the Vallejo Way on the I-5 S to be a recurrent bottleneck. Even though there is no inverse relationship between flow and occupancy at these location, the average speeds at this location were lesser than the 40 mph threshold and also lesser than the speeds at the detector immediately downstream (10th Avenue) by more than 20 mph. If these conditions are satisfied, PeMS declares a location to be an active bottleneck [4]. Hence what constitutes a bottleneck is it just a decrease in speed or a well-established flow occupancy inverse relationship, remains a question.

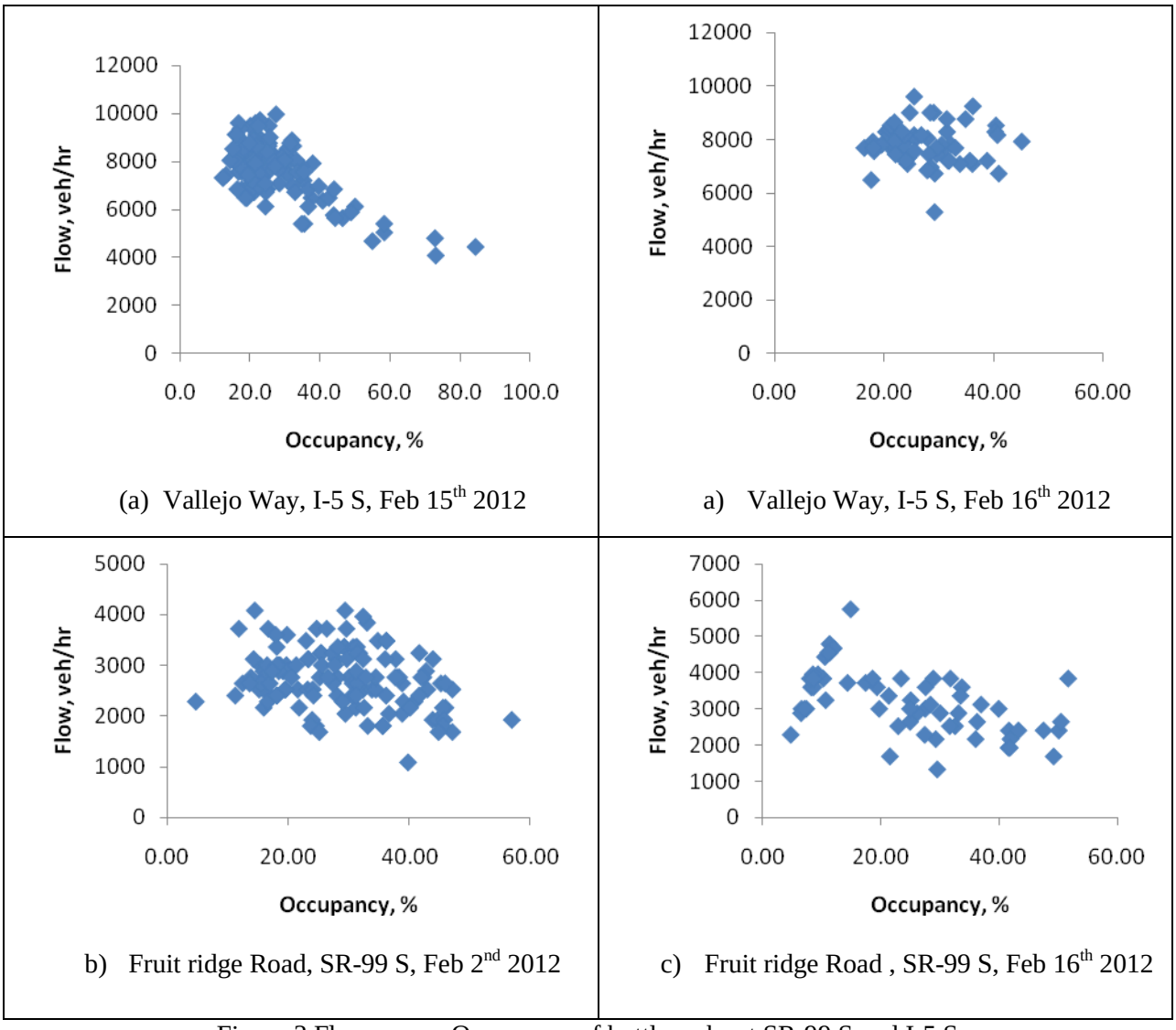


Figure 3.Flow versus Occupancy of bottlenecks at SR-99 S and I-5 S

4 Findings and Conclusions

The 10^{th} and 90^{th} percentiles were calculated for assessing the range of flows and occupancies to avoid outliers in the data. For the bottleneck on the SR-99 S, the occupancy values ranged from 6% to 60% and flow ranged from 640 to 1160 vphpl for all the 3 days for which the bottleneck was active. For the bottleneck on the I-5 S, the occupancy values ranged from 15% to 40% and the flows ranged from 1224 to 1896 vphpl for 5 out of 6 days for which the bottleneck was active. Only on the 27^{th} of February 2012, the occupancies were as high as 49% but yet the flows oscillated around 7500 vphpl. This clearly indicates that the congested flows and occupancies were distributed in a wide range in case of the bottleneck on SR-99 S. It is also evident that the discharge flows of the bottleneck at I-5 S were near its capacity of 1896 vphpl which was 5.2% less than the roadway capacity of 2000 vphpl. Such a uniform flow over the activation period may be one of the reasons for the oblique plot being not able to detect bottlenecks at this location. However, it should be noted that these empirical results may be specific only to I-5 S. Further studies are envisaged to corroborate these findings for other bottlenecks operating at capacity.

References

[1] Bertini, R.L., Leal, M.T., “Empirical study of traffic features at a freeway lane drop”, Journal of Transportation Engineering, 131(6), 397-407, 2005.

[2] Cassidy, M. J., and R. L. Bertini., “Some Traffic Features at Freeway Bottlenecks”, Transportation Research Part B, 33, 25–42, 1999.

[3] Bertini, R.L. and Horowitz, Z., "Diagnosing a Freeway Bottleneck in Portland Oregon (USA) Using Archived Sensor Data", Sixth International Conference on Traffic & Transportation Studies (ICTTS), Nanning, China, August 5–8, 2008.

[4] Chen, C., Skabardonis, A., Varaiya, P., “Systematic Identification of Freeway Bottlenecks”, 83rd Transportation Research Board Annual Meeting, Washington, D.C., 2004.

[5] Rudjanakanoknad. J., “Analysis of Factors Affecting Street Bottleneck Capacity through Oblique Cumulative Plots”, Journal of the Eastern Asia Society for Transportation Studies, 8, 2010.

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