CALIFORNIA PATH PROGRAM
INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

Evaluation of PeMS to Improve the Congestion Monitoring Program

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California PATH Research Report
UCB-ITS-PRR-2007-6

This work was performed as part of the California PATH Program of the University of California, in cooperation with the State of California Business, Transportation, and Housing Agency, Department of Transportation, and the United States Department of Transportation, Federal Highway Administration.

Final Report for Task Order 5319

June 2007

ISSN 1055-1425

CALIFORNIA PARTNERS FOR ADVANCED TRANSIT AND HIGHWAYS

Evaluation of PeMS to improve the Congestion Monitoring program: Final Report for PATH TO 5319

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August 1, 2006

Abstract

The highway congestion monitoring program (HICOMP) report is based on data from tach vehicle runs or PeMS. Research under TO 5319 compares the accuracy and cost of these two alternatives. The detailed studies described in the report lead to the following conclusions and suggestions for follow-on work:

1 In freeway sections with good quality detectors spaced at most one-half mile apart, PeMS-based estimates of the magnitude, extent and duration of congestion are incomparably more accurate than those based on tach vehicle runs.

2 Because at most four days of tach run data are used to estimate the annual congestion over a freeway segment, the error in these estimates is on the order of 25 percent. (With only one day of tach runs, which is typical, the error is 50 percent.) The error in year to year comparisons is on the order of 35 percent, and so one can have no confidence in such comparisons published in the HICOMP report.

3 Because the location and number of detectors within a district varies significantly from year to year and the quality of the loop detector data is uneven, it is hazardous to use PeMS-based congestion estimates to make inter-district or year to year comparisons. However, careful analyses using PeMS data can yield valid comparisons.

4 PeMS data collection costs a fraction of tach-vehicle runs that yield estimates with similar accuracy. It would be more beneficial to divert resources from tach runs into improving the detection system.

5 PeMS estimates the components of recurrent and non-recurrent congestion; congestion ‘hotspots’; and travel time reliability. Inclusion of these estimates will make HICOMP reports much more useful.

6 An outline of a standardized congestion reporting protocol is offered. It takes into account the errors introduced from too few tach runs, loop detectors with large spacing or poor quality. It suggests a transition plan to move towards a PeMS-based report.

Keywords: Highway congestion report, HICOMP, tach vehicle runs, detector spacing, cost/benefit comparison, congestion report protocol

Executive summary

The highway congestion monitoring program (HICOMP) report is based on data from tach vehicle runs or PeMS. Research under TO 5319 compares the accuracy and cost of these two alternatives. The detailed studies described in the report lead to the following conclusions:

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6 An outline of a standardized congestion reporting protocol is offered. It takes into account the errors introduced from too few tach runs, loop detectors with large spacing or poor quality. It suggests a transition plan to move towards a PeMS-based report.

We now summarize the detailed studies described in the main body of the report.

District practices

Although districts follow broadly similar data collection and processing practices, differences in details are very large. Districts 3, 4, 5, 6 and 10 only use tach data; Districts 7, 8, 11 and 12 also use PeMS data. Districts 3,4 and 10 are beginning to use PeMS. Use of PeMS data is increasing.

Inter-district differences in processing tach vehicle data are *systematic* (e.g. generally, districts assume a flow of 2000 vehicles per hour per lane or vphpl, but District 4 assumes 2200 vphpl); *idiosyncratic* (e.g. some tach runs are spaced 30 min apart, others are 15 min apart; some districts operate tach vehicles in spring and fall, some only in the fall; some operate the vehicles for two days, some for one day); and *random* (e.g. the choice of monitored freeway segments). Where they are used, PeMS data, too, are processed in two different ways.

Differences in data collection and data processing lead to large differences in congestion estimates and make inter-district comparison meaningless. Tach-based estimates for a single district for a single year are so inaccurate as to make it statistically invalid to make year by year comparison of congestion in the same freeway, same district or statewide.

PeMS v.6.3 directly estimates the magnitude, extent, and duration of congestion—the three main elements of the HICOMP report. Since a uniform procedure underlies these estimates, their use appears to permit valid inter-year and inter-district comparison. However, the configuration of the detector system (the number and locations of the detectors) varies significantly from year to year and loop data are of uneven quality. As a result, it is hazardous to make inter-year or inter-district congestion comparisons. But analysis that takes into account the quality of the underlying data can permit valid comparisons.

Comparing congestion using PeMS and tach vehicle data

For some freeway segment-days we have both tach and PeMS data. There is qualitative agreement in the congestion measures based on the two data sets, e.g. there is a large, positive correlation between PeMS reported speeds and tach vehicle speeds. But there is disagreement over the quantitative estimates, due to differences in the procedures used to calculate them.

A tach run is first processed to estimate the extent and duration of congestion experienced during the run. These estimates are then converted into total delay using the formula

$$\left(\text{Vehicles Affected per Hour}\right)\times\left(\textit{Extent}\right)\times\left(\textit{Duration}\right)\times\left[\frac{1}{\left(\text{Congested Speed}\right)}-\frac{1}{\text{35mph}}\right],$$

in which 'vehicles affected per hour' is a nominal number (typically, 2000 or 2200 vplph), and 'congested speed' is the average tach vehicle speed.

PeMS uses a similar formula but with one major difference: it uses individual lane speed and the actual volume in each lane. Since volume drops to 1400 vphpl on average during congestion, taking it as 2000 vphpl (as tach-based estimates do) will overestimate congestion by 40 percent! Tach-based estimates will also be unreliable for freeway segments in which speeds in different lanes vary significantly.

Impact on accuracy of number of tach vehicle runs and detector spacing

The HICOMP report publishes the *magnitude of delay* (veh-hrs), *extent* (lane-miles) and *duration* (hrs) of recurrent congestion for a typical weekday commute. Since congestion varies randomly from one day to the next, we take 'typical' weekday to mean that the report estimates the average value of magnitude, extent and duration over the 260 weekdays in the year.

We calculate the errors in tach- and PeMS-based estimates of daily peak period delay on four segments. For weekday j denote the delay on one of these segments by $D(j)$, $j = 1, 2, \ldots, 260$. The average D and the standard deviation σ of the daily delay are

$$D = \frac{1}{260}\sum_j D(j), \qquad \sigma = \frac{1}{\sqrt{260}}\left[\sum (D(j)-D)^2\right]^{1/2}.$$

Suppose tach vehicles are operated on n of the 260 weekdays in the year. (Typically n is between 1 and 4.) Then D is estimated by the empirical average D_n of the delay encountered over the n days. D_n will be different from D. The standard deviation of the error $|D - D_n|$ in the estimate is $\sigma_n \approx \frac{1}{\sqrt{n}}\sigma$.

For the 51N segment PM peak period for 2002, D = 1116 veh-hrs and σ = 640 veh-hrs. If districts operate tach vehicles once per year (n = 1), the error in the estimate will be $\sigma_1 = \sigma$. Thus if n = 1, there is a 32 percent probability that the error in the estimate of daily statewide PM delay exceeds 640 veh-hrs. (This is a percent error of 640/1116 or 57%!) If n = 4, there is a 32 percent probability that the error exceeds $\sigma_4 = \sigma / 2$ = 320 veh-hrs or 28 percent.[1]

The large error in tach-based estimates is due to the small number (out of 260) of weekdays tach vehicles are operated. PeMS-based estimates don't suffer from this error, as PeMS collects data every day. PeMS-based estimates have errors because the detectors only measure traffic at certain locations. The error will grow with inter-detector spacing. From a detailed study of four freeway segments, we find that detectors should be spaced less than 0.5 miles apart to keep the error below 10 percent.

PeMS-based estimates have errors also because of changes in detector configuration and errors in measurement. These errors could be reduced by careful analysis.

Travel time comparison

The HICOMP report relies on travel times experienced by individual probe vehicles driving in a particular lane for a few days. There is general agreement between the travel times measured from the probe vehicles and the travel times computed from the detectors in PeMS. PeMS calculates the travel times for a route by 'walking the speed matrix.' Each route is made up of a number of individual segments with a single detector in each segment. PeMS starts at time T_0 and uses the speed at time T_0 to compute the time to cross the first segment, say t_1. It then uses the speed measured at the second segment at time $T_0 + t_1$ to compute the time to cross the second segment. It continues in this manner for the entire route.

Figure 1 shows a travel time comparison between PeMS and the probe vehicles for 91-E in D12. We show the individual travel times for each lane as well as the individual travel time points from the probe vehicles. The probe drivers are typically told to drive in lane 2, but they are also told to drive with the traffic. In this situation it appears that they were driving at speeds in lane 3.

Figure 1 raises another concern with the current HICOMP approach—the variation in speeds across lanes. We can see that the difference in travel time between the fastest and slowest lanes between 5pm and 6pm is approximately 20 minutes. With a single probe vehicle per run it is not possible to capture this variation. Since the current HICOMP approach implicitly assumes that the travel time in all lanes is the same, it can lead to large errors even for a single day.

[1] Even with n = 4, there is a 5 percent probability that the error exceeds 640 veh-hrs.

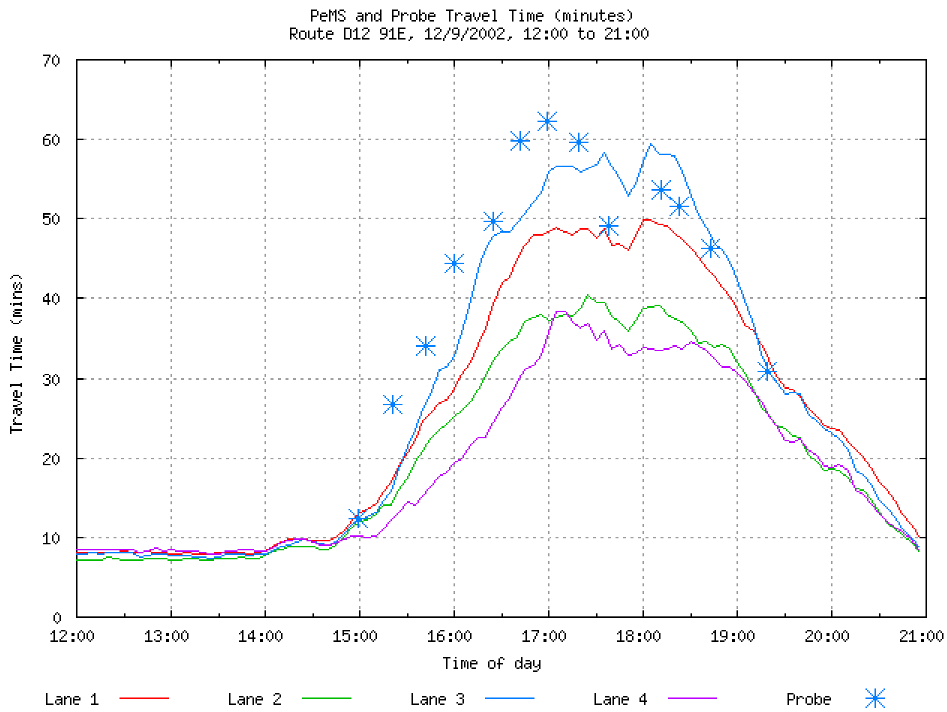


Figure 1. Travel times from PeMS and Probes.

Cost of tach runs vs. PeMS

Based on analysis of data for District 8, the cost of monitoring a 10-mile freeway segment for *one peak period for four days per year* (two days each in fall and spring) is $10,560. The estimate includes labor and operating cost, but excludes vehicle depreciation.

Based on 2004 TMS inventory costs, the *annualized cost* (including capital and O&M costs) of a 10-mile, four-lane urban freeway segment with 0.5 mile detector spacing is $126,400.[2] If we assign as much as 25 percent of this cost or $31,600 to congestion monitoring (and the rest to other functions of freeway operations such as ATMS and ATIS), the cost is comparable to that of tach runs.[3] To obtain congestion estimates with accuracy similar to that of PeMS-based estimates, one would need tach runs on 100 days each year, at a cost of $250,000 for a 10-mile segment. The detection system would provide much more accurate estimates as well as much other useful information.

Clearly, tach vehicle runs should not be used to accurately measure congestion.

A standardized reporting protocol

The study proposes a standardized congestion monitoring protocol that can be implemented across districts to document congestion. A short-term and a long-term transition plan are outlined. The short-term plan offers criteria to determine the segments for which PeMS data can

[2] This is likely to be an overestimate according to John Wolf. Besides, new sensing technologies provide more accurate detection systems than loop-based systems at one-sixth the cost.
[3] The allocation of 25 percent of the detector cost to congestion monitoring is arbitrary, but some allocation formula is needed to compare with the cost of tach runs.

be used and measures to overcome the discontinuities in the congestion estimates that will inevitably result when comparing a previous year's tach-based estimates with current year's PeMS-based estimates. The long-term transition plan provides criteria for extending detector coverage to segments where such coverage will be most useful in preparing the congestion report.

1 District practices

Each District is responsible for the congestion monitoring results that appear in the statewide HICOMP report. District practices differ in the data they collect and how they process the data. Appendix 1 fully documents these practices.

1.1 Data collection

Districts use two data collection methods. The most common method consists in driving probe vehicles equipped with tachometers (tach vehicles) at regular intervals along congested freeway segments during typical weekday commute periods. The second method relies on automatically collected data from fixed sensors located along freeways. These data are available from PeMS [1].

Districts use one of three devices to collect tachometer data (Appendix 1, Exhibit 7). Most use *Congest*/*CLOG* , a PC-based software developed in the mid-1980s by Caltrans. *PC Travel* from Jamar Technologies, Inc. is used by District 5. *Moving Vehicle Run Analysis Package (MVRAP)*, developed by the University of Florida Transportation Research Center, is used by District 7.

District 4's *Congestion Monitoring Procedures and Guidelines* provides general guidelines. Data collection season is typically during the spring and fall, avoiding days adjacent to major holidays. Two days of data collection should be performed during each season, and only "typical" recurrent congested days should be sampled. These guidelines are sometimes sacrificed because of the cost involved. Often only one day in the fall is sampled.

The freeway segments are selected on the basis of past practice and intuition. There appears to be no systematic procedure to ensure that all congested freeway segments are covered. A selected segment should be long enough to bracket the congestion and short enough so that repeated runs can be made. The headway between runs should be 15 minutes. Cost considerations restrict adherence to these precepts, and districts frequently use 30 min headways.

Drivers are cautioned to "float" with the traffic in order to collect typical trajectories. This is usually interpreted to mean staying in the middle lane, which will lead to erroneous estimates if inter-lane speeds vary considerably.

Other sources of error are poorly calibrated vehicles and incorrect time synchronization.

Automatic data collection methods use PeMS to extract 5-minute speed and volume. PeMS receives and stores data from 21,000 loop detectors grouped in 8,500 vehicle detector stations, covering 3,000 (out of a total of 30,000) direction-miles of freeway.

1.2 Data processing

The HICOMP report publishes *recurrent* congestion on *urban area freeways* for typical weekday commute periods. The report defines recurrent congestion as a "condition lasting for 15 minutes or longer where travel demand exceeds freeway design capacity and vehicular speeds are 35 miles per hour (mph) or less during peak commute periods on a typical incident-free weekday." HICOMP reports three primary parameters: extent, duration and magnitude of congestion. The HICOMP report discusses the magnitude and extent of congestion in detail, and includes maps that show the location and duration of congestion.

Each district follows its own procedure to estimate the congestion parameters. Tach runs are first processed to estimate the duration and extent of congestion. The magnitude of delay is in principle then derived using the formula

$$(\text{Vehicles Affected per Hour})\times(\mathit{Extent})\times(\mathit{Duration})\times\left[\frac{1}{(\text{Congested Speed})}-\frac{1}{35\text{mph}}\right].$$

However, the application of this formula varies a lot.

District 3's approach is summarized in Appendix 1, Exhibit 8. The total delay is ultimately calculated using the formula,

[Lanes] × [2,000 vphpl] × [Time between runs] × [Average delay between runs].

District 4's approach differs in three ways (Appendix 1, Exhibits 9,10). First, it uses 2,200 vphpl as the hourly lane volume. Second, it uses a graphical procedure to calculate congestion. Third, instead of the 35 mph reference speed, it uses a "baseline" travel time approach, which takes the speed profile plot for the most congested run of the time period and estimates the travel time for that run as if the tachometer vehicle were traveling at free-flow on the uncongested portions of the segment and at 35mph during the congested segments.

District 12's approach assumes that the delay recorded by the tach vehicle during any 20-minute time slot (Appendix 1, Exhibit 11) is constant for all vehicles traveling during that time slot.

Districts 5,6,8,11 use yet another approach (Appendix 1, Exhibit 12). Total delay for a segment is calculated by averaging over all tach vehicle delays and multiplied by the nominal 'vehicles affected per hour'.

Automatically collected detector data are processed in two ways. The "legacy" or "District 7" approach mimics the tach-based approach by having the analyst select two 'typical' days whose data are processed. The "interim" approach uses the standard deviation to select two typical days. See Appendix 1, Exhibits 14, 15.

The "interim" approach is fully documented in Appendix 2.

1.3 Consequence of different practices

Systematic differences in practice make it meaningless to compare congestion estimates across districts. A district that uses a nominal 2,200 vphpl will, all other things being equal, give 10 percent greater congestion than one that uses 2,000 vphpl for 'vehicles affected per hour'. PeMS uses actual volumes to estimate congestion, which, during congestion, may be as low as 1,400 vphpl, leading to an estimate of delay that is 40 percent lower.

Some districts space tach vehicles 30 min apart while others maintain a 15 min headway; some take tach runs for one day, others sample four days. These idiosyncratic differences cast additional doubt on inter-district or inter-year congestion comparisons.

Tach vehicle runs are confined to the AM and PM peaks, which in 2005 accounted for 64 percent of statewide congestion delay, so off-peak periods and weekends account for a significant 36 percent. (These proportions are estimated by PeMS.) Since detectors work continuously, they provide congestion estimates for these periods as well, giving a more complete picture of congestion.

Lastly, the random nature of congestion makes tach-based estimates virtually useless. Figure 1 is a scatter plot of veh-hrs of delay (VHD) vs. veh-miles traveled (VMT) on weekdays during the PM peak period (3-7PM) in 2005. The significant feature to observe is that over the year VHD varies by 300 percent from a low of 150,000 to a high of 500,000, while VMT varies only by 10 percent between 58 and 64 million. This 300 percent variation in the delay implies that one cannot meaningfully estimate the average delay from data obtained from one to four days of tach runs.

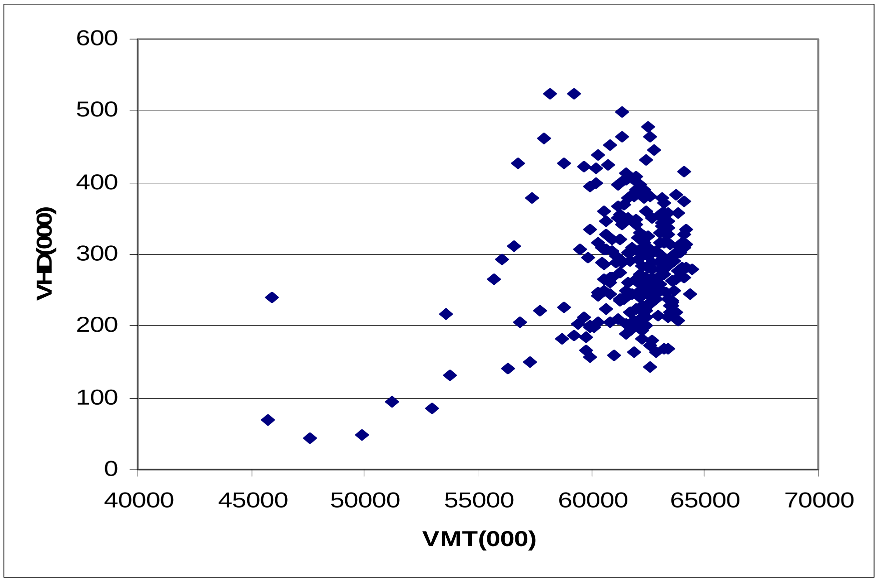


Figure 2 Statewide VHD vs. VMT during weekday PM peak, 2005. Source: [1]

PeMS-based estimates also have errors, because the number and locations of loops that comprise the detector system change frequently and because the quality of loop data is uneven. This makes it hazardous to use PeMS data to make inter-district or year to year comparisons, unless the analyst takes into account these features of the data.

2 Selection of study sites

Appendix 3 lists the available tach runs. The entries highlighted in green in the Appendix and summarized in Table 1 are for segments that have several tach runs on congested days.

ID	istrict	County	Rte	Dir	Date	Length	Number of Runs	NLoops	Nloops Std	Pts_Observed _std	PTS_Ob s_Mix _std	Selected	Notes
1	12	ORA	91	E	2004-12-09	8.295	13	13	1.57	1.09	1.33	x	
2	12	ORA	22	E	2002-11-19	11.561	9	21	1.82	0.52	1.02		
3	12	ORA	91	W	2004-11-04	6.971	12	0	0.00	0.00	0.00		
4	12	ORA	5	S	2002-11-06	7.152	10	0	0.00	0.00	0.00		
5	12	ORA	5	S	2002-11-13	6.656	10	0	0.00	0.00	0.00		
6	12	ORA	405	N	2004-10-13	11.038	10	24	2.17	0.73	1.00		
7	12	ORA	5	N	2002-11-05	8.959	11	20	2.23	0.89	1.79	x	two days are available
8	12	ORA	91	W	2002-11-20	6.971	10	0	0.00	0.00	0.00		
9	12	ORA	55	S	2004-11-03	4.211	10	0	0.00	0.00	0.00		
10	12	ORA	5	N	2004-11-18	8.959	13	20	2.23	0.79	1.34		two days are available
11	12	ORA	605	S	2004-10-07	3.94	13	0	0.00	0.00	0.00		
12	12	ORA	91	E	2004-11-04	6.948	11	12	1.73	1.14	1.29		
13	12	ORA	55	N	2002-10-29	10.464	13	23	2.20	1.43	1.82	x	
14	12	ORA	91	E	2002-11-26	9.716	9	17	1.75	0.51	1.02		
15	12	ORA	91	E	2002-06-26	9.716	8	17	1.75	0.28	0.48		
16	12	ORA	22	E	2002-11-19	11.561	7	21	1.82	0.52	1.02		
17	8	RIV	91	W	2003-02-05	9.09	20	0	0.00	0.00	0.00		
18	8	RIV	215	N	2003-02-20	2.6	17	1	0.38	0.00	0.00		
19	8	RIV	71	S	2002-12-05	3.8	10	0	0.00	0.00	0.00		
20	4	ALA	880	N	2003-04-30	20.01	10	45	2.25	0.00	0.00		
21	3	SAC	51	S	2002-11-06	6.965	17	0	0.00	0.00	0.00		
22	3	SAC	51	N	2002-11-06	7.68	14	15	1.95	1.29	1.55	x	

Table 1 Congested segments with good tach run data

The table lists: number of tach runs, number of loops on the segment, number of loops per mile (Nloops_Std), and number of loops per mile for which PeMS has good observations (Pts_Observed_std) or good + imputed observations (Pts_Obs_Mix_std).[4] Four promising sites were selected as indicated in the second to last column. These are sites for which we have tach runs and good PeMS data for the same day. Table 2 gives details of these sites.

Fwy	Seg. length	Gooddays	Run.bpm	Run.epm	Run.start	Run.ends	Run.date
D03 51N	6.738	241	0.76	8. 44	P St ON	Rte 244 Off	2002-11-6
D12 91E	9.891	261	11.49	19.79	ON from EB Imperial	Green River OFF	2004-12-9
D12 5N	13.587	261	21.30	30.26	5/405 Sep Brdg	5/55 Sep Brdg	2002-11-5
D12 55N	11.547	261	3.09	13.55	NB ON FR 22st	Chapman OFF	2002-10-29

Table 2 The four study sites

In Table 2 Run.bpm and Run.epm are the run begin and end postmiles; Run.start and Run.ends are the associated landmarks; Seg.length is the length of the segment in miles; and Gooddays is the number of weekdays for which good PeMS data are available.

[4] Caltrans' detector data vary in quality. PeMS replaces missing or incorrect detector measurements with imputed values. The analyst must ensure that the quality of PeMS data being used is adequate for the purpose.

3 Comparison of tach- and PeMS-based congestion measures

We compare tach runs with PeMS data for the four sites in Table 2.

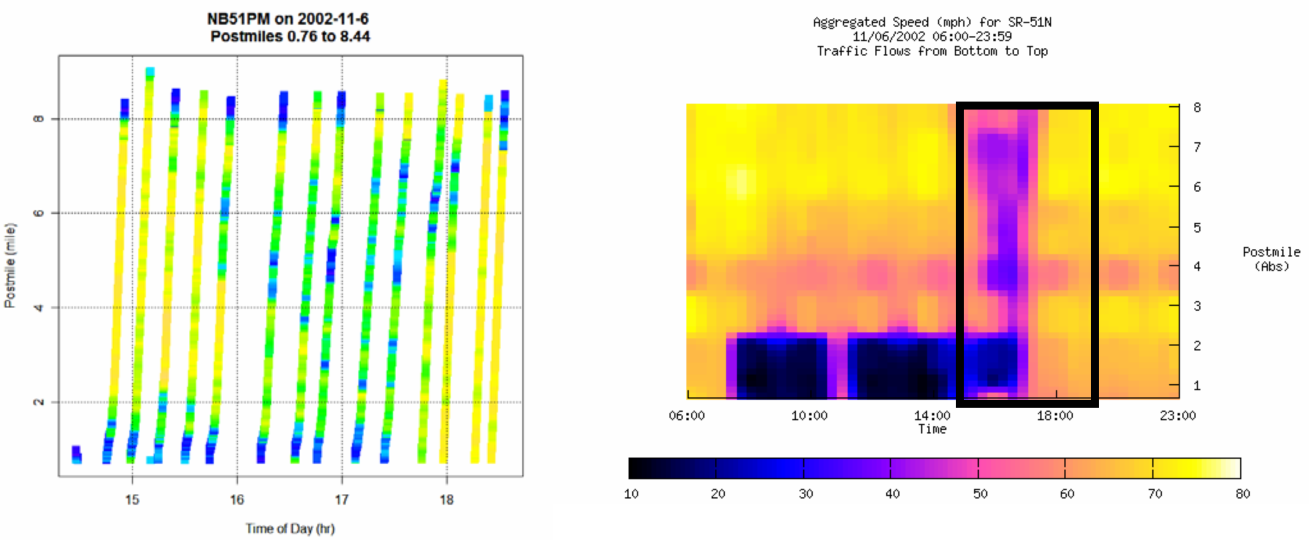


Figure 3 Tach runs on 11/06/02 on 51N (left) and PeMS average speed contour plot (right).

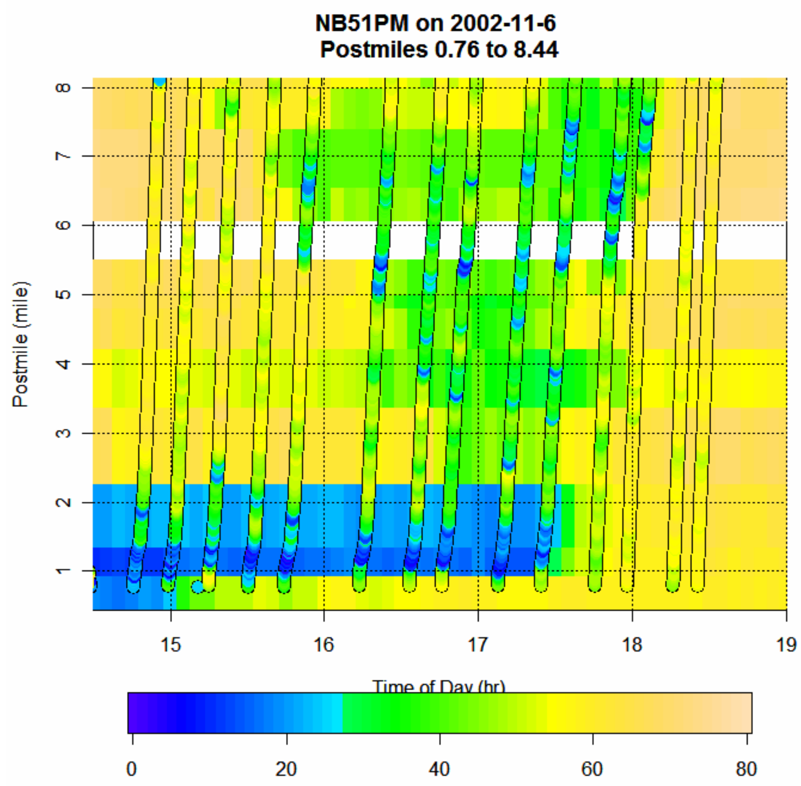


Figure 4 Tach runs superimposed on PeMS contour plot

Figure 3 (left) shows the 14 tach runs along a 7.68-mile segment of 51N during the PM peak period. The runs are color coded to indicate speed. On the right in Figure 3 is the speed contour plot for the 17-hour period for the same segment. The black rectangle indicates the space-time region covered by the tach runs on the left.

Figure 4 is obtained by superimposing the tach runs on the left in Figure 2 on the speed contour plot in the rectangle on the right in Figure 3. The white band just below postmile 6 indicates that the detector data at that location are missing. Three points are worth emphasizing.

First, there is broad agreement in the speeds calculated by PeMS and experienced in the tach runs. The areas where PeMS indicates free flow are also experienced as free flows by the tach vehicles; the areas where PeMS indicates speed of 40 mph the tach vehicles also travel at that speed. However, there are some differences. PeMS indicates speeds below 20 mph until 5:30 pm up to postmile 2.2; but the tach vehicles seem to experience these low speeds up to postmile 1.8, depending on the time. This is in part a consequence of the fact that there are detectors at postmiles 1.5 and 2.4 and none in between, so PeMS cannot distinguish speeds at locations between these detectors; and in part because the contour plot takes the average speed across all four lanes, whereas the tach vehicle only records its own speed. Third, we see in Figure 3 (right) that the congestion below postmile 2 began as early as 7AM, but these tach runs began only at 2:45PM, so the AM congestion may have been missed entirely (see Appendix 3).

The second site is an 8.3 mile segment of 91E. There are 13 runs between 3:00 and 7:30 PM as seen in the left of Figure 5, corresponding to the rectangle in the PeMS speed contour plot on the right in Figure 5.

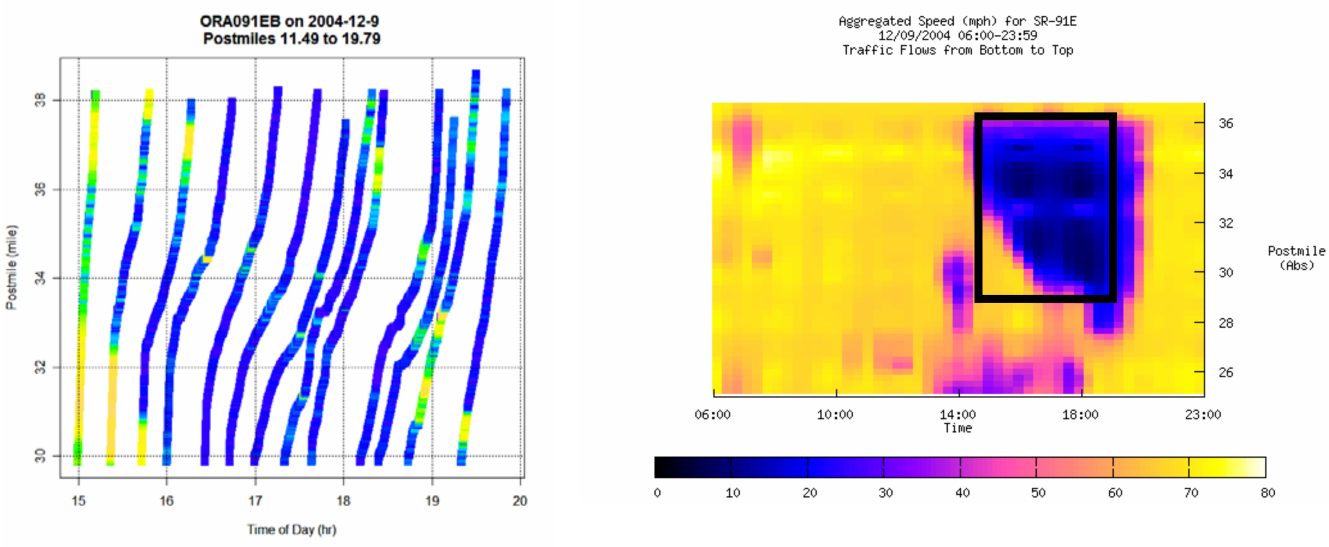


Figure 5 Tach runs on 12/09/04 on 91E (left) and PeMS average speed contour plot (right)

Once again the contour plot shows congestion outside the tach run rectangle, indicating that the tach runs may underestimate the congestion.

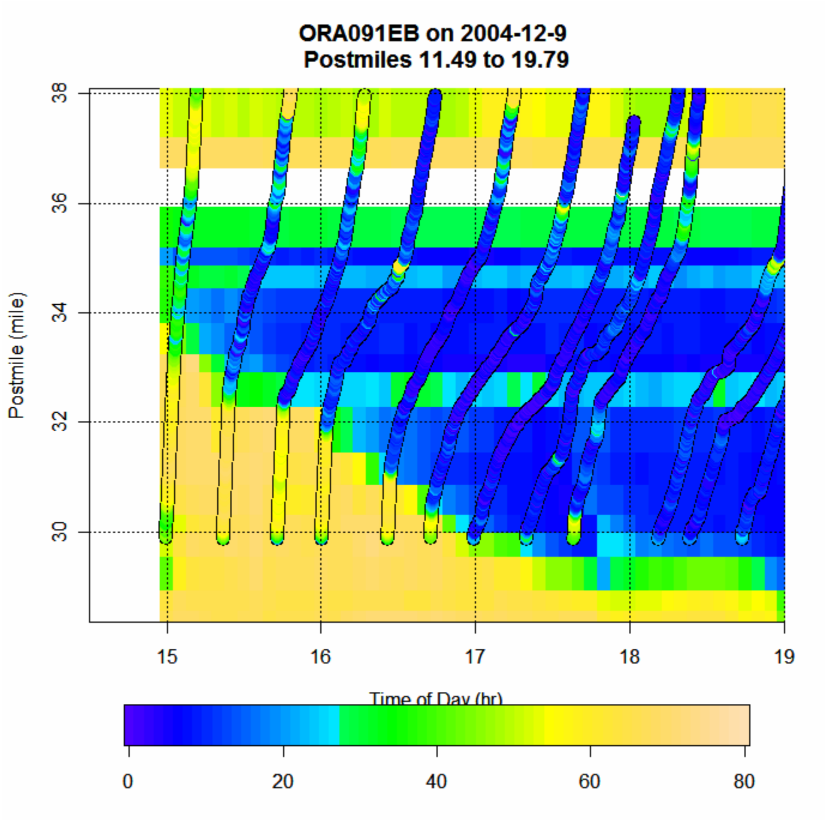
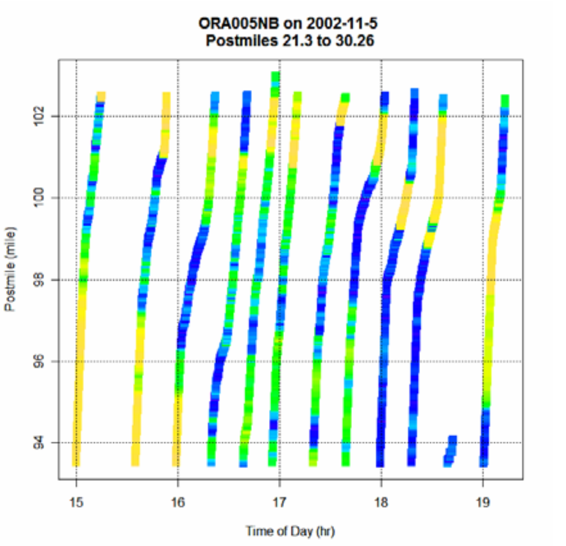


Figure 6 Tach runs superimposed on PeMS contour plot

Figure 6 reveals broad agreement in speeds, but there are differences in detail. These are again in part due to detectors at postmiles 35.39 and 36.76 not working on that day. There is also the difference between average speed across all lanes and tach vehicle speed. The difference is also in part an artifact of the color scheme to denote speed. One can see that a slight increase in speed near 30 mph will change the color from blue to green, which exaggerates the speed difference.

Figure 7 shows the tach runs for the third study site, an 8.96-mile long segment on I-5N during the PM peak on 11/05/2002. Once again, the tach runs appear to miss congestion that started before the first tach run, as shown in the contour plot outside the rectangle. Figure 8 permits comparison of the speeds given by PeMS and the tach vehicle speeds. The two speeds agree even in some of the fine structure of the contour plots, despite the missing detector data (shown as white stripes).



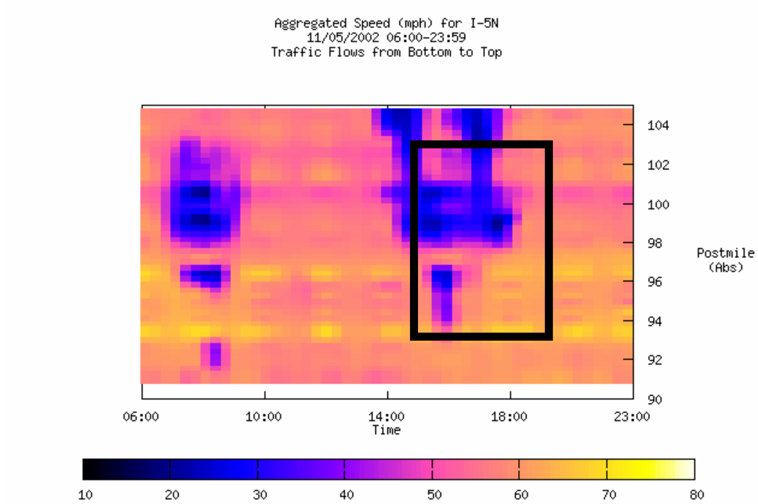


Figure 7 Tach runs on 11/05/02 on 5N (left) and PeMS average speed contour plot (right)

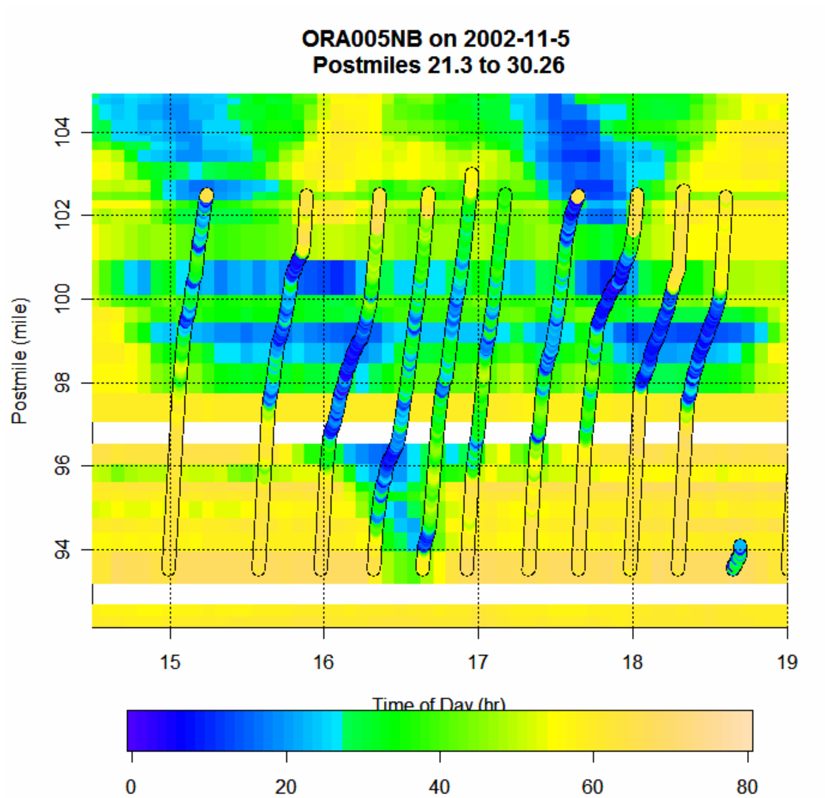


Figure 8 Tach runs superimposed on PeMS contour plot

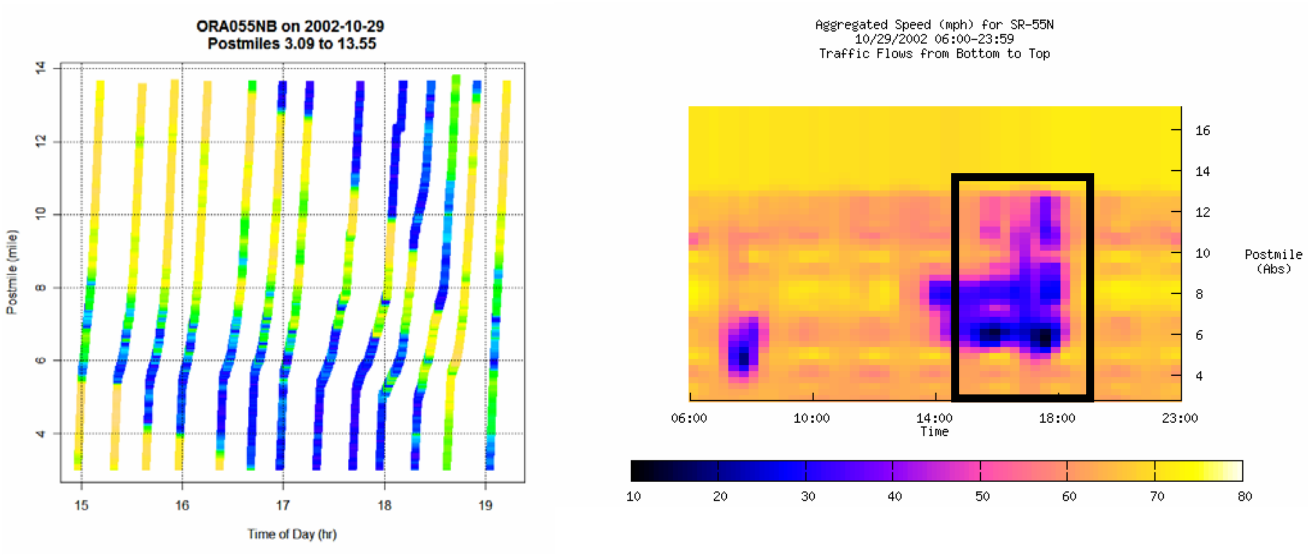


Figure 9 Tach runs on 10/29/02 on 55N (left) and PeMS average speed contour plot (right)

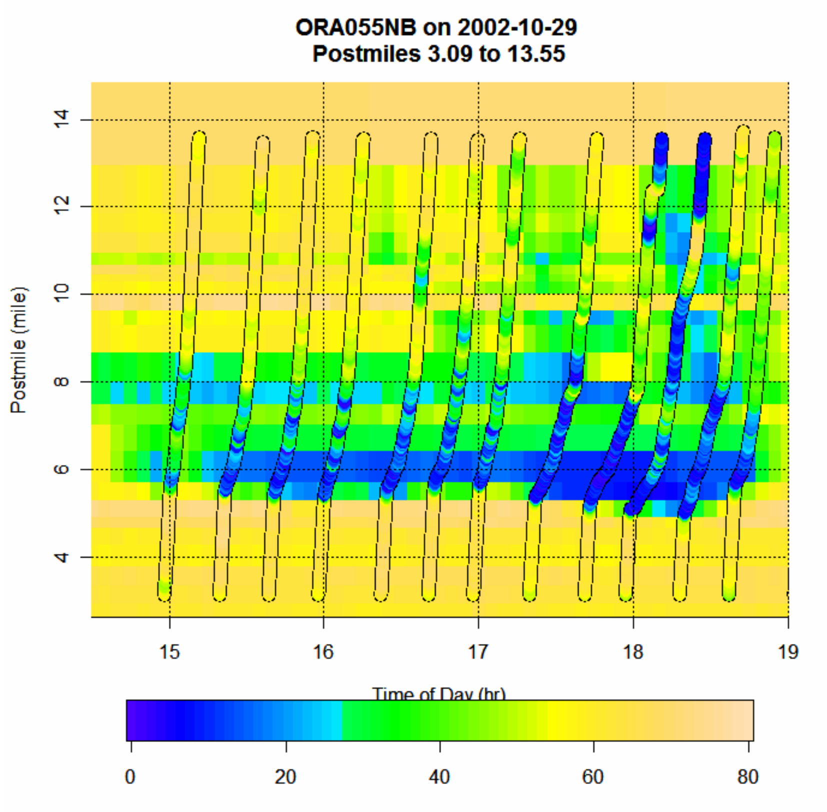


Figure 10 Tach runs superimposed on PeMS contour plot

The fourth study site is a 10.46-mile segment on I-55N. This segment has a denser arrangement of functioning detectors (see Table 1), and the conformity between PeMS speeds and tach vehicle speeds is greater, as evident in Figure 10. Thus the closer the loop detectors are spaced, the better is the agreement between tach speeds and PeMS speeds.

4 Accuracy of tach-based and PeMS-based estimates

We calculate the accuracy of tach-based and PeMS-based estimates for the four study sites listed in Table 3 (see also Table 2). The column 'gooddays' is the number of days in the year for which good (observed and imputed) detector data in PeMS are available.

The annual HICOMP report publishes three parameters: the magnitude, duration, and extent of congestion over a freeway segment, averaged over the 260 weekdays of the year. Tach-based estimates have an error because they are based on at most four (out of 260) days of measurements. PeMS-based estimates have an error because they measure the congestion only at discrete locations along the entire segment, and also because of loop detector measurement errors.

Fwy	Seg. length	Number of stations	Gooddays	Run.date
D03 51N	6.738	13	241	2002-11-6
D12 91E	9.891	17	261	2004-12-9
D12 5N	13.587	30	261	2002-11-5
D12 55N	11.547	24	261	2002-10-29

Table 3 The four study sites

4.1 Errors in tach-based estimates

Figure 2 shows that the daily delay varies randomly over the year. If we denote the delay on day j by $D(j)$, the true annual average D and the standard deviation σ of the daily delay are

$$D = \frac{1}{260}\sum_j D(j), \qquad \sigma = \frac{1}{\sqrt{260}}\left[\sum (D(j) - D)^2\right]^{1/2}. \tag{1}$$

If we measure the delay on n days, $j_1, \ldots, j_n$, and estimate the average by

$$D_n = \frac{1}{n}[D(j_1) + D(j_2) + \ldots + D(j_n)], \tag{2}$$

the error in our estimate will be $| D - D_n |$. Furthermore, the smaller the number n of samples, the larger will be the error. We estimate the magnitude of this error by the standard deviation σ_n of the error $| D - D_n |$. Errors in the estimates of duration and extent will similarly be quantified by their standard deviation. We estimate these errors for the four study sites using the following procedure.

For each study site and each day j, we obtain the delay $D(j)$ (veh-hrs), duration $T(j)$ (hrs) and extent $L(j)$ (miles) from PeMS. The delay is taken to be the extra time spent driving below 60 mph. The duration and extent are obtained taking 35 mph as the reference speed, and calculated from the PeMS speed contour plot as illustrated in Figure 10.

The top left plot in Figure 11 is the contour plot of speed on the first study site in 51N for which we have tach runs on 11/06/2002. The three other plots only distinguish speeds above or below the reference speed of 60, 50 and 35 mph. Consider the lower right plot. The blue area is the space-time region that experiences speed below 35 mph. We project this area onto the time (*x*) axis to obtain duration and onto the space (*y*) axis to obtain extent. Thus on this day the

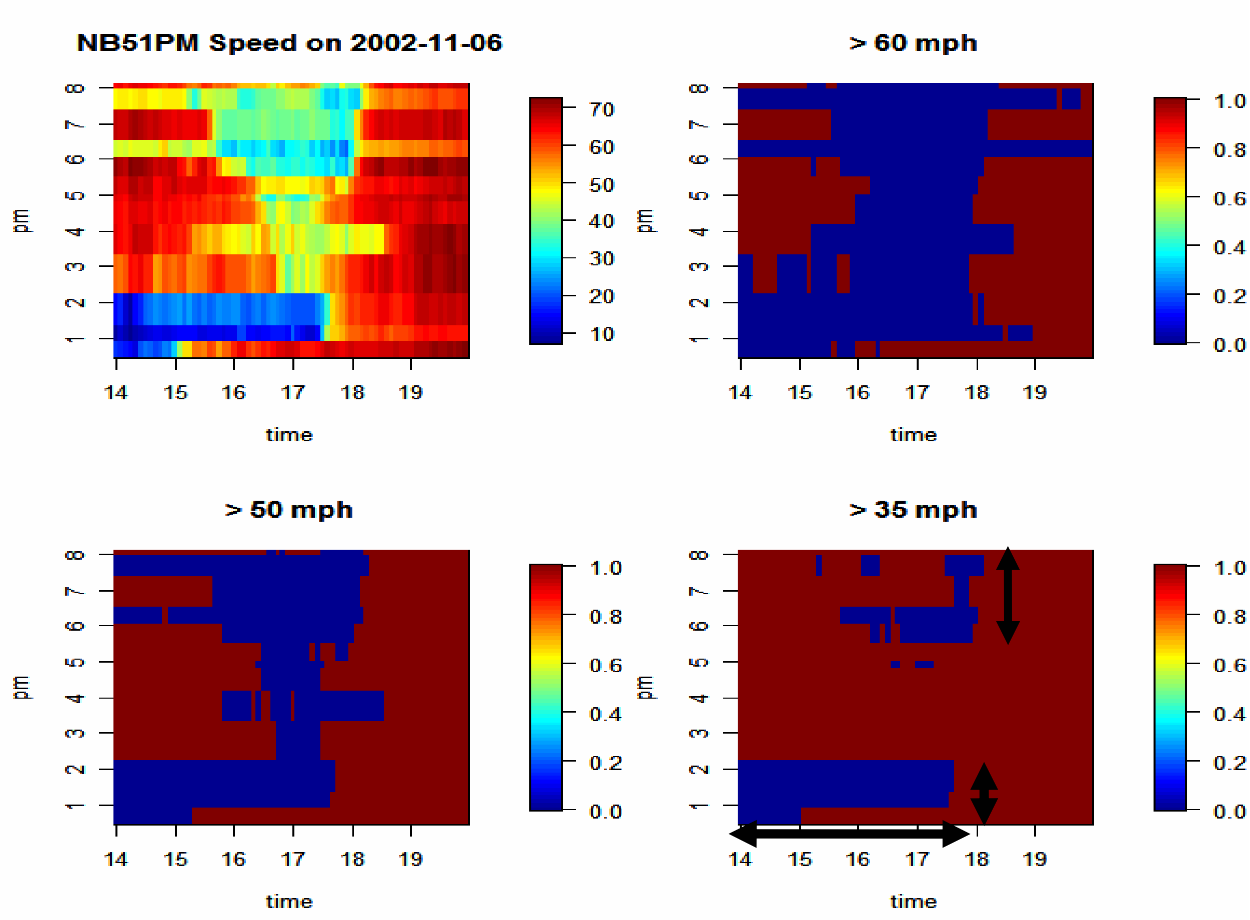


Figure 11 Obtaining duration and extent of congestion

duration of congestion is the length of the horizontal arrow and its extent is the sum of the lengths of the two vertical arrows. We repeat this for each of the *N* days for which we have data. (For the first site, as indicated in Table 3, N = 241; for the other sites, N = 261.) In this way we obtain the actual delay $D(j)$, duration $L(j)$, and extent $T(j)$ for each day $j = 1, 2, \dots, N$. From these values we calculate the true averages

$$D = \frac{1}{N}\sum_j D(j), \quad L = \frac{1}{N}\sum_j L(j), \quad T = \frac{1}{N}\sum_j T(j), \tag{3}$$

and standard deviations

$$\sigma_D = \frac{1}{\sqrt{N}}\left[\sum (D(j) - D)^2\right]^{1/2}, \ \sigma_L = \frac{1}{\sqrt{N}}\left[\sum (L(j) - L)^2\right]^{1/2}, \ \sigma_T = \frac{1}{\sqrt{N}}\left[\sum (T(j) - T)^2\right]^{1/2} \tag{4}$$

for the three congestion parameters.

If we have n days of tach runs, we average the measurements on the n days and obtain the estimates D_n, L_n, and T_n similarly to formula (2). The standard deviations of the errors $|D_n - D|, |L_n - L|, |T_n - T|$ are related to $\sigma_D, \sigma_L, \sigma_T$ by

$$\sigma_D \sqrt{(N-n)/n(N-1)},\ \sigma_L \sqrt{(N-n)/n(N-1)},\ \sigma_T \sqrt{(N-n)/n(N-1)},$$

and since n is at most 4, which is much smaller than N, these are approximately

$$\sigma_{D,n} \approx \frac{1}{\sqrt{n}}\sigma_D,\ \sigma_{L,n} \approx \frac{1}{\sqrt{n}}\sigma_L,\ \sigma_{T,n} \approx \frac{1}{\sqrt{n}}\sigma_T. \tag{5}$$

Table 4 lists the true average values and the standard deviations obtained from (3) and (4) for the four study sites.

Average				
	51N	91E	5N	55N
D (veh-hrs)	1116.6	3744.7	2072.8	1299.3
L (miles)	3.46	4.74	3.47	3.98
T (hrs)	4.47	6.21	5.54	3.64
Standard deviation				
σ_D (veh-hrs)	640.1	2283.6	1235.3	630.0
σ_L (miles)	1.08	1.29	1.58	1.11
σ_T (hrs)	1.75	2.43	2.31	1.40

Table 4 Average values of the congestion parameters and their standard deviation

The numbers in Table 4 have the following meaning: On roughly 68 percent of the days in 2002, the congestion delay on the 51N study segment was in the interval 1116.6 ± 640.1 veh-hrs, the extent was within 3.46 ± 1.08 miles, and the duration was within 4.47 ± 1.75 hrs. A similar interpretation holds for the other three sites. Observe that the standard deviation is almost 50 percent of the average value, indicating a large variation in congestion from one day to the next.

We gain a deeper appreciation of the variation in congestion from Figure 12, which shows the histograms of daily delay, duration and extent for the four sites. The vertical blue lines are the annual averages, calculated from (3) and also given in Table 4. The vertical red lines correspond to the delay, duration and extent of congestion measured on the day of the tach run. The difference between the red and blue lines is the error that one would make by taking the measurements of the tach run to be the true averages. Of the twelve estimates (three parameters for each of the four sites) in Figure 12, eight have an error smaller than their corresponding standard deviation and four have an error exceeding the standard deviation.

From the fact that the standard deviations for the four sites in Table 4 are nearly 50% of the true average values, and that typically only one day of tach run data is available, the errors in the tach-based estimates of the true congestion parameters is on the order of 50 percent! (If four days of tach data are available, relation (5) implies that this error would be on the order of 25 percent!) We conclude that *tach-run based estimates published in the HICOMP congestion parameters are not reliable*.

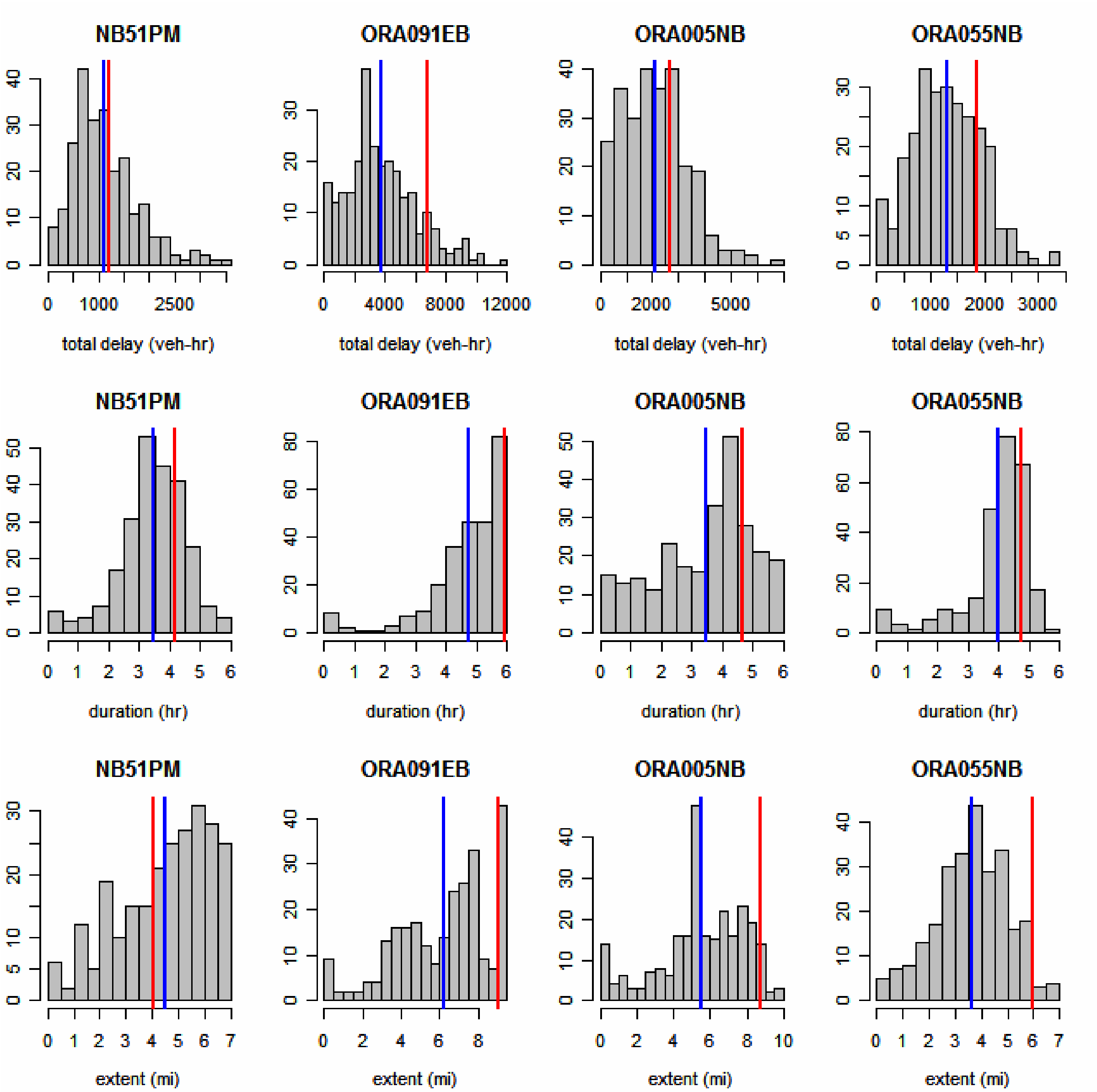


Figure 12 The histogram of delay, duration, and extent for the four sites

Suppose we take tach run estimates over two successive years and use the difference to conclude whether congestion is increasing or decreasing, and by how much. The error in the estimate of the true difference increases by a factor of $\sqrt{2} \cong 1.4$, which means the error is on the order of 1.4 × 50 = 70 percent!. With such a large error *makes it impossible to place any confidence in the congestion trends in Figure 12 published in the HICOMP report*.

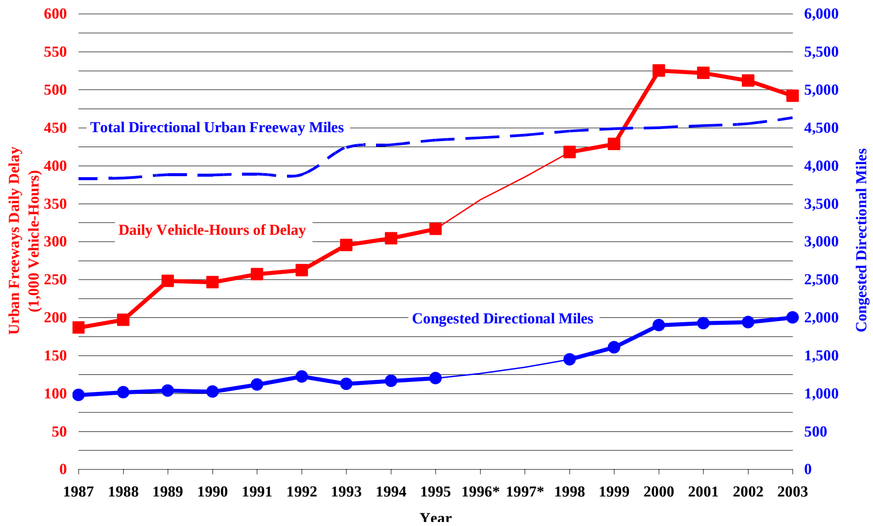


Figure 13 Trends in congestion. Source: Caltrans 2003 HICOMP report

4.2 Errors in PeMS-based estimates

We now calculate the errors in PeMS-based estimates. There are two types of errors. The first type of error occurs because traffic is monitored at a few discrete locations along the freeway segments. We call this (spatial) *sampling error*. The second type of error arises from aggregating measurements from a system of detectors that changes over time and whose data quality is uneven. We call this *aggregation error*.

Sampling error

This error occurs because the congestion parameters are calculated from measurements at a few discrete locations on the freeway segment. We estimate this error as follows. Consider the 51N study segment, which has13 detectors, corresponding to a detector density of 13/9 = 1.4 detectors/mile. We take the measurements reported by these 13 detectors as 'ground truth'. We now simulate the effect of having data from fewer stations.

Consider one day. We randomly pick n = 1, 2, … ,12 out of the13 stations, and estimate the congestion parameters for that day from the n selected detectors. For each n, we make a different random selection 65 = 5 × 13 times. In this way, for each sample size n, we get 65 measurements of the congestion parameters, which we compare with the ground truth given by measurements from all 13 stations.

The three 'box and whiskers' plots in Figure 14 summarize the distribution of the 65 values of the congestion parameters for each sample size. The speed contour plot is the ground truth from all 13 detectors on 11/06/2002.

We explain how to interpret the box plots. Consider total delay on the study segment displayed in the top left plot. Pick a sample size, say n = 3. The lower limit of the gray box is the 25th percentile, the bold black horizontal line towards the middle of the box is the median or 50th percentile, and the upper limit of the box is the 75th percentile of the 65 values. The two

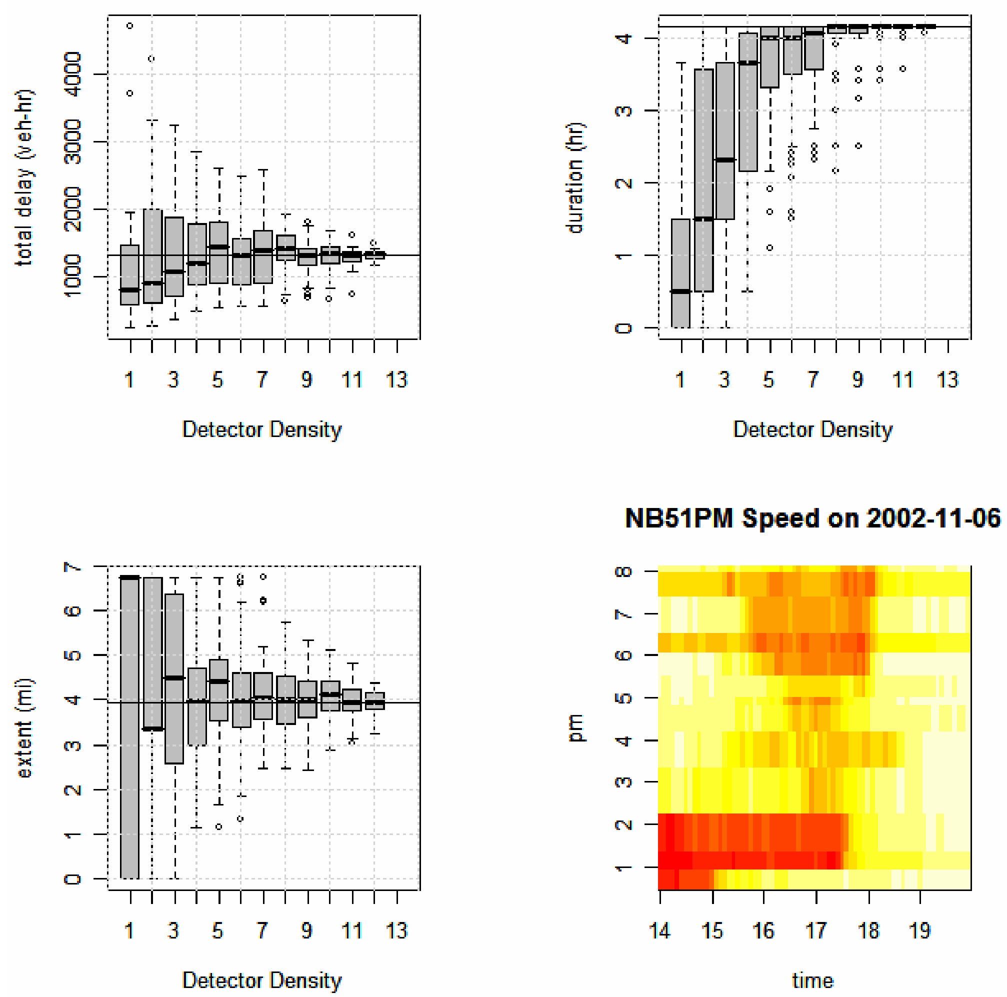


Figure 14 Simulation of congestion parameters with n = 1, 2, … , 13 detectors over a 9-mile section of 51N on 11/06/2002

'whiskers' extend from the box to smallest/largest points that are within by 1.5 × the inter-quartile range from the box boundaries. Finally, the small circles denote 'outliers'. As one can see for n = 3, the median value is 1,100, the 25th percentile is 700, and the 75th percentile is 1,800 veh-hrs. As expected, as n increases, the variability reduces, until for n = 13 we get the 'ground truth', which is 1,300 veh-hrs. A commonly accepted statistic that summarizes the error is RMSE, the square root of the mean square error (MSE), defined as

$$\mathrm{MSE} = \mathrm{variance} + \mathrm{bias}^2, \qquad (6)$$

in which 'bias' is the difference between the median and the true value. Figure 15 shows how the RMSE decreases with *n*. We can see from the top left plot of Figure 15 that we must have at least 10 detectors if we want the RMSE error to be less than100 veh-hrs. (Recall that the true average delay is 1,300 veh-hrs.)

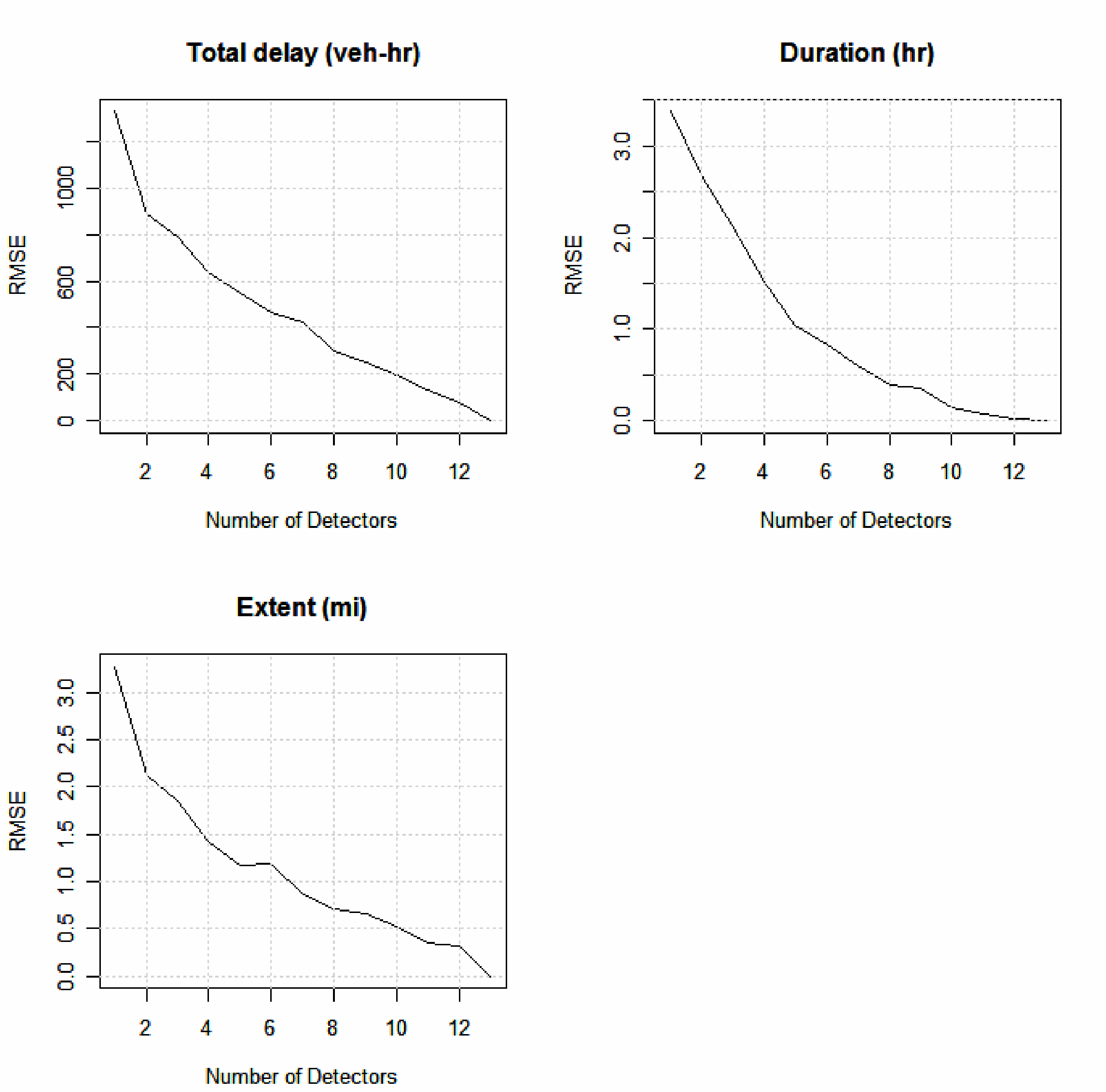


Figure 15 RMSE of the congestion parameter estimates with number of detectors $n = 1, \ldots, 13$ over a 9-mile section of 51N on 11/06/2002.

The error calculations summarized in Figures 14 and 15 are for a single day, 11/06/2002. A different day would yield different calculations. We pick 10 random days in the year, and obtain 10 RMSE curves, similar to those of Figure 15. Figure 16 depicts the result for all four sites.

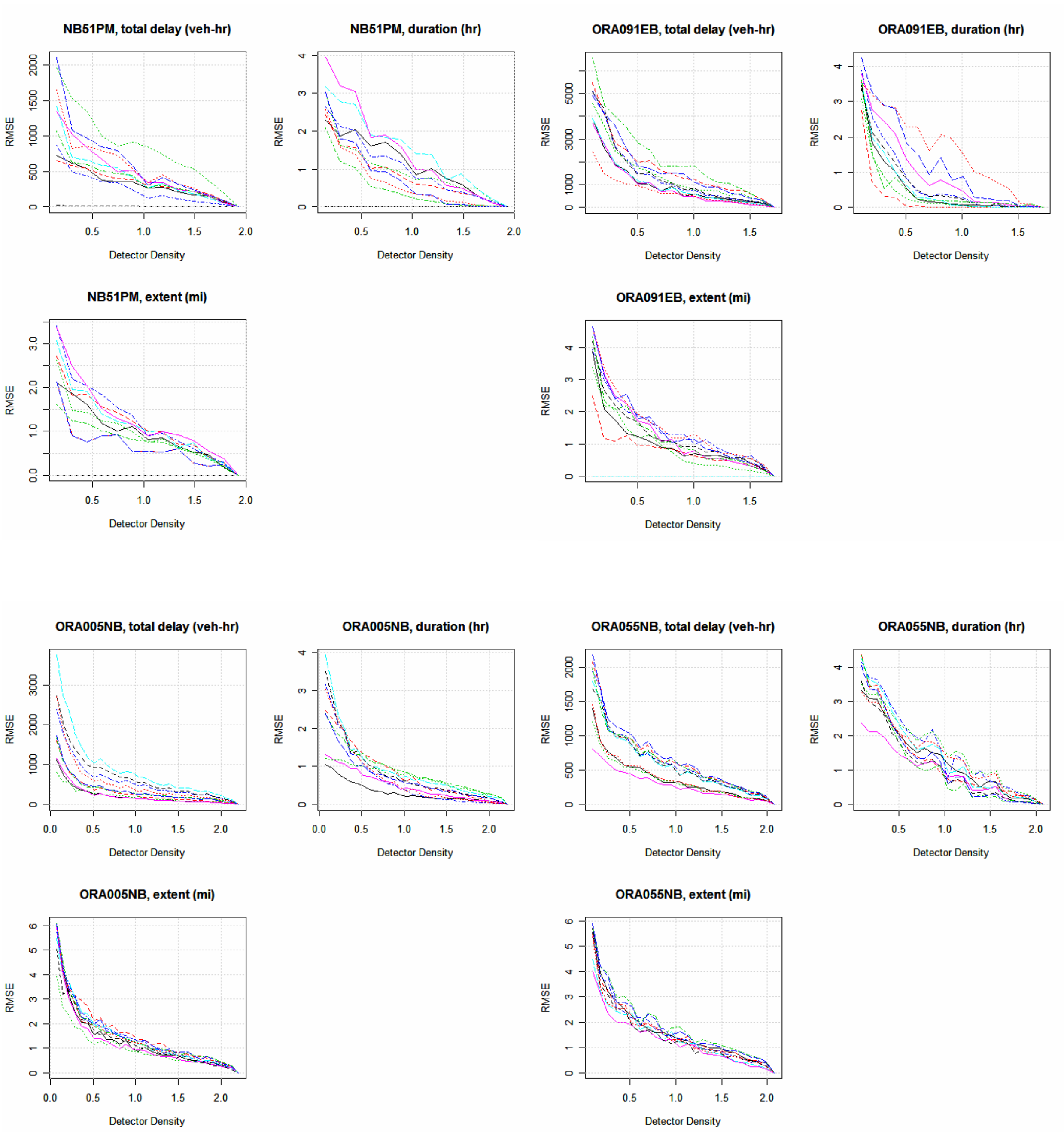


Figure 16 RMSE curves of the congestion parameters for 10 randomly selected days for the four sites

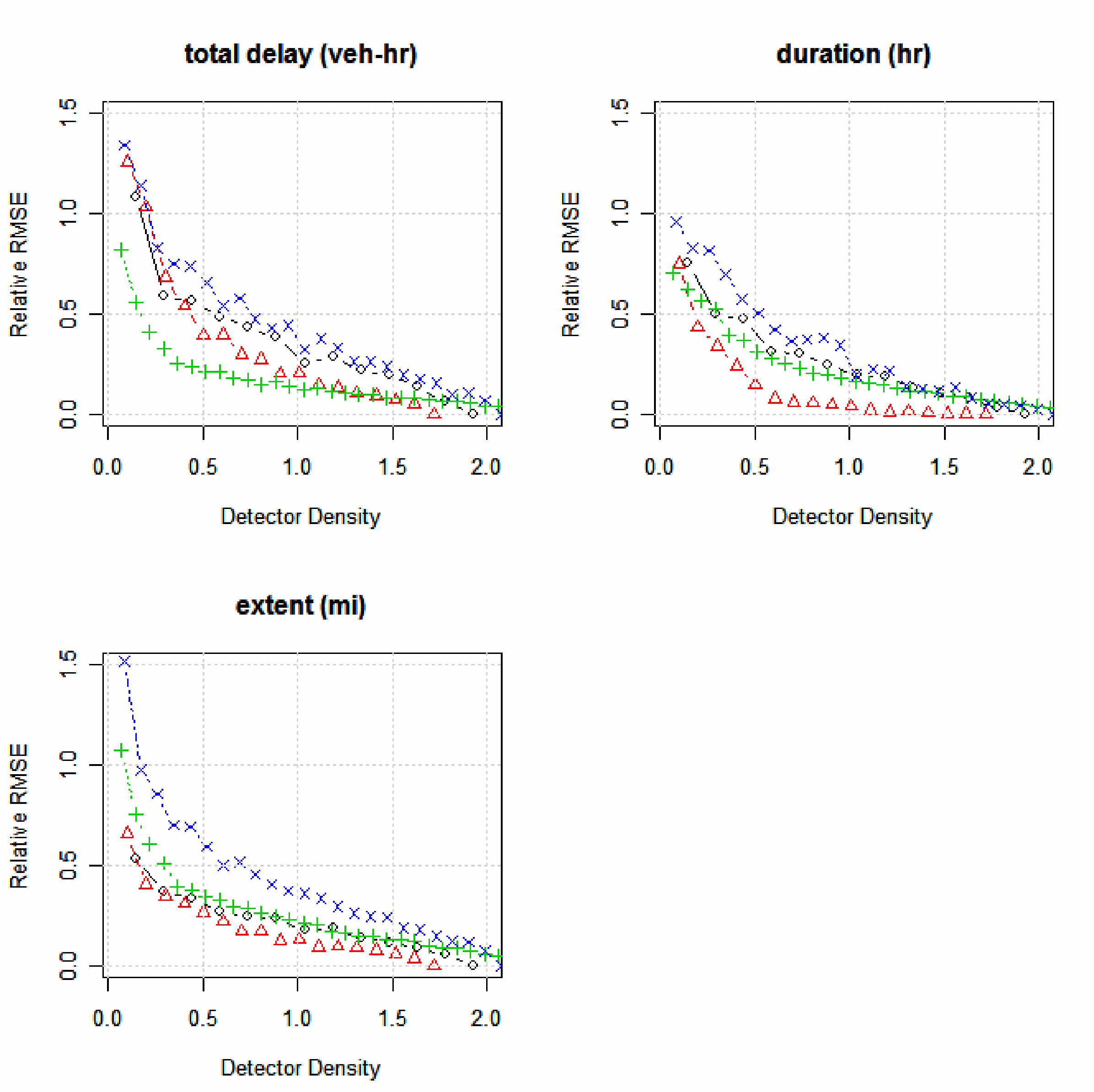


Figure 17 Summary of the RMSE error for the four sites as a function of detector density (number of detectors per mile)

Figure 17 gives the final summary of the accuracy of the congestion parameter estimates. It is obtained as follows. We first replace the 10 curves in Figure 16 by a single curve given by their median values. Next we replace the number of detectors (the *x* axis in Figure 16) by the detector density, i.e. we divide the number of detectors in each segment by the length of the segment. Thus the *x* axis in Figure 17 is the number of detectors per mile of freeway. Lastly, we divide the RMSE in Figure 16 by the average value of the congestion parameter over the entire year. Thus the 'relative RMSE' of 0.5 means a RMSE equal to 50 percent of the average value. Furthermore, detectors may miss congestion whose extent is smaller than the detector spacing. Combining this observation and Figure 17, we see that *if one wants a relative RMSE of 0.1, one must have a density of at least one detector every 0.5 mile.*

Aggregation error

This error in PeMS-based estimates occurs because of frequent changes in the configuration of the detector system, i.e. the number and location of the detectors, and the uneven quality of detector data. Figure 18 illustrates the concern raised by configuration changes.

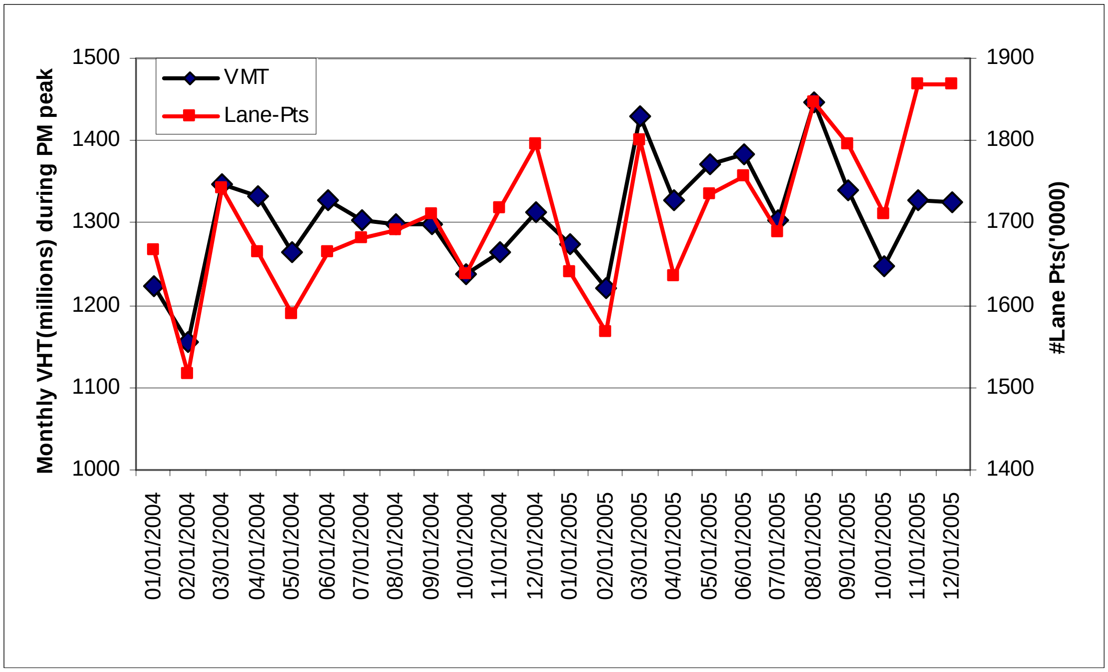


Figure 18 Total monthly statewide VHT during PM peak and expected number of lane points

The red graph in Figure 18 gives the monthly total data coverage, measured as the number of lane points of data that PeMS expects. Observe that this total fluctuates considerably from month to month. For instance, from February 2004 to December 2005, the coverage increased by 23 percent, of which 10 percent is accounted by the increase in the number of days from 28 to 31.

The black graph is the monthly statewide VMT during the PM peak hour, calculated from the data whose coverage is depicted by the red curve. The correlation between the two series is so high (0.72), that one cannot avoid the conclusion that the monthly VMT fluctuation is an artifact of the fluctuations in coverage, and reflects changes in the detector system configuration reported by the Districts and in the number of days in each month.

We can attempt to compensate for these changes by dividing the monthly VMT by the coverage as in Figure 19. The *x*-axis is now the monthly PM peak VMT per expected number of lane points. The month-to-month variation is now quite different from that suggested by Figure 18. Indeed, Figure 18 suggests that monthly PM peak delay increased slightly in 2005 compared with 2004, whereas Figure 19 shows the seasonal fluctuations: high VMT during March-May and low VMT during September-December. The point is that one must take care to take into account the underlying detector configuration when using PeMS data.

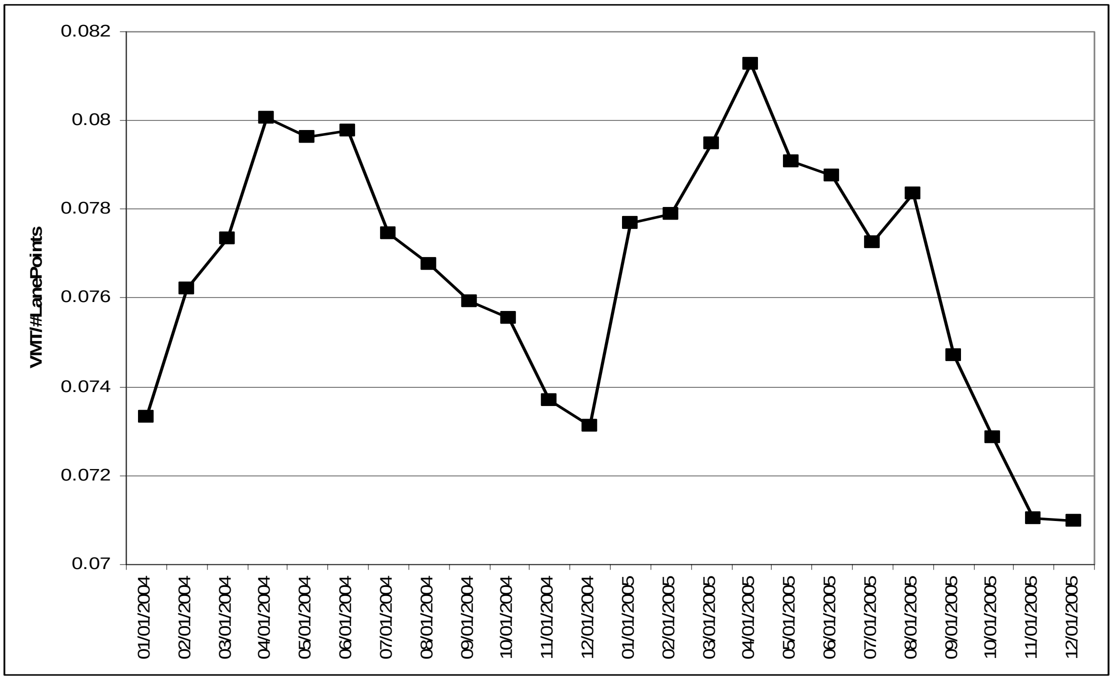


Figure 19 Monthly statewide PM peak VMT/expected number of lane points

Figures 20, 21 illustrate the concern about data quality. Figure 20 is the counterpart of Figure 18 for total monthly PM peak delay and detector coverage. The black graph is the monthly delay and the red graph is, as in Figure 18, the expected number of lane points. The correlation of 0.64 between the two series is smaller than in Figure 18, because fluctuations in delay are far more pronounced than fluctuations in demand or VMT, so the quality of the data plays a more significant role. This is suggested in Figure 20: the correlation between the series of observed samples and delay is 0.67.

To summarize: *Accuracy in PeMS-based congestion estimates requires a detector spacing of less than 0.5 miles. Congestion measures using PeMS data should not be used to make inter-year or inter-district comparisons, unless sufficient care is taken to account for the underlying changes in the configuration of the detector system and the quality of the data.*

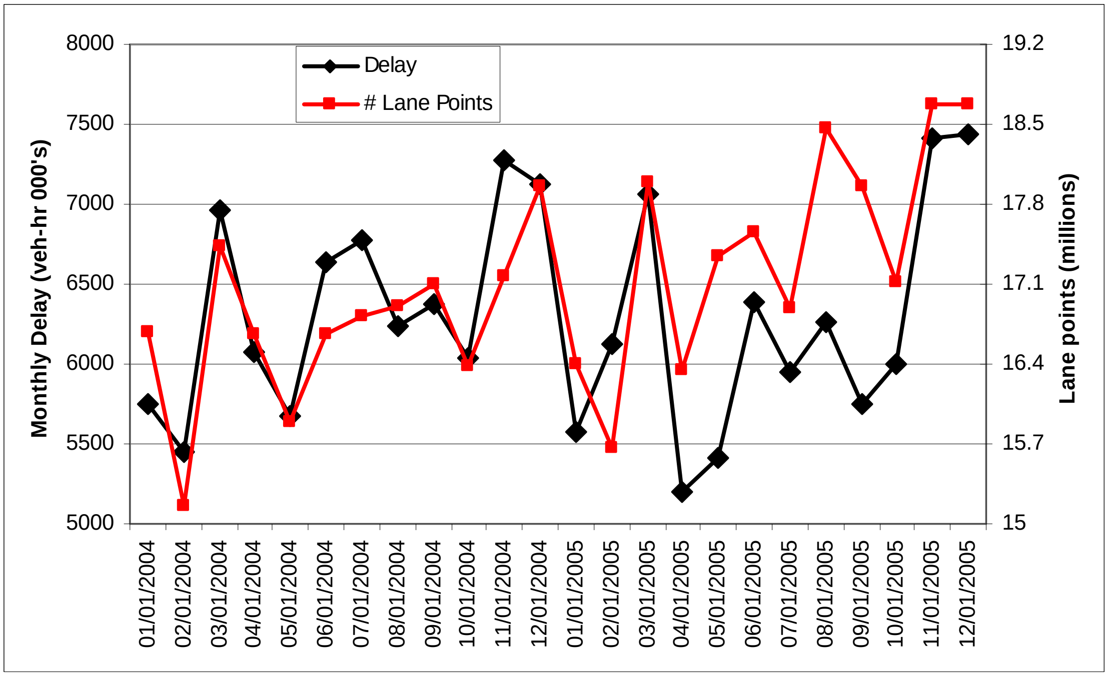


Figure 20 Monthly statewide PM peak delay and expected number of lane points

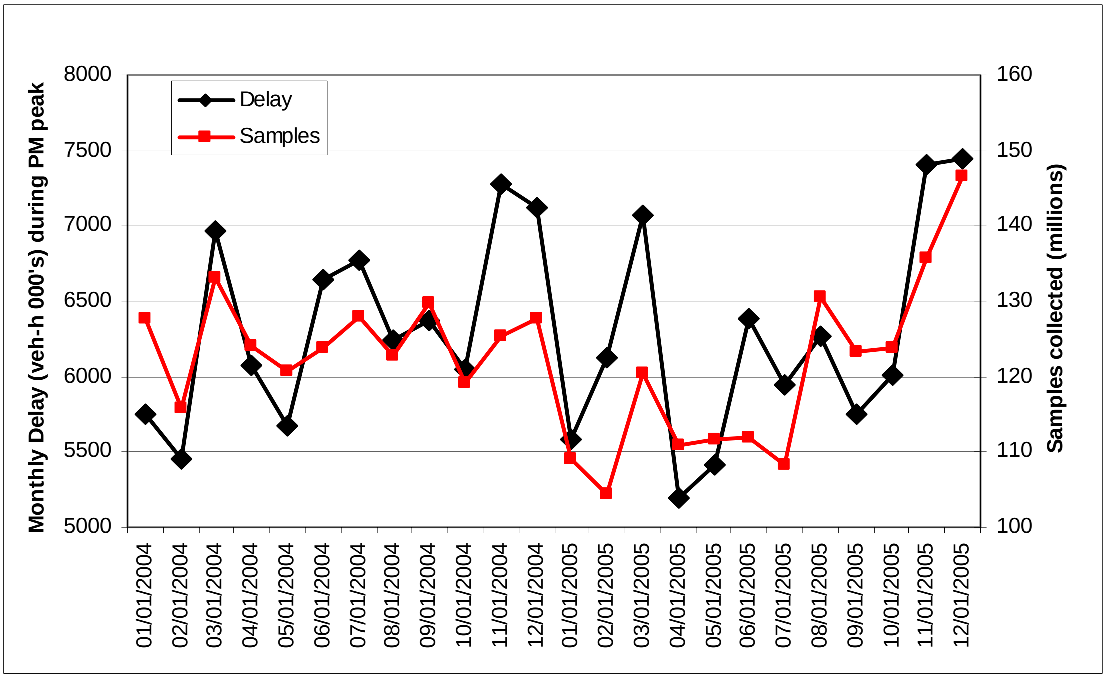


Figure 21 Monthly statewide PM peak delay and number of samples collected

4.3 Error characteristics of tach-run based and PeMS-based congestion monitoring

This section summarizes the empirical relationship between the error characteristic (in terms of percent error or, equivalently, relative RMSE) and the two 'sampling' parameters, the number of days sampled and detector density.

Effect of sampling of days

We computed the population mean (D, L and T) and standard deviation (σ_D, σ_L and σ_T) of the three congestion parameters for the four study sites in section 4.1 (Table 4). The percent error in estimating D, the total delay, is given by

$$\text{Percent error} = \frac{\sigma_D}{D}\sqrt{\frac{N-n}{n(N-1)}},$$

in which N = 260 is the population size (total number of weekdays in a year) and n is the number of days sampled. The percent errors in estimating the two other parameters L and T are defined similarly.

Figure 22 shows the relationship between the percent error and n for the four sites. Thick lines represent the average of the four curves.

Effect of detector density

The empirical relationship between the percent error and the detector density was already presented in section 4.2 (Figure 15). Figure 23 summarizes the result. (The only change from Figure 15 is that the independent variable is detectors/mile.) Each line corresponds to the four study sites and thick lines represent the average of the four curves. Since detector density is irregularly spaced, a smooth curve was fitted via LOESS [5] to obtain the average curve.

Use of the empirical error curves

The error characteristic curves presented above can be used to approximate the percent error that can be achieved by a given sampling scheme and detection density. For a tach run-based method, assuming that each tach run produces accurate congestion measurements on that day, the percent error can simply be found using Figure 22. For a loop detector-based method, if detectors report on many days (at least 20 days out of 260), detector density will dominate the error and the percent error can be found using Figure 23.

Detector data may not be available for many days because of detector or communication failures. In that case, sampling of days and detector density both contribute to the percent error. The simple formula

Percent error = Percent error from sampling of days + Percent error from spatial sampling

can be used to approximate the percent error in such case. This formula is based on the assumption that errors from sampling of days and detector density are independent, which seems reasonable.

Fixed detectors, especially loop detectors, can be unreliable and the data could contain many missing and/or imputed values. The approach described above could be used to handle missing or imputed values as well: detectors that are broken most of times would increase percent error, the effect of which can be quantified in terms of detector density; on the other hand, many detectors that fail together on many days can be analyzed as the reduction in the number of days sampled. Note though that such computation yields a conservative or pessimistic estimate of the accuracy of the loop based method, especially PeMS, since imputation in PeMS is done intelligently to capture and reflect traffic patterns and using imputed values would be better than not using them at all.

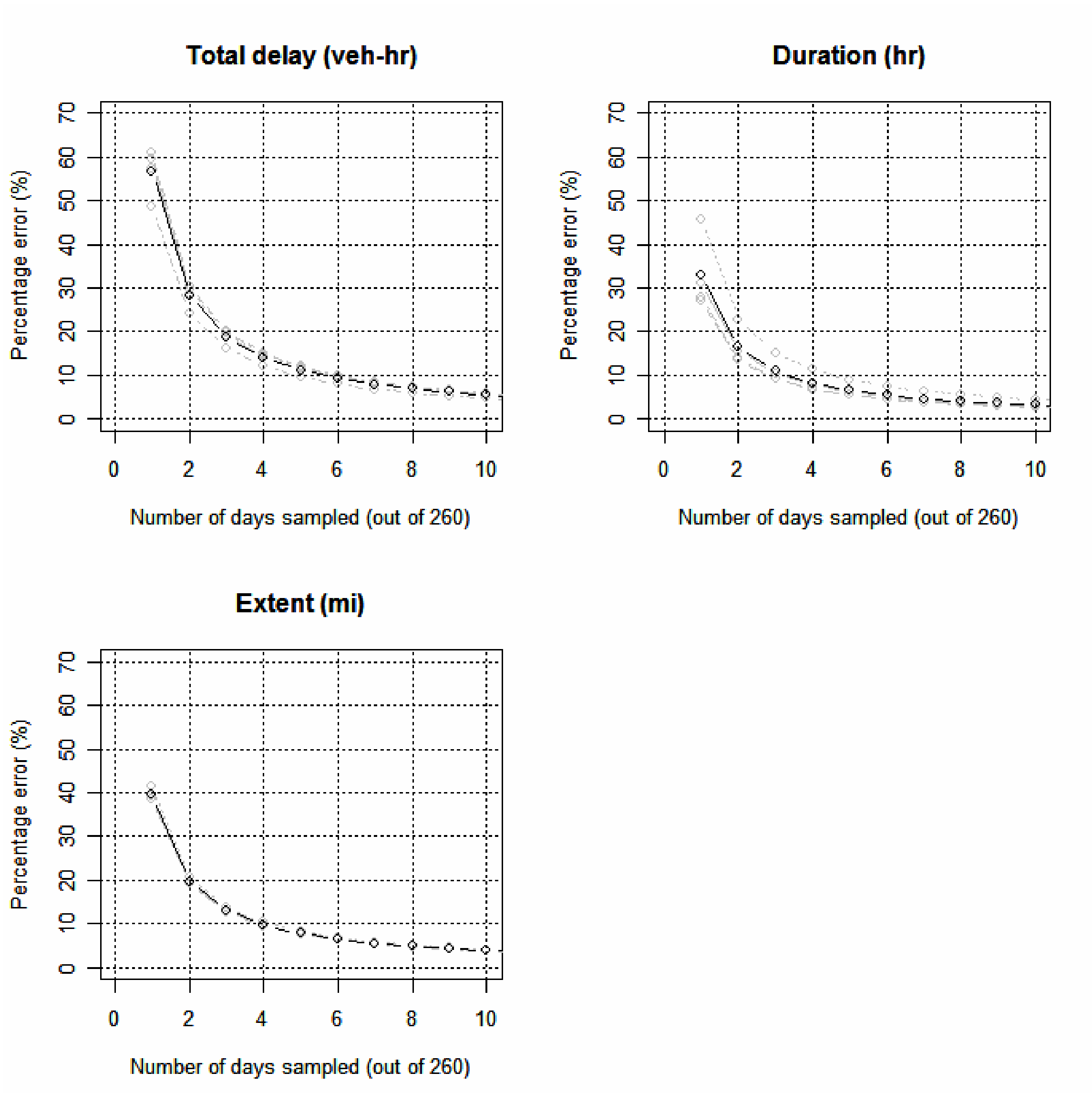


Figure 22 Percent error for congestion parameters vs. number of days sampled (out of 260 weekdays in a year)

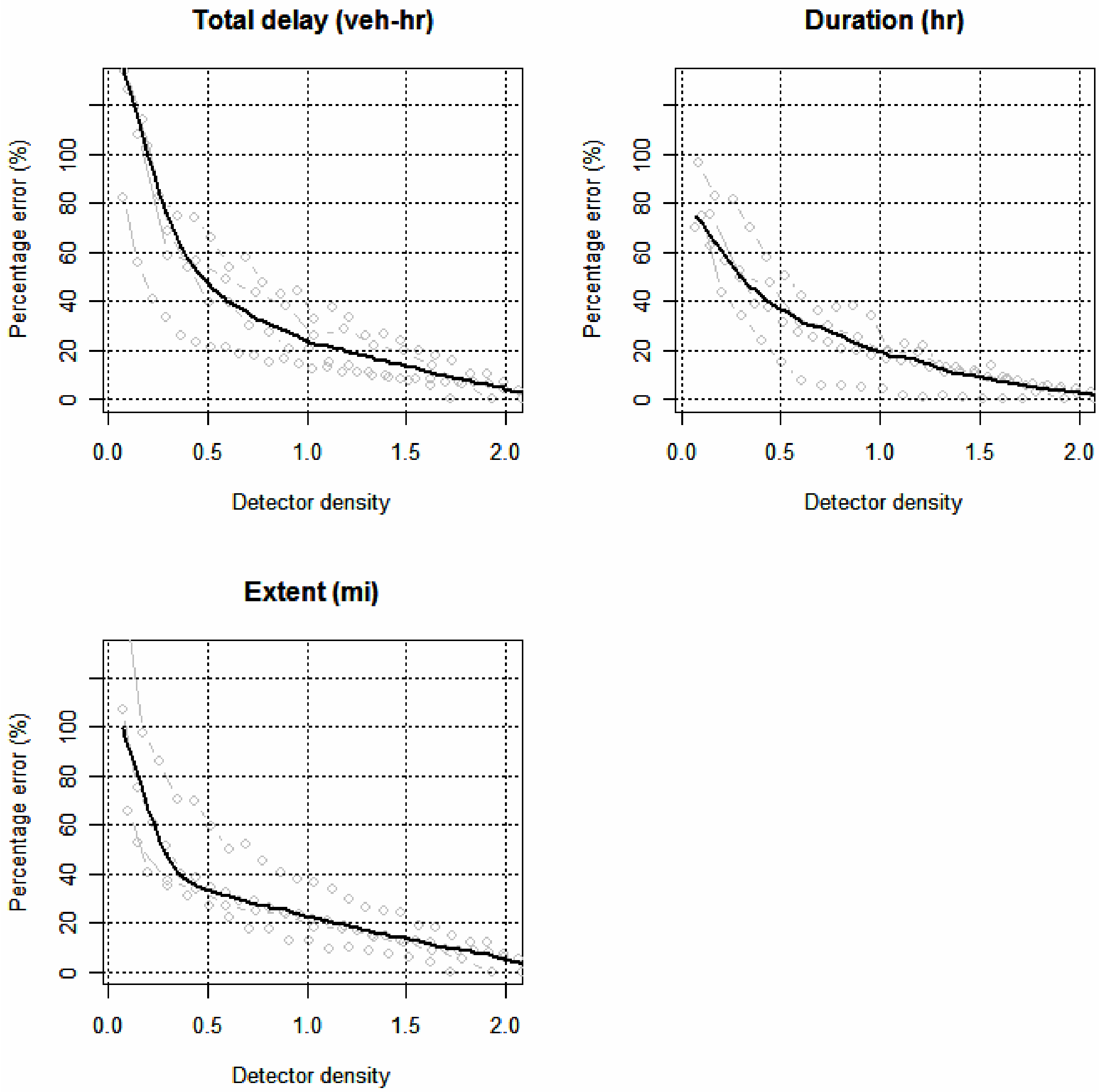


Figure 23 Percent error for congestion parameters vs. detector density (detectors/mile)

5 Cost comparison

5.1 Tach vehicle cost

The estimate of probe vehicle cost of $264 per monitored mile per day of data collection is based on:

- Analysis of District 8 tach run data for a total of 166 directional miles
- Assuming 3 vehicles running at 20-minute headway for one time period monitored (AM or PM), not the entire day
- Assuming labor cost of $72,000 per person per year plus 100% overhead or $258 per monitored mile per day
- Vehicle operating cost (gas, oil, maintenance, tires, insurance) equal to $0.18 per mile, or $6.00 per monitored mile per day, based on AAA "Cost of driving" analysis.

Thus using tach vehicles to monitor 10 miles of freeway for four days in the year will cost $264×10×4 = $10,560. This estimate excludes vehicle depreciation.

5.2 Detection cost

Detection costs are based on an analysis of a 10-mile urban freeway segment with metered interchanges every 0.5 mile.

Assumptions for TMS Inventory costs are:

- Typical TMS installation assumes 4 lanes in each direction and 2 loops per lane
- Annual maintenance and support staff cost is in the Division of Traffic Operations
- Hardware and software lifecycle is 25 years
- Hardware lifecycle cost is taken as 60% of the hardware lifecycle cost for traffic signals
- IT software developed in-house and development cost included in the per unit implementation cost.

These assumptions lead to an annualized life cycle cost (capital + O&M) of $6,300 per station. A10-mile freeway with stations every 0.5 mile needs 20 stations at an annualized cost of $126,000.[5] We allocate 25 percent of this cost or $32,000 for the HICOMP application, and the remaining 75 percent to all other PeMS applications.[6] This is equal to the cost of 12 days of tach vehicle runs per year. As we have seen, the resulting accuracy of the estimates is much greater.

[5] It should be noted again that the detector station cost estimates may be exaggerated. Moreover, new detection technologies provide data that are more accurate than loop data at about one-sixth the cost presented here.

[6] These applications include ramp metering, traveler information, vehicle census counts, bottleneck location, etc. Together, these applications are far more valuable than providing HICOMP congestion estimates. Nevertheless, the allocation of 25 percent of the detection cost to the HICOMP application is arbitrary.

6 Proposal for PeMS-based congestion reporting protocol

The purpose of this section is to outline a standardized congestion reporting protocol that can be implemented across districts to document congestion.

Caltrans has been working toward a standardized congestion reporting protocol using a wide range of performance measures since 1998. In that year, Caltrans embarked on an initiative to develop transportation system performance measures and in 2002, the Transportation Management System (TMS) Master Plan included a *Performance Measurement Framework* report that identified additional measures to analyze the operational aspects of the transportation system.

These measures focus on operational strategies to improve the safety, mobility, reliability and productivity of the transportation system. The report recommended a new measure, productivity, and identified additional indicators to evaluate the relative performance of TMS strategies, including ramp metering, incident management, arterial system management, and traveler information systems. Theses measures were incorporated into the Caltrans' "One Vision/One Mission" statement adopted in 2003 to improve mobility across California. In 2005, Caltrans and regional planning agencies agreed on revised performance measures to include improved productivity and reliability measures.

Currently, Caltrans maintains a website within the Division of Transportation System Information (TSI) that provides the public with information related to performance measurement. This site is located at http://www.dot.ca.gov/hq/tsip/tspm/.

Beginning in 2002, Caltrans also began to implement some of these measures for congestion monitoring by using PeMS in the annual *Comprehensive Monitoring Reports*. This on-going effort is used to "test drive" comprehensive performance measurement and to see how they can be routinely be applied to freeway congestion monitoring. Although the comprehensive reports do not address the entire State or all the indicators needed, it is a step in the direction that leverages the wide spectrum of data that automatic congestion reporting can provide including:

- Delay by quarter, month, weekday, and hour of the day for severe (<35mph) and other (<60mph) congestion
- Productivity changes as measured by lost-lane miles
- Travel times, speeds and travel time reliability between significant origins and destinations, measured by the percent variation in travel time
- Impacts of accidents on congestion (i.e., measuring recurrent vs. non-recurrent congestion)

In contrast to the annual vehicle-hours of recurrent delay estimates provided by tachometer-based data collection, using automatic data collection can provide planners and operational staff with robust and wide-ranging information from which decisions can be made to mitigate congestion.

The current HICOMP reporting methodology using tachometer vehicles is not a cost effective way to capture the types of information needed for effective transportation system management. As shown in Section 5 of this report, it is very costly to collect these data, and the resulting congestion estimates are not reliable. In addition, each district uses different approaches to analyze tachometer data, which further makes inter-district comparisons difficult. In one example, there is no consensus on the constant flow-rate to use for calculating delay (i.e., 2,200 vehicles per lane per hour vs. 2,000 vehicles per lane per hour). As shown in Section 2 of this report, the different methodologies used can result in different answers from the same tachometer data.

In the protocol that we suggest below, we attempt to answer a number of questions:

(1) What mechanisms in PeMS can be used to assist in the automated generation of the HICOMP report?

(2) What framework can be used to determine where to use tachometer runs and where to use PeMS?

(3) When using PeMS, what information should be collected in the HICOMP report?

(4) What steps can be taken to mitigate the transition from tachometer runs to PeMS-based reporting?

(5) In the short run, where should Caltrans invest to improve detection on freeways to better capture on-going traffic data?

(6) How will tachometers be used in the future and which consistent and uniform methods should be used statewide for collecting and analyzing the tachometer data?

PeMS Reporting Mechanisms

The basic unit of analysis for HICOMP is a section of the freeway. These sections are defined by the district personnel as locations that are important to monitor from year to year. A freeway section consists of a single freeway from a given starting postmile to an ending postmile (usually from on-ramp to off-ramp). PeMS has the ability to do a number of reports over arbitrarily defined portions of the freeway system. To generate these reports a user navigates to a particular freeway, enters a postmile range of interest and then requests various types of reports (average delay versus time of day, LOS analysis, etc). While these reports provide a great deal of control (the user can select any postmile range on the freeway system and see a plot for any requested performance measure right away), they suffer from the fact that all values are computed on the fly when the report is requested by the user. The result is that these reports are relatively slow and the maximum time range that a single report can span is relatively small.

In response to this, PeMS has the ability to let users define a *route* on the freeway. A route is a path through the freeways that an individual driver would take. It typically starts at an on-ramp, continues along one or more freeways, and then ends at an off-ramp (one can also define a route from a specific starting to ending postmile). Once a route is defined in PeMS all of the performance measure computations and aggregations over time are performed in real-time and stored in the database. The result is that reports over these predefined routes are very fast.

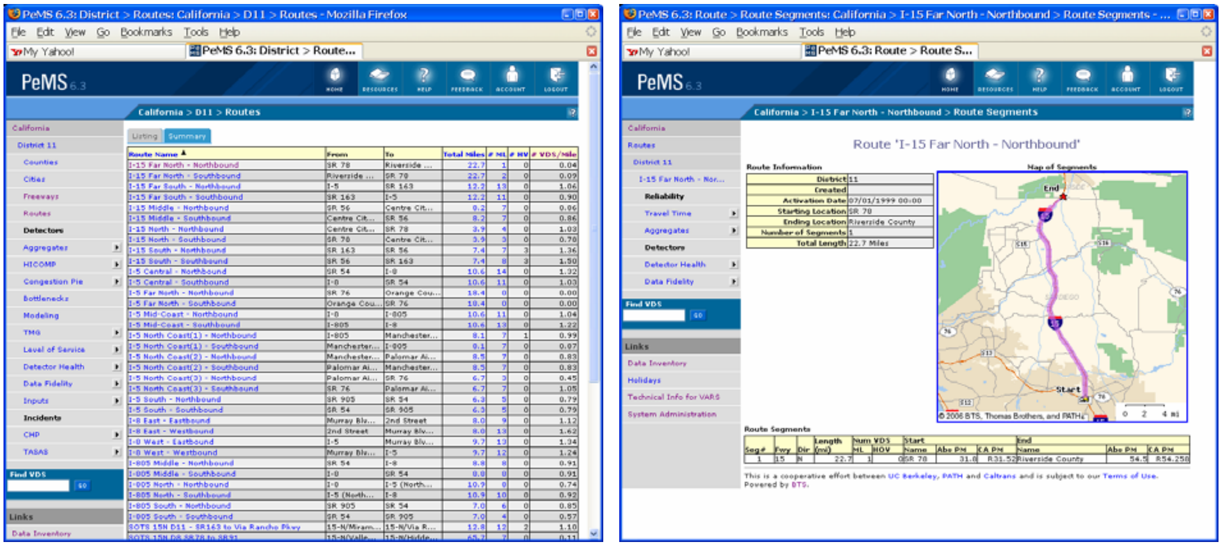


Figure 14. List of routes in D11 (left). Route configuration page for a single route (right).

In Figure 14 on the left is a list of predefined routes in District 11. In this particular District the routes were defined by the local MPO, SANDAG. In other districts a small set of routes have been predefined by UCB personnel for demonstration purposes. On the right of Figure 14 is a route configuration page from PeMS. This page shows the location of the route on the freeway and gives some simple configuration information.

The route feature in PeMS has been optimized for long-term reporting of performance measures. The set of reports that currently can be generated over routes fall in to two main categories and include:

(1) Travel time, as computed via the extrapolation method. These reports include:

   a. Travel time versus time of day.

   b. Average travel time versus a particular day.

   c. Average travel time versus time of day (including other descriptive statistics).

   d. Average travel time for a given departure time over long periods of time.

   e. Travel time variability for each plot.

(2) Aggregate performance measures. These are the standard spatial freeway performance measures, including:

   a. VMT, VHT, Q (VMT/VHT), Delay (versus different speed thresholds), Travel Time Index.

   b. Performance measures versus time.

   c. Average performance measures versus time of day and day of week.

   d. Ability to restrict to a particular time range of the day.

In addition users can investigate detector health and data quality over routes.

Given these features, we recommend that Districts use the route feature in PeMS as the basic mechanism to organize their HICOMP reporting. Hence we propose that the Districts create routes in PeMS that correspond to freeway sections that need to be examined. The knowledge of which freeway sections should be reported upon, which sections of freeway should be grouped together in a route when reporting, and how many sections, is all contained within the experts in the District. Using HICOMP congested segments as a starting point might be a good approach. In addition, we also recommend that the District define routes to completely cover the freeway system in the District. It is important to note that once defined, the computations for the route are done automatically – one essentially gets the resulting reports for free. Whether one chooses to use the report for a route directly or to augment it with tachometer-based reporting is addressed next.

Deciding Between Tachometer Runs and PeMS-Based Reporting

The research here indicates that detector spacing ½ mile apart or less is necessary for accurate, automatic monitoring along a route. The detectors also need to be producing consistent and reliable data over an extended time period for that route. In other words, it's not just the detector density that we need to look at, but, in addition, whether the detectors on the route are functioning. PeMS has both of these pieces of information and they can be used to determine whether or not tachometer vehicles need still to be used for a particular route.

As part of the standard display of routes, PeMS reports the density of detectors – the number of mainline (ML) detectors per mile. In addition, every night, for every lane detector in the system PeMS performs a series of diagnostic tests on the data received from the detectors. It determines whether the detector is "good" depending on the results of these tests. This information is stored and then can be used to assess the quality of the detectors along a route.

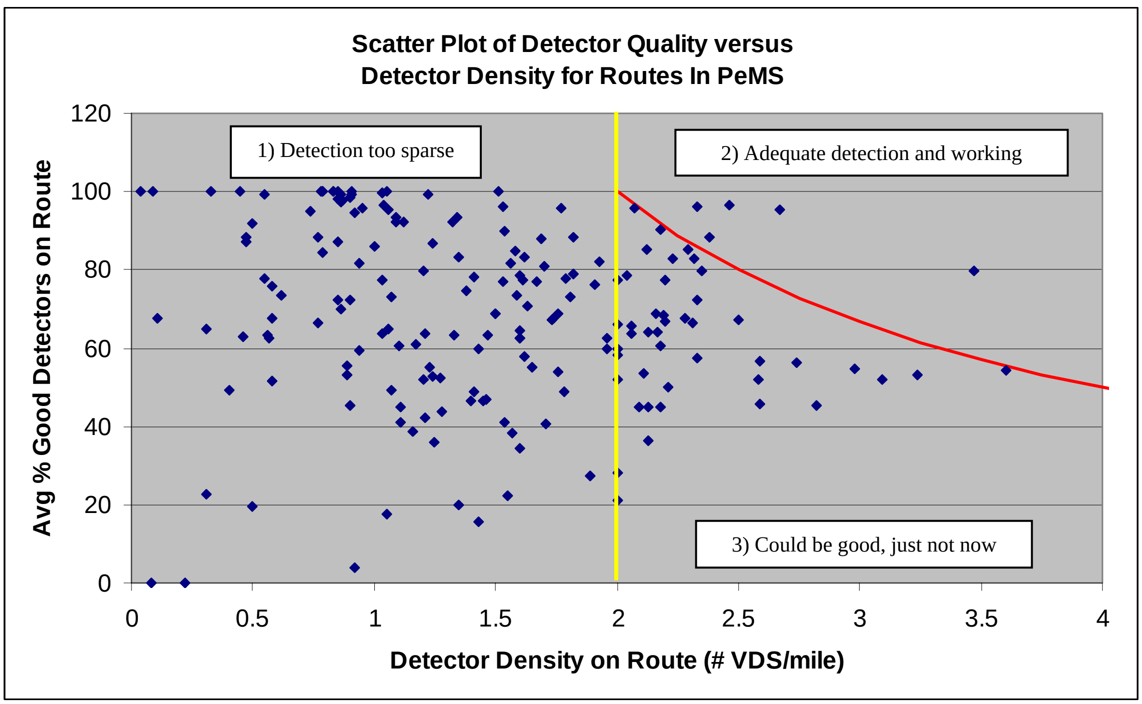


Figure 25. Scatter plot of detector health and detector density for each route currently in PeMS.

Figure gives a representation of what the analysis might look like to support a decision as to whether to use tachometers or PeMS. As we mentioned before, PeMS has a number of routes predefined (just over 160). With the exception of D11 these are mostly for demonstration purposes. This figure is a scatter plot of two statistics about each route (each point represents a route). Along the x-axis is the density of mainline VDSs for the route. The y-axis gives the average percent of detectors along the route that are good, for the month of July, 2006. In addition to the route points, we've added two additional lines. The vertical yellow line is the density threshold at 2 VDS per mile (i.e. average spacing of ½ mile). All of the points to the right of the yellow line are routes that have a density higher than 2 VDS per mile. All of the routes to the left of the yellow line have a density below this threshold and should only be monitored with tachometer vehicles. As we mentioned, the detector density is a necessary condition to monitor a route with PeMS, but it's not sufficient. Not only does the route need more than 2 VDSs per mile, it needs the VDSs to be working. One way to compute the "effective" density of detectors is to multiply the density of detectors by the percentage of detectors working along the route. The red sloping line in Figure delineates the region where there are "effectively" more than 2 VDSs per mile (it is an isoline for effective detector density). Anything above this line is considered a good route because it has an effective density of 2 or more VDSs per mile. Any route below this red line, but to the right of the vertical yellow line, is a route that has the necessary density of detectors installed, but too many of them aren't working. Hence they should still be monitored by tachometer vehicles.

This analysis was done for the month of July, 2006, and it is based on the detector health during that month. This type of analysis can be used to determine where to use PeMS in a *post hoc* analysis. But it is slightly deficient when trying to determine where to run tachometer vehicles – the detector quality is for the past, not the future (which is when one is going to run tachometer vehicles). Hence one can use this type of analysis as a starting point if you assume that the detector quality won't change much over time. Hence it is prudent to fold in knowledge of any programs, like detector improvement projects, or construction projects, that might change the health of the detectors along a route in the future when the tachometer runs will take place.

Information to Collect for PeMS-Based Reporting

As mentioned earlier, Caltrans is moving towards more extensive and detailed monitoring of the congestion on the freeway system. PeMS has the ability to assist in that process with a number of different reports and tables. As was discussed above in the section on PeMS-based estimates, the current recommendation is that for freeway-direction segments that have a density of 2 detectors per mile that PeMS-only congestion monitoring techniques be utilized. Nevertheless, we are recommending that the following PeMS-based performance measures and information be captured on all freeway segments each year regardless of the density of detectors. Since future congestion monitoring reports will always include measures about the data quality, having consistent reports will allow future engineers to simply note the given data quality and use this to make assessments on where to improve detection coverage in the future.

The current HICOMP report is meant to quantify the extent, duration and magnitude of congestion. There is a growing realization that travel time and travel time reliability are important measures to consider when looking at freeway performance measurement. These are measures that individual users traveling through the system experience directly. In a customer-focused environment it is critical to be responsive to the perceptions of the individuals using the system. Hence our proposal below will capture not only the traditional HICOMP measures but these new measures that are receiving increased attention.

Given these discussion points, we recommend that for each defined route in the district the following three groups of information be recorded:

1. Configuration Information
    a. Basic freeway information
        i. Length of route.
        ii. Average number of lanes.
        iii. Are there HOV lanes? Occupancy requirements? Time of day policy? Length?
    b. Sensor information
        i. Sensor coverage
        ii. Number of individual mainline, HOV, on-ramp, and off-ramp lane detectors
        iii. Number of mainline and HOV stations (VDSs)
        iv. Number of mainline and HOV stations per mile
    c. Sensor health
        i. Percentage of samples collected per month
        ii. Number of good detectors per month
2. Performance Measures
    a. Route demand information
        i. For the whole year: AADT for each sensor
        ii. For 2-3 sensors on route, weekday ADT per month over the entire year
        iii. For the whole year year: weekday, non-holidays, AM and PM shift, VMT/month
    b. Route congestion information
        i. For the year: weekday, non-holidays, AM and PM shift, Delay(Vt=60)/month
        ii. For the year: weekday, non-holidays, AM and PM shift, (lost productivity(Vt=40) as a percentage of total lane-mile-hours)/month
        iii. For the year: weekday, non-holidays, AM and PM shift, average spatial extent of congestion per month.
    c. Trip congestion information
        i. For year: weekday non-holidays, AM and PM shift, (Avg Travel Time, BTI) per month for a trip starting:
            1. AM shift: 6:30am, 7am, 7:30am, 8am;
            2. PM shift: 4:30pm, 5pm, 5:30pm, and 6pm.
3. Exogenous Effects
    a. Freeway operations information
        i. Was a rotating tow-truck program in place? When? Where?
        ii. Was ramp metering in place? What algorithm? What time of day?
        iii. Any CMS? Number of messages shown per month.
        iv. Any changes in operational strategies?
    b. Construction information
        i. Description of any major construction events on route during the year (lane widening efforts, shoulder work, HOV extensions, resurfacing, etc)

ii. Plot of the number of construction event-days per month

c. Incident information
    i. Plot showing the number of accidents, breakdowns and other per month for route
    ii. Incident segment analysis plot with overlapping segments with bin width of 2 miles and steps of 0.2 miles
    iii. Plot showing the incident rate (inc/vmt) per month over year

d. Weather information
    i. Number of days per month that have any precipitation
    ii.

In addition to these measures on each route, we recommend that for the entire district we collect the additional information:

1. List of the top 10 bottlenecks per quarter sorted by number of days activated showing average delay and spatial extent for each.
2. List of the top 10 incident hot spots (as identified by the overlapping segment analysis).

Most of the performance measures are automatically calculated by PeMS. The parts that need to be collected on a periodic basis (weekly?) include the list of operational activities, the construction events, and the weather.

Transitioning from Tachometer Runs to PeMS-Based Reporting

Caltrans is legislatively required to prepare an annual HICOMP report. Furthermore, this report is used in part to fund the Freeway Service Patrol (FSP) around the state. Until detection is improved so that all statewide reporting can be done by PeMS, for reporting consistency, Caltrans is continuing to produce the "traditional" HICOMP report.

In the year that a district decides to transition a segment from tachometer-based data collection to PeMS, there will certainly be a difference in the delay reported given the inherent errors in the two approaches described in the preceding sections of this report. A district has two options to mitigate any political or FSP funding repercussions caused by congestion being reported as declining during the transition year when "everyone knows that congestion is getting worse".

If discontinuity in congestion trends is not a major issue, the district can simply add an explanatory footnote to the results stating that the delay number in the current year may reflect the transition to a new methodology rather than a change in congested conditions. The footnote can explain that subsequent reporting years will reestablish a trend.

Another way to mitigate negative repercussions of transitioning is to use PeMS to go back one or two years and generate reports of delay along the transitioning segments for prior HICOMP years. An explanatory footnote can explain the newly established trend. The advantage of going back a year or two is that in the current reporting year, FSP funding will be based on the change from the previous year to the current year and will not be affected by the transition due to the change in methodology. This is because the discontinuity occurred in the prior year when funding had been already been allocated based on the old trends.

Framework for Short-Term Detection Improvements

Caltrans needs a plan to implement additional detection on California' freeways. This plan can be phased to first address corridors where there is the most need for detector improvement. There are two parts to our proposed prioritization scheme. First, it's clear that the set of routes to initially address are those in Figure that are to the right of the vertical yellow line and below the red sloping line (labeled category 3 in the figure). These are routes that have an adequate density of detectors already installed on the freeway but for some reason they aren't functioning. Hence maintenance, possibly configuration checking, needs to be performed for the detectors on these routes. These detectors represent the "low hanging fruit" for detection improvements. No new detectors need to be installed, only the current ones need to be fixed, and we'll have adequate coverage for continuous congestion monitoring.

The second part of our proposed prioritization involves combining information about routes that have a low detector density with information about congestion. Figure , below, illustrates how this prioritization might take place. The goal of this exercise is two-fold: (1) identify segments where the average effective detector spacing is greater than ½ mile, meaning the effective density is less than 2 VDSs/mile, and (2) identify segments with higher levels of congestion.

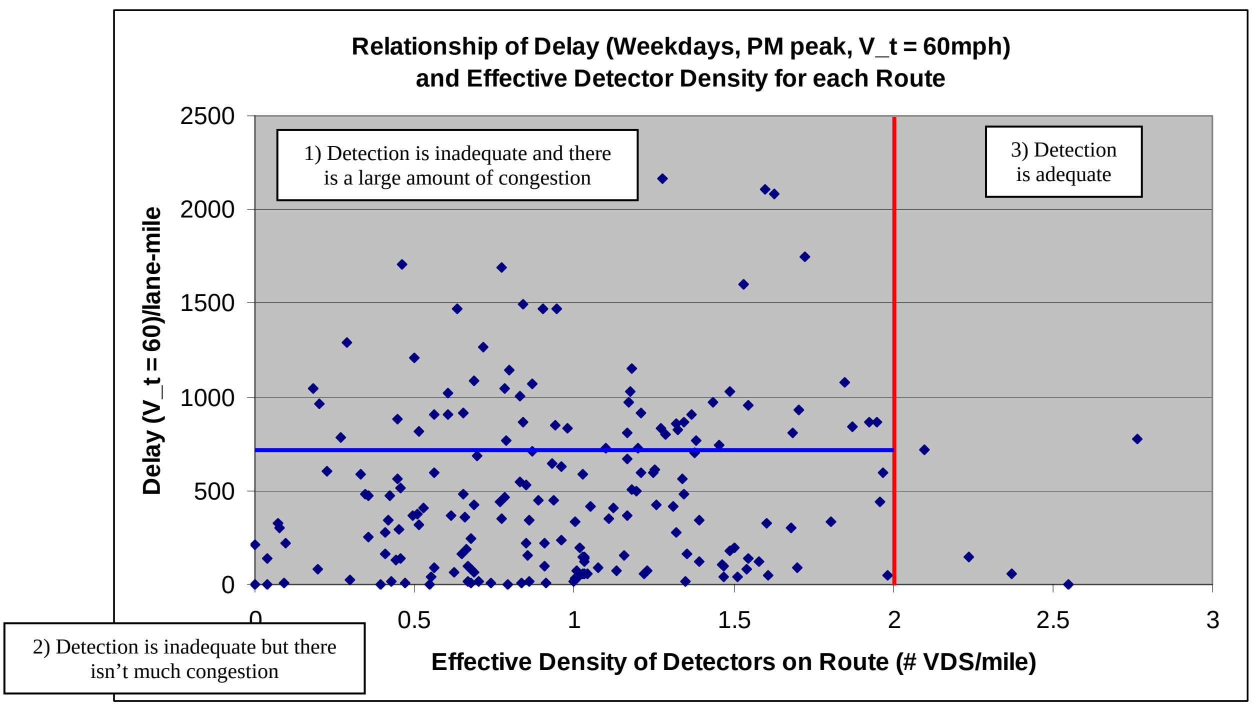


Figure 26. Scatter plot of congestion versus effective detector density for routes currently in PeMS.

In Figure we have taken the routes currently in PeMS and we've placed them on a scatter plot to illustrate the congestion on the route and the effective detector density. The x-axis is similar to the x-axis in Figure but we're now plotting effective detector density. We've simply multiplied the detector density by the average percentage of good detectors on the route. Hence the red sloping line in Figure , which delineated the routes with sufficient good detectors, becomes the red vertical line here. All of the routes to the right of this line have sufficient effective detector density. The y-axis is a measure of congestion along the route. Specifically, we measured the average delay per weekday during the PM peak period during the month of July, 2006 (one could easily have used the AM peak, or some other measure). We then normalized this delay by the number of lane-miles in the route so that we can compare them to each other.

The routes with the highest priority for detection improvement (in this second phase of improvement) are routes with existing high levels of congestion and that have inadequate detection coverage. These fall in the upper left corner of Figure . We can consider these as priority 1 detectors to repair. Conceptually, these routes are experiencing significant congestion and we aren't adequately measuring it. Hence they are problem areas that we can't measure correctly. Priority 2 routes have inadequate detection coverage, but lower levels of congestion. It would be nice to improve the monitoring on these routes but since there isn't much congestion it's a lower priority. Finally, priority 3 routes, which lie on the right side of the red line in Figure already have sufficient effective detector density.

Within Priority 2 there may be additional criteria for prioritization. These criteria would be for routes that are growing in congestion over time. This would require a trend analysis for the route to identify these emerging hot spots (which can be done by PeMS).

In summary, our prioritization scheme is as follows:

1. Fix existing detectors on routes that already have sufficient detector density.
2. Install additional detectors on routes that are experiencing high congestion yet have inadequate detector coverage.
3. Install additional detectors on remaining routes that don't have adequate detector coverage.

The Future of Tachometer Data Collection and Processing

There is some agreement among Caltrans district staff that tachometer data collection will likely continue for some time into the future in areas where automatic detection is not available and congestion exists. If tachometer data collection is to continue in some form, then Caltrans needs to have district staff involved in data collection agree on a methodology for analyzing tachometer data. Current analysis procedures allow for too much variation in results across districts.

Acknowledgements

The work reported here has benefited from advice, comments and interest of Rex Cluff, Robert Ferwerda Jr, Mohammed Khazari, Ron Kyutoku, Joe Palen, Charles Price, Brian Simi, Bill Wald and Zhongren Wang of Caltrans; Lisa Klein of MTC; and Alex Skabardonis and J.D. Margulici of U.C. Berkeley.

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[1] PeMS website: http://pems.eecs.berkeley.edu/

[2] Caltrans, District 4, *Congestion Monitoring Procedures and Guidelines*, September 1996.

[3] Caltrans, *State Highway Congestion Monitoring Program (HICOMP): Annual Report*, January 2005.

[4] *Guide to Effective Freeway Performance Monitoring*, NCHRP 3-68, March 2006.

[5] Cleveland, W. S., LOWESS: A program for smoothing scatterplots by robust locally weighted regression. *The American Statistician*, Vol. 35, Issue. 54, 1981.

[6] Margulici, J.D., Babiceanu, S., and Huang, C-L., *Next-generation HICOMP system, Final Report*, July 2006.

Appendix 1: Caltrans District Practices

This appendix documents past and current methodologies used to monitor congestion on California's urban freeway and expressway system. The California Department of Transportation (Caltrans) monitors traffic congestion to produce the annual Statewide Highway Congestion Monitoring Program Report (HICOMP). This report will detail the data collection and processing methodologies in use to develop the HICOMP report.

Specifically this appendix will discuss:

- The HICOMP report, its history and the types of information that it provides;
- The two data collection approaches—probe vehicle and automatically collected—used for the report;
- The various Caltrans District office methodologies used to process the data.

Statewide Highway Congestion Monitoring Program (HICOMP) Annual Report

Caltrans is legislatively mandated to report statewide congestion levels annually. This has been done historically since 1987, and the importance of the annual HICOMP report was reiterated on September 5, 2002 when Governor Gray Davis signed into law AB2535 (Diaz) which states:

"The department shall, within existing resources, collect, analyze, and summarize highway congestion data and make it available upon request to California regional transportation planning agencies, congestion management agencies, and transit agencies." (California Government Code Section 14032.6)

The stated purpose of the HICOMP report is to measure *recurrent* congestion on *urban area freeways* for typical weekday commute periods. *Recurrent* congestion is that common day-to-day traffic congestion caused by too many vehicles being on the freeway at the same time, exceeding roadway capacity. The HICOMP report specifically excludes *non-recurrent* congestion that is caused by accidents, bad weather, special events or other incidents. State law defines a *freeway* as a "divided arterial highway for through traffic with full control of access and with grade separations at intersections". An *urban* freeway is one that lies in an urban area as defined by the Census Bureau.

The HICOMP report is also used in part to determine funding distributions to urban areas for the Freeway Service Patrol (FSP). FSP are teams of tow trucks that patrol congested urban freeways offering stranded motorists free services such as changing a flat tire, "jump-starting" a dead battery, repairing hoses, refilling radiators, or providing a gallon of fuel or a tow to a safe location off the freeway. Instituted in 1991 in Los Angeles County, the FSP has expanded to eleven urban areas. The FSP funding statewide is currently determined by formula with the HICOMP Report.

The HICOMP report defines recurrent congestion as a "condition lasting for 15 minutes or longer where travel demand exceeds freeway design capacity and vehicular speeds are 35 miles per hour (mph) or less during peak commute periods on a typical incident-free weekday". The published report describes congestion primarily at the District level, but county-level congestion statistics are also reported. Exhibit 1 is a map of the different Caltrans District offices and the counties that comprise each District.

Exhibit 1: Caltrans District Boundaries

HICOMP estimates three primary parameters: Extent, duration and magnitude.

Extent is the length of a freeway segment by direction that experiences speeds below 35 mph for 15 or more minutes. Extent is expressed in terms of congested directional miles (cdm). It is important to note that a one-mile stretch of roadway contains two directional miles (one mile for each direction of travel). Directional miles differ from lane-miles, which is the number of lanes in a given direction multiplied by the length of the segment in that direction.

Duration is the length of time expressed in hours that the directional segment remains congested. The HICOMP report only reports on typical weekday morning and afternoon commute period congestion, which is defined by the District. It is common for the morning commute period to cover the time between 4:00 AM and 10:00 AM with the afternoon or PM commute period covering 2:00 PM to 8:00 PM. The duration varies by segment.

Magnitude is the difference in travel time under congested conditions compared to the time that it takes to travel a freeway segment at 35 mph. Vehicles traveling at speeds above 35 mph are considered to incur no delay. HICOMP measures delay in terms of "Vehicle-hours of delay per day" (vhdpd), and it is calculated by the following formula:

$$\left(\text{Vehicles Affected per Hour}\right)\times\left(\mathit{Extent}\right)\times\left(\mathit{Duration}\right)\times\left[\frac{1}{\left(\text{Congested Speed}\right)}-\frac{1}{35\text{mph}}\right]$$

The number of vehicles affected per hour is fixed as the number of vehicles per hour per lane (vphpl) times the average number of lanes along the segment. Most Caltrans District offices use 2,000 vphpl, although District 4 in the Bay Area uses 2,200 vphpl. The numbers 2,000 or 2,200 vphpl are commonly used by engineers as the design capacity of an urban freeway lane. The average number of lanes includes only mainline traffic lanes and does not include High Occupancy Vehicle (HOV) lanes. It is calculated by taking the number of lane-miles along the segment and dividing it by the number of directional miles. Where there is no change in the number of mainline lanes, the District simply uses that number of lanes.

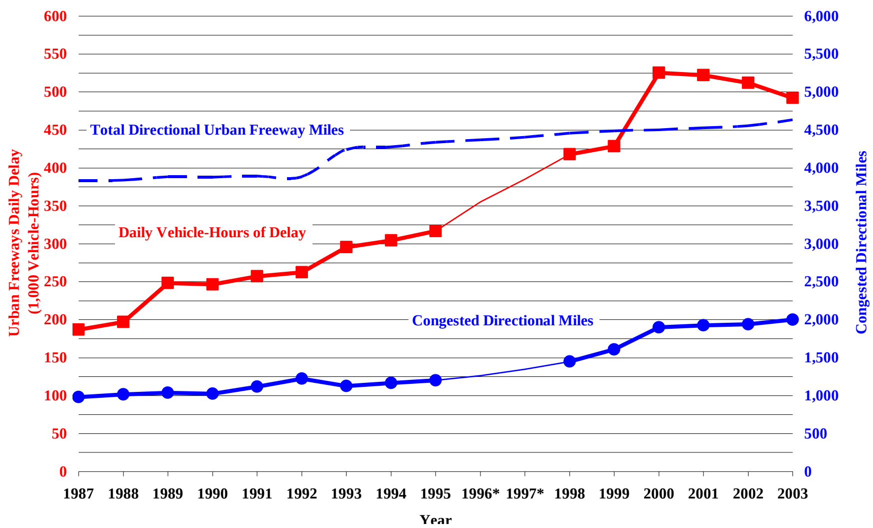
The HICOMP report discusses the magnitude and extent of congestion in detail, while maps included in the report show the location and duration of congestion for all Caltrans Districts experiencing congestion. Other statistics reported in the HICOMP include:

- Urban area freeway directional miles
- Excess fuel consumption
- Travel cost
- Emissions due to congestion
- Annual State Highway Vehicle-Miles Traveled (VMT)

The following exhibits from the 2003 HICOMP report illustrate some of the information that is presented in the report.[7] Exhibit 2 is a chart from the 2003 HICOMP report showing trends for statewide average daily vehicle-hours of delay and congested directional miles. It also shows the total annual directional urban freeway miles to provide reference for how many miles of freeway are congested. Exhibit 3 shows delay trends for each Caltrans District, while Exhibit 4 is a map showing AM peak period congestion for District 3 (Sacramento area). The map shows not only the location of congested segments, but also indicates the time of day that each segment is typically congested.

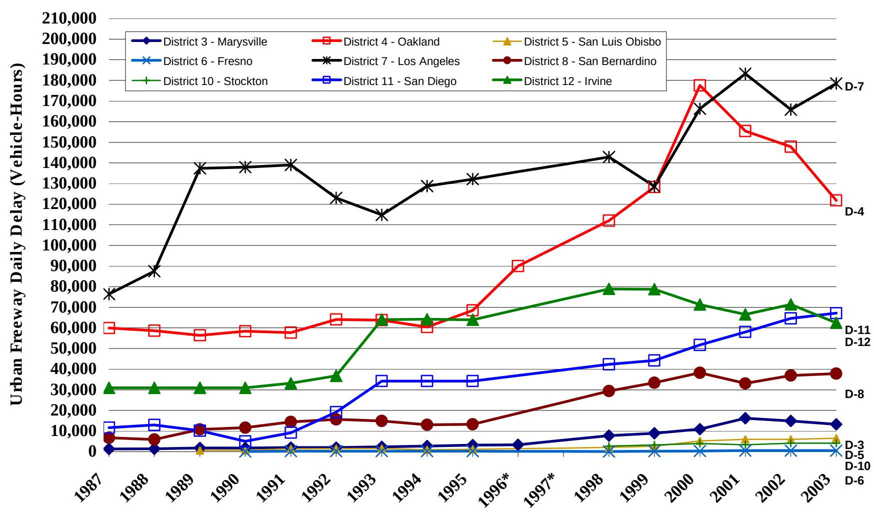
[7] http://www.dot.ca.gov/hq/traffops/sysmgtpl/HICOMP/index.htm

Exhibit 2: 1987-‘03 Vehicle-Hours of Delay & Congested Directional Miles Trends



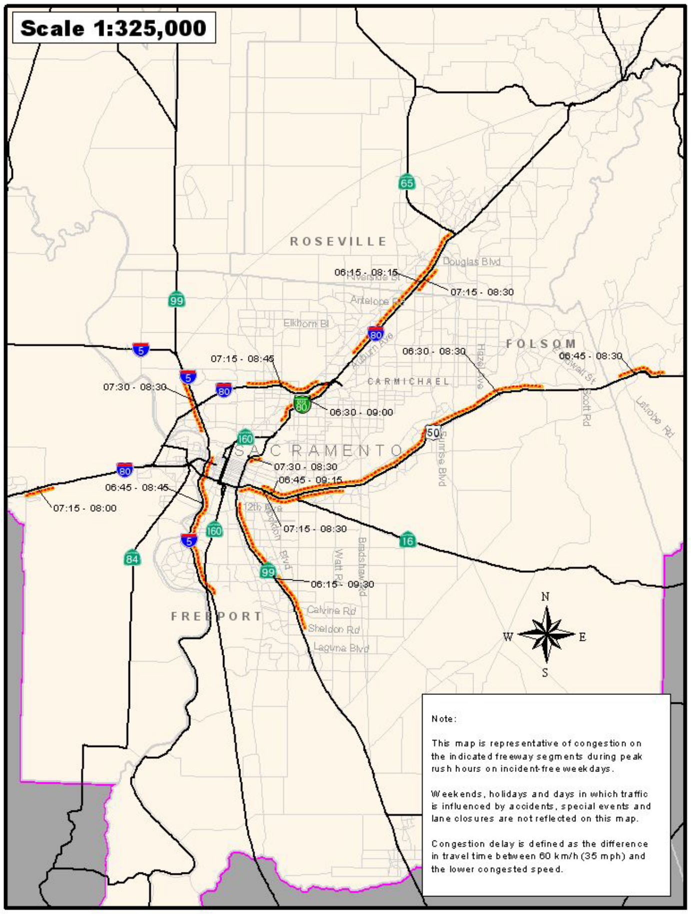
Source: Caltrans, 2003 HICOMP Report.

Exhibit 3: 1987-2003 Vehicle-Hours of Delay Trends by Caltrans District



Source: Caltrans, 2003 HICOMP Report.

Exhibit 4: Caltrans District 3 AM Peak Period Congested Segment Locations and Duration of Congestion



Source: Caltrans, 2003 HICOMP Report.

The following section explains how the data are collected for the HICOMP report. It discusses data collection methodologies in general, and then provides details on the data collection activities for each District.

Data Collection Practices

Each District is responsible for the congestion monitoring results that appear in the statewide report. There are two general data collection methods used by the Districts. The first, and most commonly used method historically, is performed by driving probe vehicles equipped with tachometers at regular intervals along congested freeway segments during typical weekday commute periods. The second relies on automatically collected data from fixed sensors located along freeways. Exhibit 5 lists the Districts and the data collection methodologies used in that District.

Exhibit 5: Caltrans District Current Data Collection Methodologies

District (Office Location) Counties Monitored	Tachometer	Automatic Detection
District 1 (Eureka)	No Congestion Monitoring	
District 2 (Redding)	No Congestion Monitoring	
District 3 (Marysville) El Dorado, Placer, Sacramento	✓	
District 4 (Oakland) Alameda, Contra Costa, Marin, San Francisco San Mateo, Santa Clara, Solano, Sonoma	✓	✓ May be used for 2004
District 5 (San Luis Obispo) Monterey, San Luis Obispo Santa Cruz, Santa Barbara	✓	
District 6 (Fresno) Fresno, Kern	✓	
District 7 (Los Angeles) Los Angeles, Ventura	✓	✓
District 8 (San Bernardino) Riverside, San Bernardino	✓	✓
District 9 (Bishop)	No Congestion Monitoring	
District 10 (Stockton) San Joaquin, Stanislaus	✓	
District 11 (San Diego) San Diego	✓	✓
District 12 (Irvine) Orange	✓	✓

In Districts where both tachometer and automatic detection data are used, the tachometer runs are used to fill in gaps where no automatic monitoring exists, but over time, as detection improves in the districts, more districts are switching over to automatic detection.

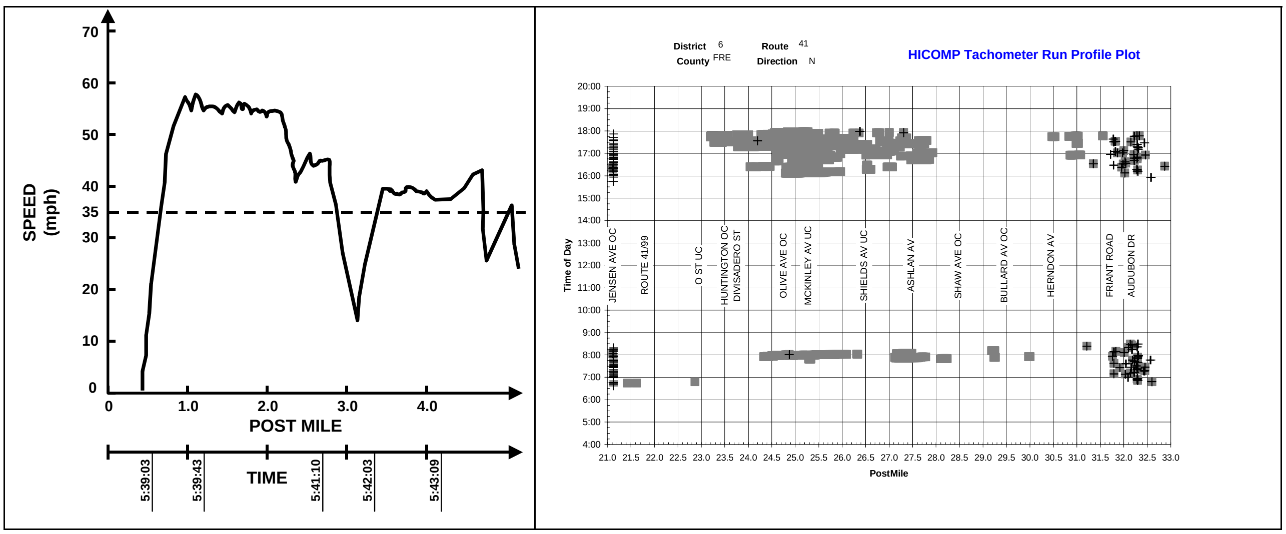
The following sections describe the various data collection technologies used by the Districts.

Tachometer Equipped Probe Vehicles

A tachometer system consists of a transmission sensor mounted in the engine compartment in line with the speedometer cable, a signal conditioner and a laptop computer. The sensor counts the number of wheel rotations in one second and sends that data to a laptop computer or other data storage device. Software on the computer then translates this data into meaningful time, distance and travel speed information.

Tachometer runs have the advantage of being able to monitor changes in congestion along the entire distance of a congested segment. When presented in graphical form, a typical tachometer profile allows the analyst to see where the probe vehicle experienced congestion as shown in Exhibit 6.

Exhibit 6: Illustrative Tachometer Profiles



Caltrans Districts currently use one of three devices to collect tachometer data as shown in Exhibit 7, and described below.

***Congest*/CLOG** was developed internally by Caltrans in the mid-1980s by what is now known as the Division of Research and Innovation (DRI). The software is now maintained and modified as needed by the Caltrans Transportation Laboratories. *Congest* is a PC-based software that records the location, time and the number of times the wheels rotate in one-second and translates that count data into distance. *Congest* produces output files that can be read by the *Congestion Location Output Graphics* (CLOG) program residing in a computer where the data is then converted into speed and delay data. A new version of CLOG is spreadsheet based and is compatible with any recent version of Microsoft Excel.

Jamar Technologies, Inc. PC Travel is commercially available travel time/delay software that is used by some Districts to estimate delay. Either the data can be directly collected by the PC that will be used to perform the analysis or it can be collected by "count boards" used to collect intersection traffic counts. Detailed information about PC Travel can be found on Jamar's website at http://www.jamartech.com/

Moving Vehicle Run Analysis Package (MVRAP) was developed by the University of Florida Transportation Research Center to evaluate travel speed, delay, fuel consumption and driver comfort. This program is used only by District 7 at this time. MVRAP is a database program that presents the results of a moving vehicle study in a tabular and graphical form. Recently, software has been developed to import GPS data into MVRAP.

Exhibit 7: Tachometer Software Currently Used by Caltrans

	Caltrans *Congest/* CLOG	**Jamar** PC Travel	**Univ. of Fla.** Moving Vehicle Run Analysis Package (MVRAP)
District 03	●		
District 04	●		
District 05	● Prior to Year ’00	● After Year ’00. No data collection for ’03-’04	
District 06	●	●	
District 07			● In Year ’02 only
District 08	● No data collection for ’03		
District 10	● Prior to Year ’’01, & since ’04	● Years ’02-’03	
District 11	●		
District 12	● No data collection for ’03		

In general, there are a few general guidelines to collecting data for tachometer vehicle runs. District 4’s *Congestion Monitoring Procedures and Guidelines* are available at http://www.dot.ca.gov/dist4/d4hwops/98HICOMP/98_hicomp_method.html. Below, some of the general requirements are outlined.

The data collection season is typically during the spring and fall months of each year (April through June and September through November), avoiding days adjacent to major holidays such as Thanksgiving and Labor Day. These two seasons are considered to be more representative of commute traffic and avoid summer vacation traffic.

Two days of data collection should be performed during each season to ensure that only "typical" recurrent data is being collected. Tuesdays, Wednesdays, and Thursdays are the only days collected because Mondays and Fridays are considered to be atypical.

In practice however, these guidelines are sometimes sacrificed due to resource constraints. It is now common for Districts to collect only fall data and often only one day of data is collected. In a few cases, out of season data is collected at times to meet tight scheduling timelines. Districts still collect data during the midweek days.

There is no set time period during the day for collecting data other than the requirement to collect "typical" AM and PM commute period data. Typically, data are collected from 6:00 AM to 10:00 AM and from 2:00 PM to 8:00 PM, but it can vary by segment. For example, SR-91 in Riverside County has severe congestion that begins around 4:00 AM. Sometimes, Districts have collected PM peak period data as early as 1:00 PM in the afternoon.

The length of the segment selected for data collection should be long enough to bracket the congested portion of the freeway, but should also be short enough so that drivers can complete the run, return to the starting point for the next run, rest and re-set the computer for the next run. Typically, three or four drivers are used to monitor a segment, and the average run lengths tend to be between five and ten miles long.

The headway between runs is also a factor that needs to be considered. Headways tend to be between 15 and 20 minutes providing between three and four tachometer runs per hour of monitoring. Sometimes Districts have performed runs every 30 minutes. The errors from large headways have the same character as the sampling errors discussed in Section 4.1, and could be analyzed in a similar manner.

During the tachometer runs drivers are encouraged to "float" in traffic (hence the name "floating" car method), meaning that for every vehicle that the tachometer vehicle driver passes, another car should pass the tachometer vehicle. It is common for drivers to attempt to stay in the middle lanes of the freeway since the right lane is considered slow while the far left lane is considered the fast lane.

Other factors that need to be considered include verifying that tachometer vehicles have been calibrated prior to performing the tachometer runs. This will ensure that the distance estimates produced by the vehicle are accurate. This is done by driving on a test track or on a known distance down a freeway. The calibration factor is simply the ratio of feet driven per rotation of the tires. The calibration can vary due to changes in air temperature, tire pressure, or other factors.

In addition, the computers used in the vehicles need to have their dates and times synchronized. Sometimes drivers of tachometer vehicles can input the wrong start time for runs. The most common mistake is to have the clock be off by 12 hours (i.e., reading 9:30PM instead of 9:30AM). Another common error is to fail to include the correct date, or to fail to input a date.

Automatically Collected Data

Automatically collected data have been provided by Berkeley Transportation Systems, Inc. from the Freeway Performance Measurement System (PeMS). PeMS uses data collected by Caltrans electronic sensors or vehicle detectors in the pavement. PeMS data have been used historically to process results for Districts 7 and 8. Five-minute speed and volume data for the fall data collection season (typically mid-September to mid-November) is retrieved from PeMS and used to develop the HICOMP report.

In recent years, District 12 results have been estimated using PeMS data. District 11 continues to use sensor data that come directly off their Front End Processor, used for their Advanced Transportation Management System, rather than rely on PeMS data, although PeMS stores the same data.

Below, the two principal approaches for processing the PeMS and sensor data are discussed.

Data Analysis Practices

Although the data collection practices are fairly consistent across Districts, each District has considerable leeway in how it processes the data. There are almost as many approaches as there are Districts experiencing congestion.

The following section describes in detail the processes used by each District to process the tachometer data. At the end of the section, results from the various approaches are compared.

Following the discussion of the tachometer approaches, the two procedures for processing automatically collected data will be discussed.

Tachometer Data Processing

There are four primary approaches used to process tachometer data. For the purpose of this memorandum, each will be called by the District's name that uses that approach.

"District 3" Approach

District 3's approach is summarized in Exhibit 8. In column "2" the start time for each tachometer run is input, while the corresponding seconds in delay spent by each vehicle is input in column "3". The seconds in delay comes directly from the Congest program.

The time interval between successive runs is calculated (in column "4") and the average delay for each time interval is calculated in column "5". The total delay for the individuals tachometer runs are finally calculated in column "6" by using the formula:

[Lanes] x [2,000 vhphl] x [Time between runs]*[Average delay between runs]

The delay in column "6" is summed to arrive at the average delay for the day. District 3 monitors two or more days per year. The days are averaged to arrive at the average daily vehicle hours of delay for the year.

Exhibit 8: District 3 Tachometer Processing Methodology

EB 50 AM1

LIMITS: 1.342-17.801 **DATE: 10/28/2004**

DRIVERS: M. Smith **DAY: Thursday**
M. Auslam

RUN NO. 1	BEGIN RUN TIME 2	ACTUAL DELAY (Sec.) 3	TIME INTERVAL (Min.) 4	AVE.-TIME DELAY (Hr.) 5	TOTAL DELAY (Vh.-Hrs.) 6
1A	7:08:00				
1B	7:23:00	57	15.00	0.0079	16.63
2A	7:50:00	43	27.00	0.0139	52.50
2B	8:13:00		23.00	0.0060	19.23
3A	8:32:00		19.00		
3B					
4A					
4B					
5A					
5B					
6A					
6B					
7A					
7B					
8A					
8B					

Flow Rate (Vphpl)	No. of Lanes	Total Volume	Total (Veh.-Hrs/day)	88.36
2,000	4.2	8,400	TOTAL (Veh.-hrs/yr)	**22,089**

Source: Caltrans District 3, Traffic Operations

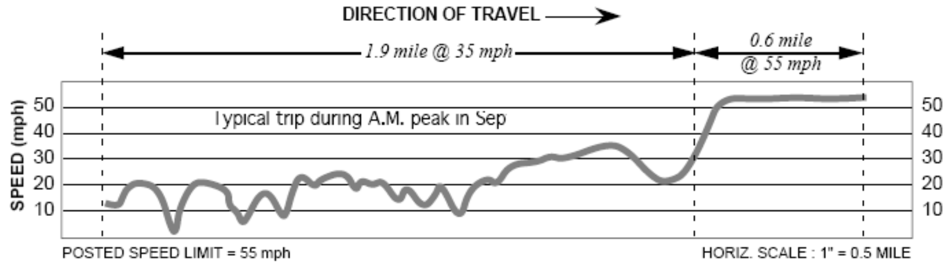
"District 4" Approach

District 4 uses an approach that differs from other Districts in three key areas. First, District 4 uses 2,200 vphpl as the hourly lane volume based on their experience that this flow rate is the flow experienced by vehicles passing through a bottleneck. Since other Districts use 2,000 vphpl, this means that District 4 will show 10% more delay than other Districts under the same travel time conditions.

A second distinguishing feature of the District 4 approach is that it uses a graphical procedure to calculate congestion. It involves drawing a scatter plot of travel times (y-axis) versus time of day (x-axis) and calculating the areas under the curve to arrive at an average delay per vehicle. In general, other methods simply assume that the travel delay for each tachometer vehicle is representative of all vehicles traveling over the segment during that same interval or is based on some average of consecutive tachometer vehicle travel times. The differences between these approaches are not significant in most cases.

Another feature of the District 4 approach is that they do not use 35mph as their baseline speed to calculate delay. They use a "baseline" travel time approach, which takes the speed profile plot for the most congested run of the time period and estimates the travel time for that run if the tachometer vehicle were traveling at free-flow on the uncongested portions of the segment and at 35mph during the congested segments. An example of this step is shown in Exhibit 9.

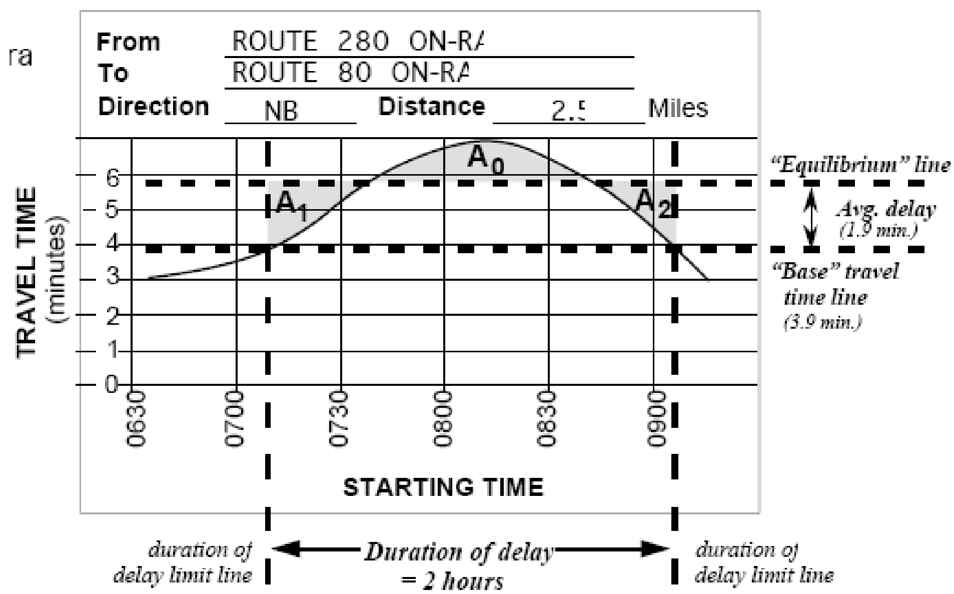
Exhibit 9: Illustrative District 4 Speed Profile Plot



Source: District 4 Congestion Monitoring Procedures & Guidelines, 1996.

Exhibit 10 shows the graphical procedure used by District 4. A complete detailed description of this methodology can be found in Appendix B of this memorandum.

Exhibit 10: Illustrative District 4 Congestion Monitoring Graphic



Source: District 4 Congestion Monitoring Procedures & Guidelines, 1996.

To calculate delay per vehicle, the District first calculates the "Base" travel time using the congested extent (i.e., length of congested segment) and the total length of the segment. The congested extent base travel time is estimated using 35mph, while the uncongested travel time (using total length – congested extent) is calculated by using free-flow speed. The sum of the two travel times is the "base" travel time.

An equilibrium travel time line is estimated (sometimes visually) such that the area under the curve labeled A_0 in Exhibit 10 is equal to the sum of the areas A_1 and A_2. The difference between the equilibrium line and the base travel time line is the average delay per vehicle. Again, the differences among these approaches are not significant in most cases.

Calculating total vehicle-hours of delay is performed in a manner similar to the other approaches by taking the duration of congestion (shown in Exhibit 10, above) and multiplying that value by the number of lanes. When calculating delay per vehicle, District 4 only considers the number of lanes at the bottleneck and not the average number of lanes along the segment.

"District 12" Approach

In contrast to the District 4 approach, the "District 12" approach uses a spreadsheet to enter in the travel delay from each tachometer vehicle. This approach is used by Districts 11 and 12. Travel delay per vehicle is a direct output of CLOG and can be readily obtained from the other commercial data collection packages.

The basic assumption of the District 12 approach is that the delay recorded by the tachometer vehicle during any 20-minute time slot (See the "Run Time" column in Exhibit 11) is constant for all vehicles traveling during that time slot. Knowing average number of lanes (by taking the lane-miles across the congested segment and dividing by the directional miles), the spreadsheet calculates the vehicle-hours of delay for that 20-minute period using the formula *Tachometer Delay x (2000vphpl x (20min/60min) x (Lanes)* converted to the appropriate units of measure.

The average daily vehicle-hours of delay for the segment are the summation of the delays for each time slot. The duration of delay is the difference in time from the time that the first vehicle hit congestion to the time slot when no congestion is recorded. The extent, or congested directional miles, is the distance from the start postmile where congestion was first encountered to the last postmile where congestion was encountered.

Exhibit 11: District 12 Approach Data Entry Spreadsheet

Route: ORA-055 SOUTH
Date: 10/26/2004 (A.M.) 10/21/2004 (P.M.)
From: SB ON FROM EB CH — P.M. 013.507
To: SB OFF TO FAIRVIEW — P.M. 003.098
Distance = 10.409 Miles *(10 Min @ 65 MPH)*
Exact Time (Min) 9.61

Period: AM

Run Time	Start P.M.	End P.M.	Delay (*Sec*) < 35 MPH	VHD Per Lane	Number of Lanes	Total VHD/Day	CI (%)	Travel Time (*Min*)	Driver	Start Time (hh:mm) Scheduled	Start Time (hh:mm) Actual	End Time	65 MPH (*hh:mm*)
6:00-6:20	3.797	3.793	1	0.185	4.720	0.874	0.0	10	Viet	6:00	6:05	6:15	00:10
6:20-6:40	0.000	0.000	0	0.000	4.720	0.000	0.0	10	Hung	6:20	6:18	6:29	00:10
6:40-7:00	13.467	10.094	243	45.000	4.720	212.400	32.4	16	Bryan	6:40	6:43	6:59	00:10
7:00-7:20	13.488	6.477	349	64.630	4.720	305.052	67.4	19	Phil	7:00	7:00	7:19	00:10
7:20-7:40	13.505	3.763	565	104.630	4.720	493.852	93.6	24	Viet	7:20	7:18	7:42	00:10
7:40-8:00	13.507	6.461	1172	217.037	4.720	1024.415	67.7	34	Hung	7:40	7:37	8:12	00:10
8:00-8:20	13.487	3.125	1030	190.741	4.720	900.296	99.5	32	Bryan	8:00	8:02	8:34	00:10
8:20-8:40	13.487	6.563	1168	216.296	4.720	1020.919	66.5	34	Phil	8:20	8:20	8:54	00:10
8:40-9:00	13.505	3.811	1294	239.630	4.720	1131.052	93.1	35	Viet	8:40	8:40	9:16	00:10
9:00-9:20	13.505	3.091	866	160.370	4.720	756.948	100.0	28	Hung	9:00	8:59	9:27	00:10
9:20-9:40*				0.000		0.000	0.0	00		9:20			00:10
		Total:	6688	1238.519	Avg = 4.720	5845.807	Avg = 62.0	Avg = 0:24:40					

Source: Caltrans District 12, Traffic Operations

"Other" Approach

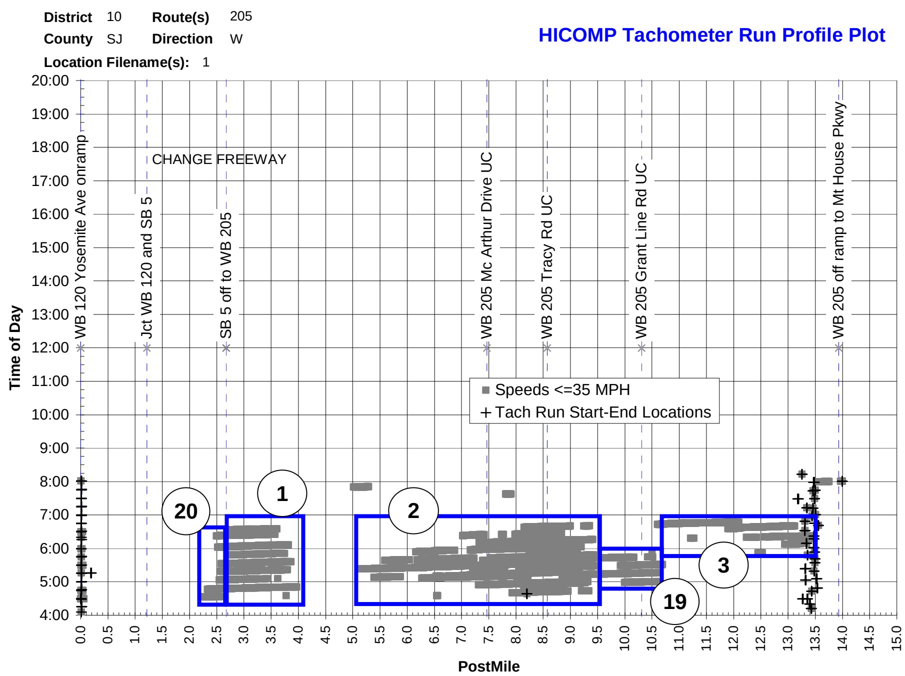
Another approach is used by Districts 5, 6, 8, and 10. In this approach, all the tach runs on all days performed along a segment are combined, total delay for a given segment is calculated for all the tachometer vehicles and the number is divided by the total number of tachometer runs during the congested period to arrive at the average delay per vehicle. The average daily vehicle hours of delay is calculated using the standard formula described above.

Exhibit 12 shows the key elements of this approach. The plot in the exhibit shows time of day on the y-axis and highway postmile or distance traveled on the x-axis. The points on the chart represent a one-second interval in which the tachometer vehicle's speed dropped below 35mph. The number of data points represents the total seconds spent below 35mph by all the tach vehicles traveling the segment. The difference in the total seconds spent below 35mph by a tachometer vehicle and the travel time along that same section at 35mph is the seconds in delay for that vehicle.

The average delay spent per vehicle is the summation of delay for all tachometer vehicles divided by the total number of tachometer vehicles making runs along the segment. The total number of vehicles includes tachometer vehicles during the congested period that do not experience congestion. This is a common occurrence along corridors with light congestion levels. It can be the case on these segments where a tachometer vehicle run will record no congestion, but where vehicle passes before and after that tachometer run will record congestion. Since this vehicle run occurred during the "congested period" it is counted, but with no time spent in delay.

Exhibit 12 also shows how different congested segments are identified based on the location of congestion and the duration of congestion. In this example from District 10, the tachometer runs span three different freeways, so segments are created where the vehicle enters a new freeway. Also, note the different durations of congestion. Since the duration is a variable in the delay formula, it is important that the durations of different segments be recorded accurately. In this example, durations range from one hour for segment #3 in the exhibit to more than 2½ hours in segment #2. Also, note that there is a 1-mile gap in congested segments between segments #1 and #2. This affects the congested directional miles calculation for the HICOMP report.

Exhibit 12: "Other" Approach Illustrative Example



Differences in Tachometer-based Approaches

Each of the approaches described above has merits with advantages and disadvantages, and each in general produces similar results. However, results do vary depending on the approach used as well as how the analyst interprets the data. For example, in collecting the data, the vehicle operator may inadvertently begin or end the recording of the software prematurely. This most often happens when tachometer vehicles are beginning or ending a tach run on the freeway access ramp. This can be observed in Exhibit 12 above, which shows "blips" of congestion near the beginning and ending locations of the runs. These are often simply the driver accelerating at the beginning of the run or slowing at the end of the run while merging to exit the freeway.

Exhibit 13 shows how the different approaches produce different results. This example is based on 2003 tachometer data from SR-99 between Hammet Road and Whitmore Avenue in Stanislaus County. For this example, no approach varies from another by more than 5%. This variance would be within 3% if District 4 used 2,000 vphpl. Moreover, changes in assumptions in the other approaches could also contribute to higher or lower variances.

For example, District 12's approach is dependent on whether all tachometer runs are completed. In this case, one vehicle pass in the middle of the congested period was aborted resulting in one time slot containing missing data. This could have been caused by a vehicle or computer malfunction or for any number of reasons. Where the other approaches take into account missing data as a part of the process, for the District 12 approach the missing data has to be estimated before entering data into the spreadsheet. This is often not significant, which in this example was handled by taking the average of delay for the two adjacent runs.

Exhibit 13: Illustrative Example of Different Approaches for Estimating Delay

Method	Used by…	Volume (vphpl)	Lanes	Congested Time Period	Duration Of Congestion (Hours)	Average Daily Vehicle Hours per Day
District 3	D3	2,000	3.0	16:30 - 18:00	1.500	**378**
District 4	D4	2,200	3.0	16:35 - 18:00	1.417	**395**
District 12	D11 & D12	2,000	3.0	16:30 - 18:00	1.500	**373**
Other	D5, D6, D8, D10	2,000	3.0	16:30 - 18:15	1.750	**357**

What this example illustrates is that each method, though dependent on a range of assumptions and analyst interpretation of the data, provide similar results. However, changes in assumptions can dramatically alter results. For example, if one analyst uses three lanes in the calculation based on the number of lanes that predominates along the section, while another uses an estimate based on lane-miles and the mileage of the congested segment the results could change dramatically. For example, if one analyst used 3.25 lanes instead of three lanes, the delay would increase by 8% with no other assumptions used. A similar result would occur in the estimate of duration.

The following section discusses the two methodologies for analyzing automatically collected data for HICOMP.

Automatically Collected Data Processing

This section discusses two methods for using automatically collected data to produce the HICOMP report. The first method has been used since the late 1980s by District 7 to analyze congestion and is modeled after the approach used to analyze tachometer data in terms of the number of days and time periods sampled. For the purposes of this memorandum, it is termed the “Legacy” or “District 7” approach.

The second approach is used in Districts 8 and 11 and for purposes of this memorandum is called the “Interim” approach. Caltrans has been working over the past several years to improve the PeMS system to make it a tool for comprehensive freeway performance measurement and analysis. The anticipation is that with improved methodologies for estimating recurrent and non-recurrent delay and with more comprehensive data, the need for tachometer analysis for HICOMP can be eliminated in some urban areas. Therefore, the approach described in this memorandum is termed “interim” until the PeMS system replaces it for congestion monitoring purposes.

The primary difference between the interim approach and the “District 7,” is that the interim approach uses the statistical tool of the standard deviation to select “typical” recurrent days for analysis rather than having the analyst select two “typical” days.

“Legacy” Approach (District 7)

There are three major steps in the legacy approach. The first step is to select two “typical, **recurrent**, commute days” for each freeway segment under analysis. The second step is to identify congested segments and times for the two days chosen in the first step. The final step is to calculate delay for each of those two days and average the two together.

In the past, the selection of the two days was done by printing out plots showing freeway speeds below 35mph for Tuesdays, Wednesdays and Thursdays during the data collection season. The two days were selected following a visual inspection of the two days. This is similar to the approach used for the tachometer-based analysis.

Since 1999, a slightly more automated approach for selecting days has been used as illustrated in Exhibit 14. For all the sensor locations on the freeway, the average speed is calculated for all days (Tu, We, Thu) during the data collection season. Each line on the plot represents one day. The average speed for all the days is then calculated, and the two days with speeds appearing to be closest to the average speed are chosen for the analysis.

Based upon the two selected days, congestion profile graphs for each directional freeway are produced as shown in Exhibit 15. These show when and where speeds are below 35 MPH (the HICOMP definition of congestion). Based on this plot, congested segments are identified, “boxed” out, and the times and postmiles noted in a database table.

Exhibit 14: “Legacy” Approach Average Speed Graph Example

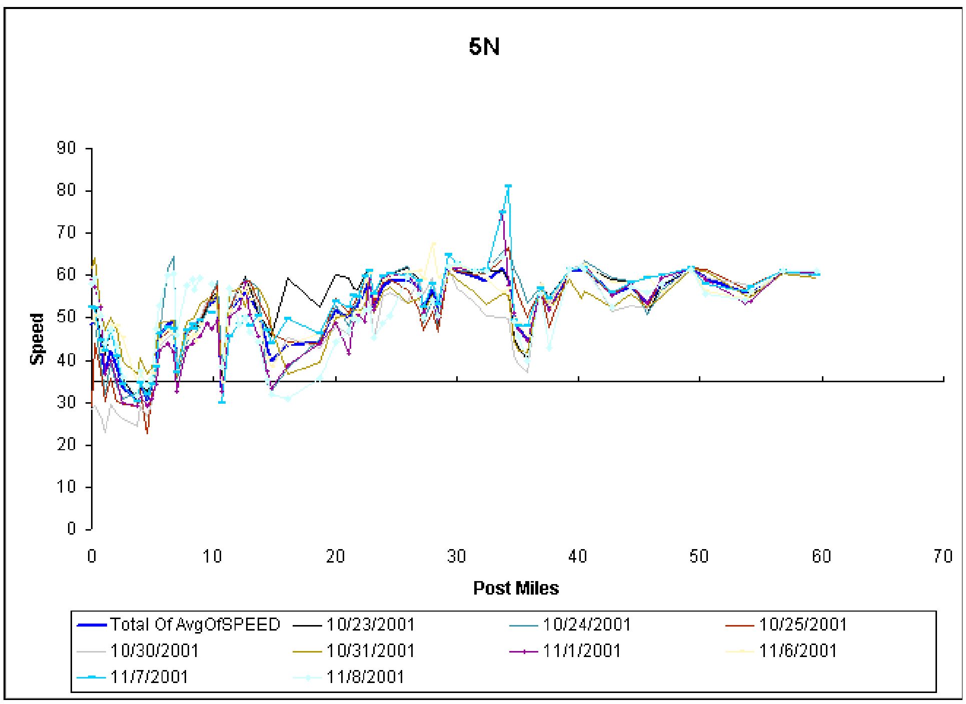
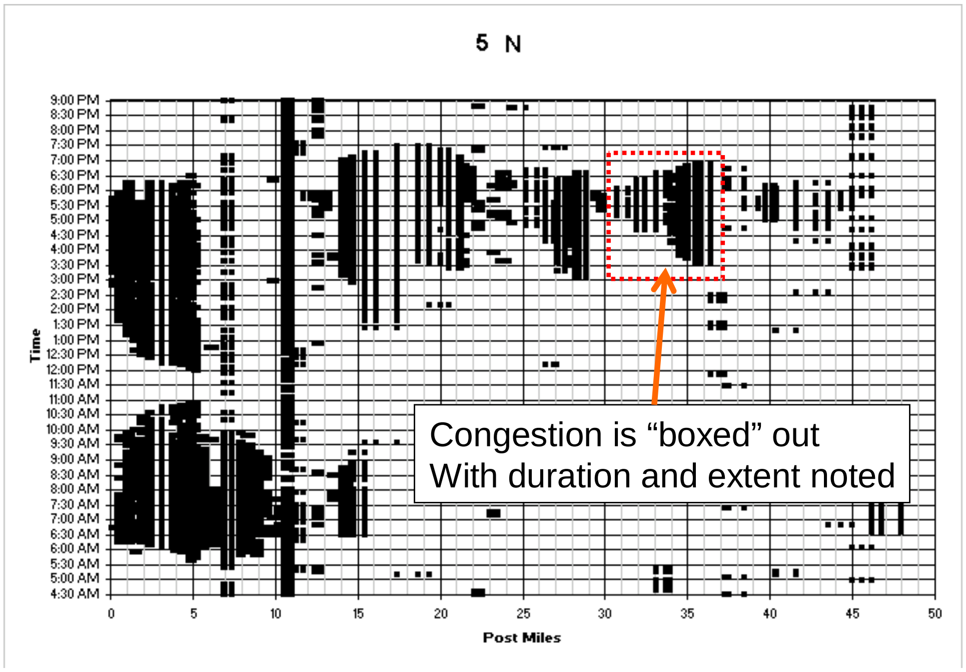


Exhibit 15: Legacy Approach Congestion Profile Graph Example



Based on this boxing out of congestion, a Microsoft Access database is used that selects all PeMS records with the times and postmiles selected in Step 2, above (See Exhibit 15). The delay is calculated for the segments and averaged over two days.

"Interim" Approach (Districts 8 and 11)

The "Interim" approach was first developed in 1999 to analyze District 11 congestion from the District's automatic vehicle detection system. Data were downloaded onto CD-ROMS for the data collection season and pre-processed to get the needed data.

The interim approach differs from the legacy approach in one major way. Rather than attempt to visually identify two days, this approach takes the complete sample of Tuesdays, Wednesdays, and Thursdays during the data collection season and attempts to filter out days that appear to be atypical. There are two ways that this can be done. First, the analyst can decide to eliminate days and time periods from the analysis for any freeway segment based on knowledge about those days. For example, there may have been a rainy day that the analyst wants to eliminate, or a day when an accident occurred.

The interim approach takes 5-minute detector data and uses that data to estimate average daily vehicle hours of delay and congested directional miles for the HICOMP report. It attempts to cull "typical" days from the available data by using the statistical tool of the standard deviation to select a sample of "typical, recurrent" days. The approach compares the speed and the volume for each detector station, for each 5-minute interval, for each day in the database against the average speed and standard deviation across all days in the database (for that station and 5-minute interval). Any data point that falls in that range for speed and volume is considered a typical day.

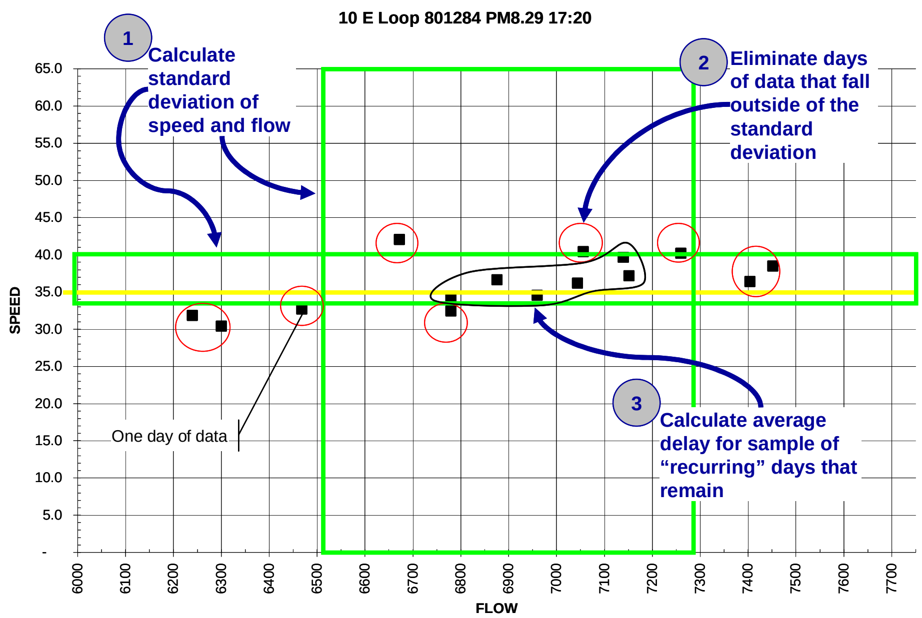
Exhibit 16 illustrates this analysis (This example was taken from HICOMP 2001, and is loop detector identification number 801284 on I-10 eastbound at Caltrans postmile 8.29 in San Bernardino County in District 8 at 5:20 PM.).

First, the standard deviation for flow (x-axis) and speed (y-axis) are calculated. Then each day, represented by the data points, is compared against the average and standard deviation. Those data points that fall outside of the range for standard deviation are rejected.

For the remaining days, delay is calculated and averaged across the remaining days by using the formula: (2000 vphpl/12 five-minute intervals) x (LANES) x (EFFECTIVE LENGTH) x [1/(SPEED)-1/(35mph)] for segments where speeds are less than 35mph. Where speeds are greater than 35mph, the delay is equal to zero.

The "Effective Length" is a critical variable in the calculation. The effective length of a fixed-point sensor station is the distance over which the speeds reported by the sensor are considered to be constant. The effective length is the distance between the mid-points between the detector in question and its adjacent detectors. Where a detector is located at the end of a string of detectors and there is no adjacent detector, then the effective length is extended out 0.5 miles from the detector or another distance (e.g., detectors near county lines are often less than 0.5 miles, so the effective length is extended only to the county line.).

Exhibit 16: "Interim" Approach Illustrative Example for One Sensor Station



The interim approach does this analysis automatically. One manual step is required where the analyst must review the output data and select segments based on time and postmile, much in the same manner as in the District 7 Legacy approach described in the previous section. A more detailed discussion of the Interim approach analysis procedures is attached as Appendix C.

Differences in Automatic-based Approaches

There has been no formal rigorous comparative testing between the two automatic detection approaches described above. However, informal comparisons between the two approaches performed in the past suggest that the results produced by the two approaches are similar and that the differences are insignificant in most cases.

Appendix 2 HICOMP Interim Detector Analysis Database Documentation

This appendix documents the Microsoft Access 2000 database used to process automatic detection data for the 2003 HICOMP report for Caltrans Districts 8 and 11. The report first briefly describes the database. It then provides some background information explaining how the database calculates delay for HICOMP. Finally, the paper identifies each object in the database (tables, queries, and macros) and provides definitions for each element in the objects (fields, etc.).

It is expected that the person using the database has a comprehensive understanding of database applications in general, and experience in working with Microsoft Access in particular. This paper does not attempt to explain concepts used in working with databases.

This document also does not provide detailed information on congestion monitoring. For more information about congestion monitoring, please refer to the following sources:

2003 Statewide HICOMP Report – A copy can be obtained from the Caltrans Division of Traffic Operations at headquarters in Sacramento.

PeMS (Freeway Performance Measurement System) – This interactive traffic data and analysis website is under development at the University of California, Berkeley. The data used in the District 8 HICOMP database was obtained from PeMS. This website explains in detail the procedures for collecting and aggregating the data. The site is located at http://pems.eecs.berkeley.edu. Please contact the webmaster for a login and password.

Congestion Monitoring Procedures and Guidelines – This document was prepared by the Caltrans District 4 Office of Highway Operations in September 1996. It was written with the District 4 congestion monitoring program in mind (which differs from the approaches used in other Districts). However, it is a good background source for understanding congestion monitoring. It can be obtained by contacting the Caltrans District 4 Traffic Operations Division in Oakland.

Background

The purpose of the automatic detection analysis database is to take 5-minute automatic detection from the Freeway Performance Measurement System (PeMS) and use that data to estimate average daily vehicle hours of delay and congested directional miles for the annual HICOMP report. Under HICOMP, delay occurs when travel speeds drop to 35MPH or less for a period of 15-minutes or longer during typical, incident-free weekday commute periods.

This database cannot estimate delay along highway segments where no detection exists or for days or time periods where no data is reporting to PeMS. In addition, the person using this database must have basic skills in Microsoft Access databases and understand congestion monitoring concepts. This database is not a “black box” that automatically produces results from raw data. The user must be able to review and understand speed profile plots, and be able to determine if data being produced by the detection is “good” or “bad” data. The user has to enter data into the database to make it run properly.

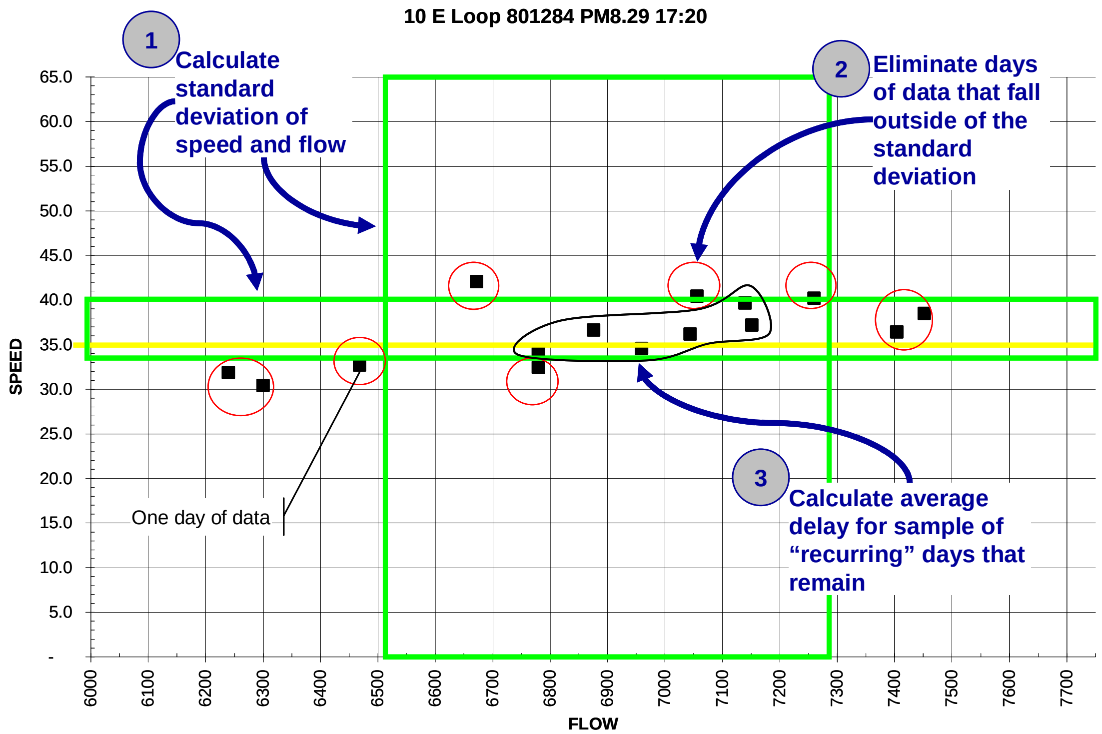
This database attempts to identify "typical" days that are "incident-free". In other words, it attempts to identify recurrent congestion. Currently, there is no accepted methodology to distinguish between recurrent and non-recurrent congestion using automatically collected data.

This database attempts to cull "typical" days from the available data by using the statistical tool of the standard deviation to select a sample of "typical, non-recurrent" days. The database compares the speed and the volume for each detector station, for each 5-minute interval, for each day in the database against the average speed and standard deviation across all days in the database (for that detector station and time interval). Any data point that falls in that range for speed and volume is considered a typical day.

Exhibit 1 illustrates this analysis. This example, taken from HICOMP 2001, shows loop detector station 801284 on I-10 eastbound at Caltrans postmile 8.29 in San Bernardino County (District 8). The time under analysis is 5:20 PM.

First, the standard deviation for flow (x-axis) and speed (y-axis) are calculated (See 1 in the exhibit). Then each day, represented by the data points, is compared against the average and standard deviation. Those data points that fall outside of the range for standard deviation are rejected. For the remaining days, delay is calculated and averaged across the remaining days by using the formula: **(2000 vphpl/12 five-minute intervals)** x **(LANES)** x **(EFFECTIVE LENGTH)** x [1/**(SPEED)**-1/**(35mph)**] for segments where SPEED<35mph. Where SPEED>=35mph, the delay is equal to zero.

Exhibit 1: **Selecting Days for Analysis**

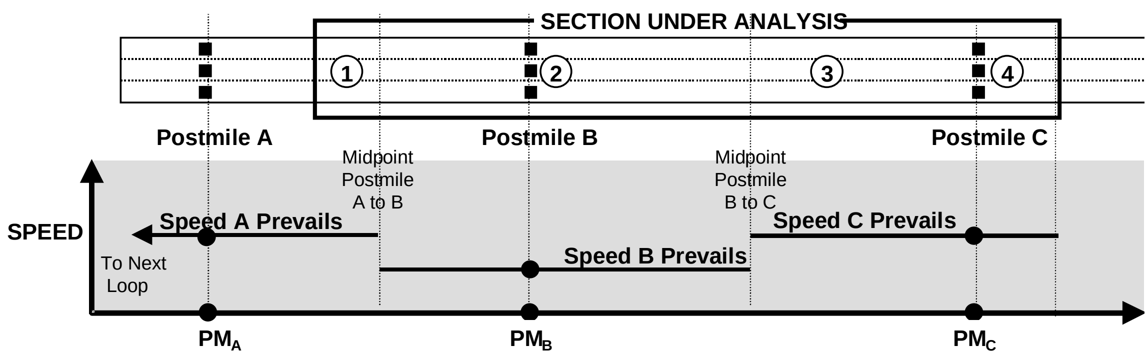


The concept of the "Effective Length" is critical for understanding the calculation. The effective length of a detector station is the distance over which the speeds reported by the detector station are considered constant. The effective length is the distance between the mid-points between the detector in question and its adjacent detectors. Where a detector is located at the end of a string of detectors and there is no adjacent detector, then the effective length is extended out 0.5 miles from the detector or another distance (e.g., detectors near county lines are often less than 0.5 miles, so the effective length is extended only to the county line.).

Exhibit 2 below illustrates this approach for a pre-defined "Section Under Analysis". In the exhibit, there are three detector stations (with one detector in each of three lanes along the segment), one each at postmile "A", "B", and "C".

Assume that between station "A" and "B", there is a county line. Therefore, in section ①, the speed from detector station "B" prevails from the county line to the end of section ② (at the midpoint between postmiles "B" and "C". Likewise, the effective length of section ④ extends from the midpoint of "B" to "C" some distance past postmile "C" (e.g., 0.5 miles).

Exhibit 2: Illustrative Example of the Effective Length



The effective length can greatly affect the calculation of delay, especially when detectors are spaced far apart. For example, if detector stations are spaced an average of one mile apart then the speed reported by a given detector station is assumed to hold constant over that one mile – an assumption that is false in some cases.

The effective length approach may also not be as accurate as using a simple average speed from two adjacent detectors. This is particularly true when the speed differential between adjacent detectors is large. However, this latter approach fails when a detector station is not reporting data for any reason (a common occurrence), and the effective length approach eliminates this problem.

For the 2003 HICOMP analysis, 2000 vehicles per hour per lane (vphpl) is assumed. This is done to maintain consistency with the current HICOMP reporting practice even though PeMS reports actual flows. However, it is very easy to have the database calculate delays based on actual flows reported by the detector stations.

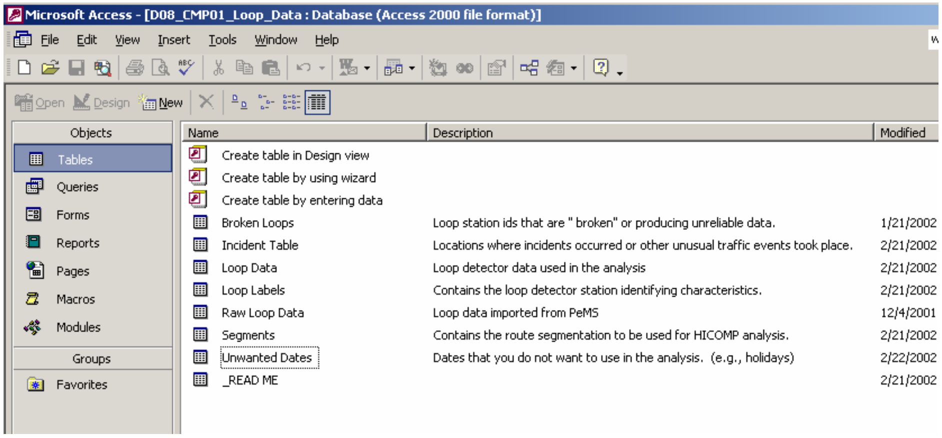
The next section explains specific elements of the database in detail.

About the Database

The database uses three common features of Microsoft Access databases: Tables, Queries, and Macros. Over time, some of these queries may have been modified to meet the needs of individual Districts. However, the other procedures should remain the same.

A *table* is a collection of data about a specific topic. Exhibit 3 shows where the tables are found in the HICOMP database.

Exhibit 3: HICOMP Database Tables



This is where the "hard" data used by the database is stored. There are eight tables in the HICOMP database:

Broken Loops – table indicating detector stations that are broken or that produce questionable data. This data is used by the database queries and macros to eliminate questionable data. The term "loops" is a misnomer since detection can include other devices other than inductive loop detectors embedded in the pavement. Newer technologies such as radar, infrared, and toll transponders are being instituted around the State.

Incident Table – table where route segments with incidents are input and stored. This data is used by the database queries and macros to eliminate known or suspected incident days from the analysis.

Loop Data – where the detection data is stored (i.e., speeds, volumes, etc.). This is a very large table.

Labels – a critical table. This table identifies the detection station locations (e.g., route, direction, postmile). It also contains the effective lengths for each detector.

Raw Loop Data – This is the data received by PeMS. It has to be manipulated to get the table *Loop Data*.

Segments – another critical table. It contains the segmentation for the routes. This is where segments having similar congestion patterns are identified.

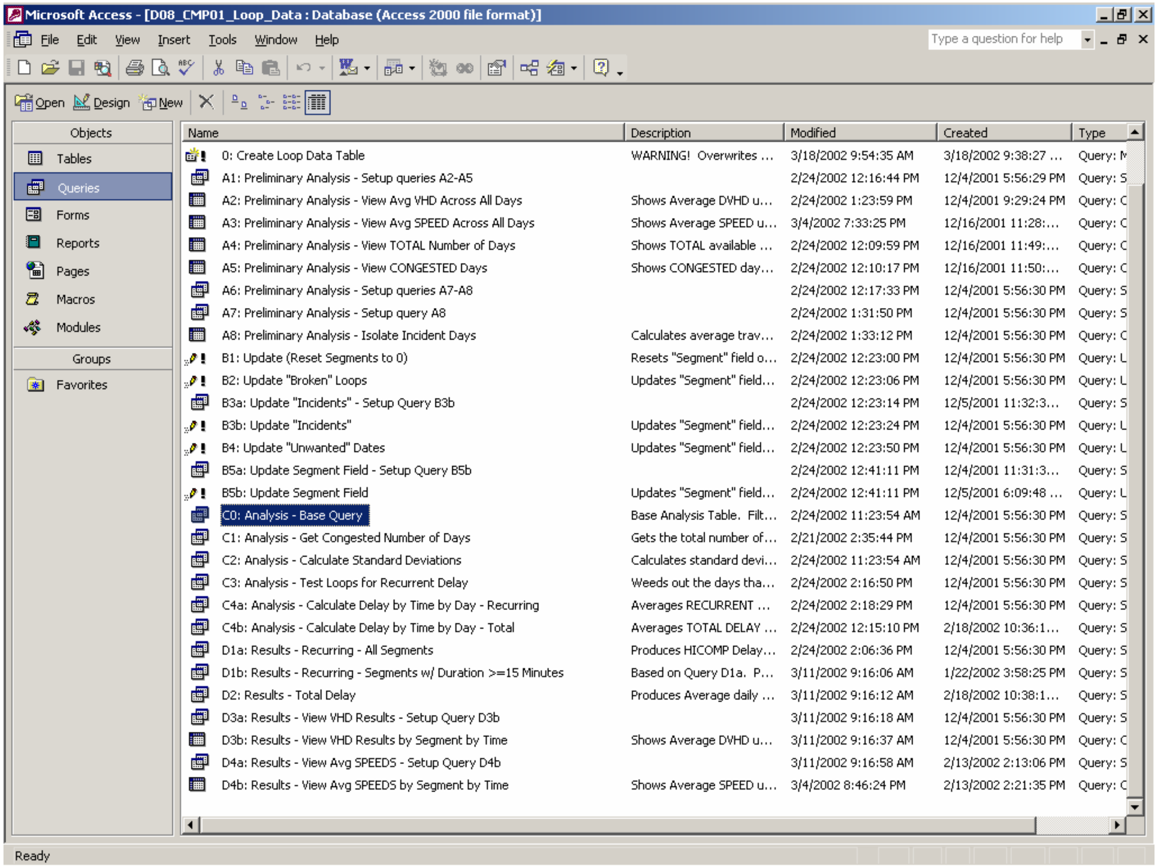
Unwanted Dates – where the user can input dates that need to be eliminated from the analysis (e.g., rainy days).

_READ ME – contains a message describing limitations of the database in identifying recurrent delay.

More detailed descriptions, including field names and definitions, for each table can be found in the data dictionary in the appendix.

A *query* is used to view, change, and analyze data in different ways. Exhibit 4 shows where the queries are located in the HICOMP database.

Exhibit 4: Queries In the HICOMP Database



There are 29 queries in the HICOMP database. These queries are divided into five general types as follows:

One "0" query is used to convert data from PeMS into a format used by the database.

"A" queries (All queries in this series begin with the letter "A" followed by the query number) allow the user to view preliminary analysis to get a better feel for the data. These queries allow the user to view average daily vehicle-hours of delay (VHD) for all available days, detectors, and time periods (i.e., before removing incidents and filtering for non-recurrent days). This is one way to identify whether a detection station is broken or producing questionable data. It also allows the user to begin to segment the data. There is a query that allows the user to look at average speeds across all days. Finally, there is a query that produces the average travel time over a pre-defined segment. The results of this query can be copied into a spreadsheet to scan for incidents. The results of this "incident" analysis can be used to populate the Incident Table described above.

"B" queries are "update" queries. An update query makes global changes to a group of records in one or more tables. Specifically, there is a critical field in the *Loop Data* table called "SEGMENT". The segment field gets either a "0" or some integer in each of the records. A zero means that the database will ignore the record from analysis. An integer is the “segmentation” number that can be found in the Segments Table. When the user populates the various tables with data (e.g., incident days, broken detectors, or route segmentation), the “B” queries are used to provide the appropriate value in the SEGMENT field in the *Loop Data* table.

“C” queries are where the analysis is performed. These queries do further testing of the data (e.g., tossing out data with speeds >90 mph or flow rates exceeding 2800 vphpl), calculated delay, calculate averages and standard deviations, and aggregate the data. This is the heart of the analysis. There are queries for estimating total delay and queries for estimating recurrent delay only.

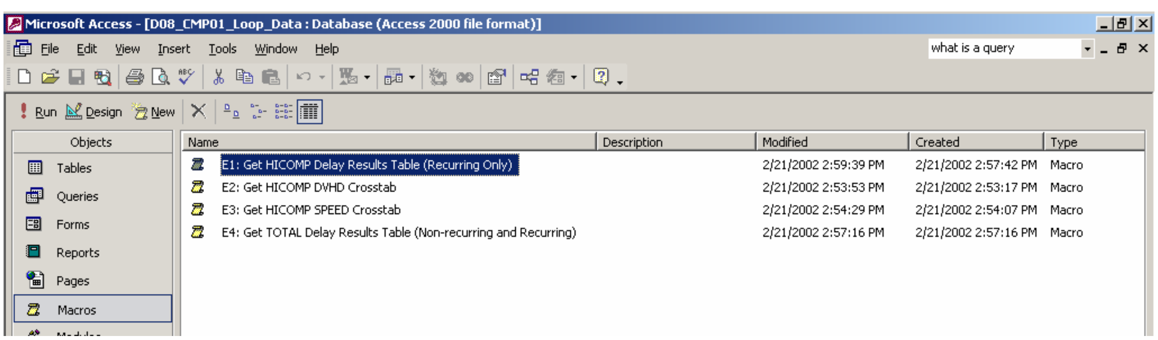
“D” queries present the results. Here, final calculations are made and tables formatted for the final outputs. There are also some queries similar to the queries in the “A” series that show delay by detection station and by time of day. These queries are similar to the “A” queries except that they show only the recurrent delay estimated by the application.

To get a better feel for these four types of queries, please review the database. Each query has a descriptive name and a brief description of its purpose. The data dictionary in the appendix of this document defines each field in all the queries.

Finally, the database has four macros shown in Exhibit 5. A macro is a set of actions that are used to automate common tasks. The HICOMP database uses macros for a specific purpose. These macros ensure that the update queries (See the “B” queries above) are run in the correct order so that the SEGMENT field in the *Loop Data* table contains the correct value. If the SEGMENT field is not updated correctly, then the database may not function correctly.

The first macro produces the recurrent delay table that is reported in the HICOMP report. The second and third macros produce the queries that show the delay and speeds for each detector station and time period. The final macro produces a data table that averages delay across all days and detector stations regardless whether an incident was recorded or not. This macro attempts to measure total delay.

Exhibit 5: Macros in the HICOMP Database



<u>How to Run a HICOMP Analysis</u>

It is expected that the person using the database has a comprehensive understanding of database applications in general, and experience in working with Microsoft Access in particular. This database is not a “black box” that automatically produces results from raw data. The user must be able to review and understand speed profile plots, and be able to determine if data being produced by the detection is “good” or “bad” data.

There are five (5) general steps to conduct an analysis using this database:

Detector data must be downloaded from PeMS in a format readable by the database’s queries. See the data dictionary listing for the table *Raw Loop Data* for a description of the PeMS raw data format. The user may either receive data in the format of the table *Raw Loop Data* or the table *Loop Data* (See the data dictionary listing for these two tables for a description of their formats). If the user imports data in the format used for *Raw Loop Data*, then query “0: Create Loop Data Table” must be run to convert this data format into the table *Loop Data* format.

The user can run queries A2 through A5 to get different looks at the data. For example, query A3 shows the average speeds for each detection station under analysis. One can copy and paste the results of this query into Excel and color code the speeds to show where extreme congestion occurs. It also becomes apparent which detection continuously report low or high speeds, which may indicate a broken detector. The user runs these queries to identify segmentation to be input into the “Incidents” tables.

The “Loop Labels” table needs to be updated to reflect new detection added since the last analysis was performed. In addition, if previously broken detectors were repaired or other detectors are not reporting good data, then the effective lengths need to be adjusted to reflect conditions as they exist at the time of the analysis.

The user needs to update the following tables:

Broken Loops
Incident Table
Unwanted Dates
Segments

Once the tables are updated, then the user can run the macros to get the final results.

This quick review understates the complexity in doing an actual analysis. The user will have to review the detection data carefully to determine which detector stations are reporting bad data. Furthermore, it is critical that the “Loop Labels” file accurately shows the detector station locations (route, direction, postmile) and effective lengths. The effective length will have to be edited when data is missing or considered “bad”.

If you have any questions concerning this document, please do not hesitate to call Bill McCullough at (415) 395-7002. You can also reach him at bill_mccullough@sysmetgroup.com.

Appendix 3 Available tach vehicle data

The attached "spreadsheet" lists the tach vehicle data available to us, together with their characteristics. The entries highlighted in green cover congested segment-days and have significant number of tach runs. The entries highlighted in red cover congested segment-days but there are too few tach runs. The entries that are not highlighted have a significant number of runs but they do not show significant congestion—all have a high average speed. Out of 363 segment-days of tach runs listed in the spreadsheet, only 23 are highlighted green, i.e., have sufficient number of runs on congested segment-days. Of these 23 'good' segment-days, 7 are in 2004, and 16 are in 2002 or 2003. Moreover, these good segment-days do not include any in D7 and D11.

Year	Tach Location Filename	District	County	Rte	Dir	Run Begin Postmile	Run End Postmile	Run Start Location	Run End Location	Run Date	Time Period	Number of Runs	Run From Time	Run To Time	Average Run Interval (Minutes)	Average Run Distance	Minimum Recorded Speed	Maximum Recorded Speed	Average Recorded Speed	Estimated Congestion	Category
2004	ORA091EB	12	ORA	91	E	11.499	19.794	ON FROM EB IMPERIAL	GREEN RIVER OFF	12/9/04	P	13	14:59	19:50	22	8.2	-	75	13	High	I
2002	ORA022EB	12	ORA	22	E	1.126	12.687	GARDEN GROVE	TUSTIN AVE OFF	11/19/02	P	9	15:19	19:17	26	11.7	-	75	26	High	I
2004	ORA091WB	12	ORA	91	W	11.379	4.408	WB IMPERIAL ON	EAST ST OFF	11/4/04	P	12	12:03	19:09	36	6.9	-	75	27	High	I
2002	ORA005SB	12	ORA	5	S	37.415	30.263	SB HARBOR ON	RTE 55 OC	11/6/02	A	10	6:07	9:14	19	7.1	-	70	29	High	I
2002	ORA005SB	12	ORA	5	S	44.157	37.501	MANCST/ART ON	HARBOR OFF	11/13/02	A	10	6:08	9:12	18	6.6	-	70	29	High	I
2004	ORA405NB	12	ORA	405	N	0.230	11.268	5/405 JUNCTION	HARBOR BLVD OH SIGN	10/13/04	P	10	15:19	19:20	24	11.2	-	75	29	High	I
2002	ORA005NB	12	ORA	5	N	21.304	30.263	5/405 SEP BRDG	5/55 SEP BRDG	11/5/02	P	11	14:59	19:13	23	9.0	-	70	30	High	I
2002	ORA091WB	12	ORA	91	W	11.379	4.408	WB IMPERIAL ON	EAST ST OFF	11/20/02	P	10	15:21	18:51	21	6.9	-	72	31	High	I
2004	ORA055SB	12	ORA	55	S	17.876	13.665	JCT RTE 91	SB OFF TO EB CHAPMAN	11/3/04	A	10	6:00	9:08	19	3.8	-	75	32	High	I
2004	ORA005NB	12	ORA	5	N	21.304	30.263	5/405 SEP BRIDGE	5/55 SEP BRIDGE	11/18/04	P	13	15:03	19:11	19	8.9	-	75	32	High	I
2004	ORA605SB	12	ORA	605	S	13.460	9.520	CARSON SB ON	RTE 405 ON	10/7/04	P	13	14:59	19:04	19	3.9	-	75	32	High	I
2004	ORA091EB	12	ORA	91	E	4.405	11.353	EAST STREET ON	IMPERIAL OFF	11/4/04	P	11	12:39	19:08	35	7.0	-	75	33	High	I
2002	ORA055NB	12	ORA	55	N	3.091	13.555	NB ON FR 22ST	EB CHAPMAN OFF	10/29/02	P	13	14:58	19:12	20	10.5	-	75	34	High	I
2002	ORA091EB	12	ORA	91	E	10.078	19.794	ON FR LAKEVIEW	GREEN RIV OFF	11/26/02	P	9	15:13	19:09	26	9.7	-	71	20	High	I
2002	ORA091EB	12	ORA	91	E	10.078	19.794	ON FR LAKEVIEW	GREEN RIV OFF	6/26/02	P	8	15:01	19:20	32	9.6	-	72	22	High	I
2002	ORA022EB	12	ORA	22	E	1.126	12.687	GARDEN GROVE	TUSTIN AVE OFF	11/19/02	A	7	6:21	9:18	25	11.8	-	75	31	High	I
2003	Wlink-a	8	RIV	91	W	9.090	-	MCKINLEY ON	ORANGE CO LINE	2/5/03	A	20	4:19	10:45	19	9.1	-	75	29	High	I
2003	NLINK-O	8	RIV	215	N	36.100	38.700	Cactus Ave. On	JCT 60/215	2/20/03	A	17	4:58	10:37	20	2.8	-	75	29	High	I
2002	Slink-k	8	RIV	71	S	7.730	11.530	SB OFF/EUCLID	JCT 91 SEP	12/5/02	A	10	5:09	9:02	23	3.2	-	75	31	High	I
2003	N88002T8	4	ALA	880	N	-	20.010	Great Mall On	Route 92 Off	4/30/03	P	10	14:31	19:41	31	18.9	-	69	44	Moderate	I
2002	SB51PM	3	SAC	51	S	8.602	1.637	RTE 244 ON	E ST OFF	11/6/02	P	17	15:03	18:55	14	7.1	-	72	42	Moderate	I
2002	NB51PM	3	SAC	51	N	0.769	8.449	P ST ON	RTE 244 OFF	11/6/02	P	14	14:45	18:33	16	7.8	-	70	42	Moderate	I
2003	S88005T6	4	ALA	880	S	-	18.800	Rte 92 On	Great Mall Off	5/1/03	A	8	5:25	10:33	38	18.7	-	71	51	Low	II
2004	ORA091WB	12	ORA	91	W	7.810	0.023	EAST STREET ON	CARMENITA POC	11/9/04	A	10	5:59	9:08	19	7.8	-	75	51	Low	II
2002	ORA091WB	12	ORA	91	W	19.811	10.272	GREEN RIV ON	LAKEVIEW OFF	6/26/02	A	10	6:01	9:11	19	9.4	-	75	51	Low	II
2004	ORA405SB	12	ORA	405	S	11.292	0.230	NB HARBOR ON TO SB 405	5/405 JUNCTION	10/13/04	P	11	14:57	19:08	23	11.2	-	75	51	Low	II
2002	ORA091WB	12	ORA	91	W	19.811	10.272	GREEN RIV ON	LAKEVIEW OFF	6/26/02	P	10	15:20	18:30	19	9.5	-	72	52	Low	II
2002	ORA073NB	12	ORA	73	N	23.732	27.992	NB ON FR BISON	FAIRVIEW OFF	10/16/02	P	13	14:58	19:04	19	4.1	-	75	53	Low	II
2004	ORA091WB	12	ORA	91	W	7.810	0.023	EAST STREET ON	CARMENITA POC	11/9/04	P	10	15:00	19:13	25	7.8	-	75	53	Low	II
2002	ORA605SB	12	ORA	605	S	13.460	9.520	CARSON SB ON	RTE 405 ON	10/17/02	P	10	14:58	19:04	25	4.3	-	75	53	Low	II
2002	ORA405NB	12	ORA	405	N	0.230	11.268	5/405 JUNCTION	HARBOR BL OFF	10/22/02	A	11	3:57	9:11	29	11.2	-	75	55	Low	II
2004	ORA005SB	12	ORA	5	S	30.263	21.320	5/55 SEP BRIDGE	5/405 SEP BRDG	11/18/04	P	13	14:54	18:58	19	8.9	-	75	56	Low	II
2002	ORA405SB	12	ORA	405	S	11.292	0.230	NB HARBOR ON	5/405 JUNCTION	10/22/02	A	10	5:58	9:12	19	11.1	-	75	56	Low	II
2002	ORA605SB	12	ORA	605	S	13.460	9.520	CARSON SB ON	RTE 405 ON	10/17/02	A	10	6:00	9:03	18	3.8	-	75	56	Low	II
2004	ORA005SB	12	ORA	5	S	30.263	21.320	5/55 SEP BRIDGE	5/405 SEP BRDG	11/18/04	A	10	6:04	9:00	18	8.8	-	75	57	Low	II
2004	ORA055SB	12	ORA	55	S	17.876	13.665	JCT RTE 91	SB OFF TO EB CHAPMAN	11/3/04	P	13	14:59	19:03	19	3.8	2	75	57	Low	II
2002	ORA605NB	12	ORA	605	N	9.830	13.250	OFF TO 605	CARSON OFF	10/17/02	P	10	15:17	19:03	23	3.3	16	70	58	Low	II
2004	ORA055NB	12	ORA	55	N	13.645	17.825	NB ON FROM WB CHAPMAN	JCT RTE 91	11/3/04	A	10	5:59	9:07	19	3.7	-	75	58	Low	II
2002	ORA005NB	12	ORA	5	N	36.481	43.976	NB HARBOR ON	MANCST/ARTESIA	11/13/02	P	13	14:58	19:04	19	6.5	5	75	58	Low	II
2002	ORA005SB	12	ORA	5	S	30.263	21.320	5/55 SEP BRDG	5/405 SEP BRDG	11/5/02	P	13	14:54	19:02	19	9.0	-	73	59	Low	II
2002	ORA005SB	12	ORA	5	S	30.263	21.320	5/55 SEP BRDG	5/405 SEP BRDG	11/5/02	A	10	6:00	9:08	19	8.9	7	75	59	Low	II
2004	ORA022WB	12	ORA	22	W	12.636	1.202	TUSTIN AVE ON	VALLEY VIEW	10/14/04	A	10	5:59	9:11	19	11.5	-	75	59	Low	II
2002	ORA055NB	12	ORA	55	N	3.091	13.555	NB ON FR 22ST	EB CHAPMAN OFF	10/29/02	A	10	5:59	9:10	19	10.5	-	75	60	Low	II
2002	ORA055SB	12	ORA	55	S	17.620	13.655	JCT RTE 91	SB OFF EB CHAP	10/30/02	P	13	14:59	19:04	19	3.8	24	75	61	Low	II
2002	ORA005SB	12	ORA	5	S	44.157	37.501	MANCST/ART ON	HARBOR OFF	11/13/02	P	13	14:56	19:03	19	6.6	31	74	62	Low	II
2002	ORA055NB	12	ORA	55	N	13.645	17.825	EB CHAPMAN ON	JCT 91 W 91/55	10/30/02	A	11	6:02	9:05	17	3.6	9	70	62	Low	II
2004	ORA005NB	12	ORA	5	N	7.116	21.304	RAMBLAS RTE 1	5/405 SEP BRIDGE	11/17/04	P	12	15:01	19:11	21	14.0	5	75	62	Low	II
2002	ORA073NB	12	ORA	73	N	23.732	27.992	NB ON FR BISON	FAIRVIEW OFF	10/16/02	A	10	6:02	9:05	18	4.1	16	75	62	Low	II
2002	ORA005NB	12	ORA	5	N	30.302	37.287	RTE 55 O.C.	OFF TO HARBOR	11/6/02	A	10	5:58	9:07	19	6.9	23	75	62	Low	II
2004	ORA073SB	12	ORA	73	S	27.728	23.737	ON FROM FAIRVIEW	BISON OFF	10/6/04	A	10	6:20	11:19	30	4.0	3	75	62	Low	II
2002	ORA091EB	12	ORA	91	E	10.078	19.794	ON FR LAKEVIEW	GREEN RIV OFF	6/26/02	A	10	5:59	8:50	17	9.5	19	75	63	Low	II
2002	ORA605NB	12	ORA	605	N	9.830	13.250	OFF TO 605	CARSON OFF	10/17/02	A	10	5:58	9:03	18	3.3	-	75	64	Low	II
2002	ORA073SB	12	ORA	73	S	27.728	23.737	ON FR FAIRVIEW	BISON OFF	10/16/02	A	10	5:55	9:01	19	3.9	29	75	64	Low	II
2002	ORA005NB	12	ORA	5	N	36.481	43.976	NB HARBOR ON	MANCST/ARTESIA	11/13/02	A	10	5:58	9:05	19	6.6	10	75	64	Low	II
2004	ORA073NB	12	ORA	73	N	23.732	27.992	NB ON FR BISON	FAIRVIEW OFF	10/6/04	P	13	14:59	19:03	19	4.2	3	75	64	Low	II
2004	ORA073SB	12	ORA	73	S	27.728	23.737	ON FROM FAIRVIEW	BISON OFF	10/6/04	P	12	15:04	19:03	20	4.0	3	75	65	Low	II
2002	ORA091WB	12	ORA	91	W	7.810	0.023	EAST ST ON	CARMENITA POC	11/21/02	A	8	6:00	9:07	23	7.7	-	73	53	Low	II
2002	ORA091EB	12	ORA	91	E	4.405	11.353	EAST ST ON	IMPERIAL OFF	11/20/02	A	7	6:18	9:07	24	7.0	10	75	54	Low	II
2004	ORA405NB	12	ORA	405	N	0.230	11.268	5/405 JUNCTION	HARBOR BLVD OH SIGN	10/13/04	A	9	6:03	9:11	21	11.2	-	75	56	Low	II
2002	ORA055SB	12	ORA	55	S	17.620	13.655	JCT RTE 91	SB OFF EB CHAP	10/30/02	A	9	5:58	9:03	21	3.8	-	73	56	Low	II

2004	ORA091EB	12	ORA	91	E	11.499	19.794	ON FROM EB IMPERIAL	GREEN RIVER OFF	12/9/04	A	9	6:00	9:10	21	8.1	7	75	57	Low	II
2002	ORA022WB	12	ORA	22	W	12.636	1.202	TUSTIN AVE ON	VALLEY VIEW	11/19/02	A	8	5:59	9:10	24	11.6	10	75	61	Low	II
2002	ORA091EB	12	ORA	91	E	10.078	19.794	ON FR LAKEVIEW	GREEN RIV OFF	11/26/02	A	7	5:57	8:48	24	9.6	16	73	62	Low	II
2004	ORA405SB	12	ORA	405	S	11.292	0.230	NB HARBOR ON TO SB 405	5/405 JUNCTION	10/13/04	A	8	6:02	9:10	23	11.3	9	75	64	Low	II
2004	ORA073NB	12	ORA	73	N	23.732	27.992	NB ON FR BISON	FAIRVIEW OFF	10/6/04	A	9	6:01	9:04	20	4.2	5	75	65	Low	II
2003	Nlink-n	8	RIV	15	N	40.520	52.280	MAGNOLIA ON	COUNTY LINE	2/5/03	P	13	14:57	19:07	19	11.9	-	75	53	Low	II
2003	WLINK-D	8	RIV	91	W	21.660	14.220	JCT 215/60 SEP	WBOFF/VANBUREN	1/28/03	P	13	14:50	19:05	20	7.9	-	75	53	Low	II
2003	WLINK-F	8	RIV	215	N	34.390	43.250	PERRIS BLVD ON	60/215/91 SEP	2/19/03	A	14	5:04	9:31	19	5.0	-	75	54	Low	II
2003	ELink-d	8	RIV	91	E	9.180	21.660	EB ON/SB MICKL	JCT 215/60 SEP	1/28/03	P	13	15:07	19:05	18	12.8	-	75	55	Low	II
2003	Nlink-h	8	RIV	215	N	43.270	47.960	JCT 215/60 SEP	NB OFF/WASHING	1/30/03	A	12	4:59	8:41	19	2.1	2	75	55	Low	II
2003	Slink-h	8	RIV	215	S	47.880	43.270	WASHINGTON ON	JCT 215/60 SEP	1/30/03	A	11	5:21	9:03	20	3.0	5	75	56	Low	II
2003	WLINK-F	8	RIV	215	N	34.390	43.250	PERRIS BLVD ON	60/215/91 SEP	2/19/03	P	13	15:12	19:04	18	5.3	-	75	56	Low	II
2003	Nlink-n	8	RIV	15	N	40.520	52.280	MAGNOLIA ON	COUNTY LINE	2/6/03	A	13	4:59	9:10	19	11.9	-	75	56	Low	II
2003	ELINK-F	8	RIV	60	E	43.250	35.410	60/215/91 SEP	HEACOCK OFF	2/18/03	P	14	15:12	19:27	18	2.9	-	75	57	Low	II
2003	SLINK-N	8	RIV	15	S	52.280	40.560	COUNTY LINE	MAGNOLIA OFF	2/5/03	P	13	14:56	19:11	20	11.8	10	75	63	Low	II
2003	SLINK-N	8	RIV	15	S	52.280	40.560	COUNTY LINE	MAGNOLIA OFF	2/6/03	A	13	5:00	9:11	19	11.8	7	75	65	Low	II
2002	SB51AM	3	SAC	51	S	8.602	1.637	RTE 244 ON	E ST OFF	11/6/02	A	9	6:40	8:53	15	6.8	-	69	52	Low	II
2003	ELINK-I	8	SBD	10	E	24.240	35.330	JCT 10/215 SEP	YUCAIPA OFF	4/23/03	P	12	14:59	18:48	19	11.3	-	75	54	Low	II
2002	NLINK-L	8	SBD	15	N	-	9.860	SBD/RIV CO./LN	NB OFF/SUMMIT	12/3/02	P	13	15:00	19:09	19	9.4	-	75	56	Low	II
2003	Nlink-h	8	SBD	215	N	43.270	47.960	JCT 215/60 SEP	NB OFF/WASHING	1/30/03	A	12	5:01	8:44	19	2.8	5	75	58	Low	II
2003	Slink-h	8	SBD	215	S	47.880	43.270	WASHINGTON ON	JCT 215/60 SEP	1/30/03	A	11	5:20	9:01	20	2.8	-	75	59	Low	II
2003	WLINK-G	8	SBD	10	W	18.360	9.940	WB ONFRM CEDAR	JCT 15/10 SEP	4/30/03	P	13	14:59	19:08	19	8.6	11	75	62	Low	II
2002	NLINK-L	8	SBD	15	N	-	9.860	SBD/RIV CO./LN	NB OFF/SUMMIT	12/4/02	A	11	4:58	8:49	21	10.0	1	75	66	Low	II
2004	4	10	SJ	99	N	-	9.240	EB 4 onramp from Fresno Ave	NB 99 Morada Lane off ramp	1/15/04	P	15	14:35	18:08	14	5.3	-	75	51	Low	II
2004	1	10	SJ	205	W	-	13.930	WB 120 Yosemite Ave onramp	WB 205 off ramp to Mt House Pkwy	1/29/04	A	15	4:01	7:46	15	11.9	-	75	51	Low	II
2003	6	10	SJ	99	S	-	8.990	SB 99 onramp from Cherokee Rd	SB 99 offramp to French Camp Rd	11/19/03	P	7	15:13	18:23	27	9.0	7	75	52	Low	II
2004	10	10	SJ	4	W	-	9.840	WB 4 onramp from Stanislaus St	NB 5 off ramp to Eight Mile Rd	1/13/04	P	16	14:30	18:15	14	1.3	5	66	53	Low	II
2003	9	10	SJ	4	E	-	9.840	SB 5 onramp from Eight Mile Rd	EB 4 off to Stanislaus Street	11/20/03	A	12	5:39	8:26	14	1.3	-	65	53	Low	II
2004	6	10	SJ	99	S	-	8.990	SB 99 onramp from Cherokee Rd	SB 99 offramp to French Camp Rd	1/14/04	P	15	14:49	18:29	15	8.4	5	75	54	Low	II
2003	10	10	SJ	5	N	-	9.840	WB 4 onramp from Stanislaus St	NB 5 off ramp to Eight Mile Rd	11/20/03	P	9	14:55	18:25	23	8.5	-	75	54	Low	II
2004	3	10	SJ	99	S	-	9.190	SB 99 Morada Lane onramp	WB 4 off to Fresno Ave	1/15/04	A	11	6:13	8:48	14	5.2	3	75	55	Low	II
2004	4	10	SJ	4	E	-	9.240	EB 4 onramp from Fresno Ave	NB 99 Morada Lane off ramp	1/15/04	P	15	14:31	18:03	14	4.0	-	75	55	Low	II
2003	5	10	SJ	99	N	-	9.250	NB 99 onramp from French Camp	NB 99 off ramp to Cherokee Rd	11/19/03	A	10	6:05	8:39	15	8.9	-	75	55	Low	II
2004	2	10	SJ	5	N	-	13.810	EB 205 Mt. House Pkwy onramp	EB 120 off ramp to Yosemite Ave	1/27/04	P	13	14:11	20:25	29	1.3	11	68	55	Low	II
2004	8	10	SJ	120	E	-	7.550	NB 5 on ramp from Mossdale Rd	SB 99 off ramp to Austin Rd	1/21/04	P	16	15:00	18:46	14	6.7	-	75	57	Low	II
2003	9	10	SJ	5	S	-	9.840	SB 5 onramp from Eight Mile Rd	EB 4 off to Stanislaus Street	11/20/03	A	12	5:31	8:24	14	8.5	16	75	58	Low	II
2004	8	10	SJ	120	E	-	7.550	NB 5 on ramp from Mossdale Rd	SB 99 off ramp to Austin Rd	2/4/04	P	13	15:00	18:07	14	6.7	9	75	58	Low	II
2004	10	10	SJ	5	N	-	9.840	WB 4 onramp from Stanislaus St	NB 5 off ramp to Eight Mile Rd	1/13/04	P	16	14:31	18:23	15	8.5	1	75	58	Low	II
2004	5	10	SJ	99	N	-	9.250	NB 99 onramp from French Camp	NB 99 off ramp to Cherokee Rd	1/14/04	A	11	5:58	8:40	15	9.4	3	75	58	Low	II
2004	1	10	SJ	120	W	-	13.930	WB 120 Yosemite Ave onramp	WB 205 off ramp to Mt House Pkwy	1/27/04	A	16	4:00	7:45	14	1.2	18	70	58	Low	II
2004	1	10	SJ	5	S	-	13.930	WB 120 Yosemite Ave onramp	WB 205 off ramp to Mt House Pkwy	1/27/04	A	16	4:01	7:46	14	1.6	8	73	59	Low	II
2004	9	10	SJ	4	E	-	9.840	SB 5 onramp from Eight Mile Rd	EB 4 off to Stanislaus Street	1/13/04	A	11	5:53	8:39	15	1.5	7	72	60	Low	II
2004	2	10	SJ	120	E	-	13.810	EB 205 Mt. House Pkwy onramp	EB 120 off ramp to Yosemite Ave	1/27/04	P	13	14:12	20:27	29	1.5	2	75	60	Low	II
2004	1	10	SJ	120	W	-	13.930	WB 120 Yosemite Ave onramp	WB 205 off ramp to Mt House Pkwy	1/29/04	A	15	3:59	7:34	14	1.2	32	72	60	Low	II
2004	2	10	SJ	120	E	-	13.810	EB 205 Mt. House Pkwy onramp	EB 120 off ramp to Yosemite Ave	1/29/04	P	20	14:28	19:39	16	1.5	3	72	60	Low	II
2003	3	10	SJ	4	W	-	9.190	SB 99 Morada Lane onramp	WB 4 off to Fresno Ave	11/18/03	A	15	5:04	8:38	14	4.1	2	75	61	Low	II
2004	3	10	SJ	4	W	-	9.190	SB 99 Morada Lane onramp	WB 4 off to Fresno Ave	1/15/04	A	11	6:18	8:52	14	4.4	-	75	61	Low	II
2004	9	10	SJ	5	S	-	9.840	SB 5 onramp from Eight Mile Rd	EB 4 off to Stanislaus Street	1/13/04	A	11	5:45	8:37	16	8.5	10	75	62	Low	II
2004	7	10	SJ	120	W	-	8.180	NB 99 on ramp from Austin Rd	SB 5 off ramp to Manthy Rd	1/22/04	A	15	4:26	8:03	14	6.6	30	75	64	Low	II
2004	11	10	STA	99	N	11.000	24.086	NB 99 on from Whitmore Ave	NB 99 off ramp to Hammet Rd	1/20/04	A	8	5:43	9:30	28	11.2	-	74	51	Low	II
2004	12	10	STA	99	S	24.000	11.772	SB 99 on ramp from Hammet Rd	SB 99 off ramp to Whitmore Ave	1/20/04	P	13	14:29	18:26	18	12.3	-	75	53	Low	II
2004	11	10	STA	99	N	11.000	24.086	NB 99 on from Whitmore Ave	NB 99 off ramp to Hammet Rd	1/28/04	A	12	5:34	8:25	14	12.3	7	75	61	Low	II
2004	12	10	STA	99	S	24.000	11.772	SB 99 on ramp from Hammet Rd	SB 99 off ramp to Whitmore Ave	1/28/04	P	14	14:29	18:11	16	12.2	2	75	62	Low	II
2002	ORA405SB	12	ORA	405	S	25.060	11.675	STEARNS ON	HARBOR BL OFF	10/23/02	A	10	6:00	9:18	20	13.4	-	75	36	Moderate	II
2004	ORA091WB	12	ORA	91	W	11.379	4.408	WB IMPERIAL ON	EAST ST OFF	11/4/04	A	11	6:00	10:58	27	7.0	-	75	37	Moderate	II
2002	ORA005NB	12	ORA	5	N	21.304	30.263	5/405 SEP BRDG	5/55 SEP BRDG	11/5/02	A	10	6:01	9:15	19	9.0	-	75	38	Moderate	II
2004	ORA022WB	12	ORA	22	W	12.636	1.202	TUSTIN AVE ON	VALLEY VIEW	10/14/04	P	13	15:01	19:13	19	11.5	-	75	40	Moderate	II
2004	ORA022EB	12	ORA	22	E	1.126	12.687	GARDEN GROVE	TUSTIN AVE OFF	10/14/04	A	10	6:01	9:14	19	11.7	-	75	40	Moderate	II
2002	ORA005NB	12	ORA	5	N	30.302	37.287	RTE 55 O.C.	OFF TO HARBOR	11/6/02	P	13	14:59	19:09	19	7.0	-	70	41	Moderate	II
2002	ORA055SB	12	ORA	55	S	13.507	3.098	EB CHAPMAN ON	FAIRVIEW OFF	10/29/02	A	10	6:01	9:12	19	10.4	-	75	41	Moderate	II
2002	ORA405SB	12	ORA	405	S	25.060	11.675	STEARNS ON	HARBOR BL OFF	10/23/02	P	13	15:00	19:12	19	13.3	-	75	43	Moderate	II
2004	ORA605NB	12	ORA	605	N	9.830	13.250	OFF TO 605	CARSON OFF	10/7/04	P	13	14:59	19:12	19	3.4	-	72	44	Moderate	II
2002	ORA405NB	12	ORA	405	N	0.230	11.268	5/405 JUNCTION	HARBOR BL OFF	10/22/02	P	12	15:00	18:53	19	11.3	-	75	45	Moderate	II
2004	ORA055NB	12	ORA	55	N	13.645	17.825	NB ON FROM WB CHAPMAN	JCT RTE 91	11/3/04	P	13	15:01	19:09	19	3.7	-	71	45	Moderate	II

2004	ORA005NB	12	ORA	5	N	21.304	30.263	5/405 SEP BRIDGE	5/55 SEP BRIDGE	11/18/04	A	11	5:59	9:14	18	9.0	-	75	45	Moderate	II
2004	ORA022EB	12	ORA	22	E	1.126	12.687	GARDEN GROVE	TUSTIN AVE OFF	10/14/04	P	12	15:11	19:20	21	11.6	-	75	46	Moderate	II
2004	ORA091EB	12	ORA	91	E	0.230	7.751	CARMENITA POC	EAST ST. OFF	11/9/04	A	10	6:00	9:08	19	7.7	-	75	46	Moderate	II
2004	ORA091WB	12	ORA	91	W	19.811	11.788	GREEN RIVER ON	IMPERIAL OFF	12/9/04	P	13	15:01	19:35	21	8.0	-	75	46	Moderate	II
2002	ORA091EB	12	ORA	91	E	0.023	7.751	CARMENITA POC	EAST ST. OFF	11/21/02	P	10	14:59	19:08	25	7.8	-	72	46	Moderate	II
2004	ORA605NB	12	ORA	605	N	9.830	13.250	OFF TO 605	CARSON OFF	10/7/04	A	10	6:01	8:58	18	3.4	-	75	47	Moderate	II
2004	ORA091EB	12	ORA	91	E	4.405	11.353	EAST STREET ON	IMPERIAL OFF	11/4/04	A	12	6:00	11:34	28	6.8	-	75	48	Moderate	II
2004	ORA605SB	12	ORA	605	S	13.460	9.520	CARSON SB ON	RTE 405 ON	10/7/04	A	10	5:58	9:03	19	3.9	-	75	48	Moderate	II
2004	ORA091EB	12	ORA	91	E	0.230	7.751	CARMENITA POC	EAST ST. OFF	11/9/04	P	11	15:02	19:10	23	7.4	-	75	48	Moderate	II
2002	ORA405NB	12	ORA	405	N	11.438	25.200	N/B HARBOR ON	PALO VERDE OFF	10/23/02	P	13	14:58	19:15	20	13.7	-	73	49	Moderate	II
2002	ORA055SB	12	ORA	55	S	13.507	3.098	EB CHAPMAN ON	FAIRVIEW OFF	10/29/02	P	13	14:58	19:12	20	10.4	-	74	49	Moderate	II
2002	ORA055NB	12	ORA	55	N	13.645	17.825	EB CHAPMAN ON	JCT 91 W 91/55	10/30/02	P	13	15:02	19:04	19	3.6	-	72	49	Moderate	II
2004	ORA005SB	12	ORA	5	S	21.304	6.972	5/405 SEP BRIDGE	SB OFF RTE 001	11/17/04	P	13	15:01	19:13	19	14.2	-	75	49	Moderate	II
2002	ORA005SB	12	ORA	5	S	37.415	30.263	SB HARBOR ON	RTE 55 OC	11/6/02	P	13	14:59	19:06	19	7.0	-	72	49	Moderate	II
2002	ORA405SB	12	ORA	405	S	11.292	0.230	NB HARBOR ON	5/405 JUNCTION	10/22/02	P	12	14:59	19:10	21	11.1	-	75	49	Moderate	II
2002	ORA405NB	12	ORA	405	N	11.438	25.200	N/B HARBOR ON	PALO VERDE OFF	10/23/02	A	10	6:00	9:14	19	13.7	-	74	50	Moderate	II
2002	ORA022WB	12	ORA	22	W	12.636	1.202	TUSTIN AVE ON	VALLEY VIEW	11/19/02	P	9	14:58	19:12	28	11.6	-	75	35	Moderate	II
2002	ORA091WB	12	ORA	91	W	7.810	0.023	EAST ST ON	CARMENITA POC	11/21/02	P	9	13:49	18:51	34	7.8	-	70	37	Moderate	II
2002	ORA091EB	12	ORA	91	E	0.023	7.751	CARMENITA POC	EAST ST. OFF	11/21/02	A	7	6:00	8:58	25	7.7	-	70	37	Moderate	II
2002	ORA091WB	12	ORA	91	W	11.379	4.408	WB IMPERIAL ON	EAST ST OFF	11/20/02	A	7	5:59	9:09	27	7.0	-	70	40	Moderate	II
2002	ORA091EB	12	ORA	91	E	4.405	11.353	EAST ST ON	IMPERIAL OFF	11/20/02	P	9	15:00	19:07	27	6.9	-	70	46	Moderate	II
2004	ORA091WB	12	ORA	91	W	19.811	11.788	GREEN RIVER ON	IMPERIAL OFF	12/9/04	A	8	5:58	8:48	21	8.0	-	75	48	Moderate	II
2002	ORA091WB	12	ORA	91	W	19.811	10.272	GREEN RIV ON	LAKEVIEW OFF	11/26/02	A	8	6:00	9:09	24	9.5	-	73	50	Moderate	II
2003	Slink-h	8	RIV	215	S	47.880	43.270	WASHINGTON ON	JCT 215/60 SEP	1/29/03	P	15	14:21	19:02	19	2.4	-	75	39	Moderate	II
2003	WLINK-F	8	RIV	60	W	34.390	43.250	PERRIS BLVD ON	60/215/91 SEP	2/19/03	A	14	5:00	9:22	19	3.8	-	75	43	Moderate	II
2003	Nlink-h	8	RIV	215	N	43.270	47.960	JCT 215/60 SEP	NB OFF/WASHING	1/29/03	P	15	14:18	18:44	18	2.1	-	72	43	Moderate	II
2003	ELINK-F	8	RIV	215	S	43.250	35.410	60/215/91 SEP	HEACOCK OFF	2/18/03	P	14	15:06	19:24	18	5.1	-	72	45	Moderate	II
2003	WLINK-F	8	RIV	60	W	34.390	43.250	PERRIS BLVD ON	60/215/91 SEP	2/19/03	P	13	14:58	18:59	19	3.9	-	75	48	Moderate	II
2003	ELink-d	8	RIV	91	E	9.180	21.660	EB ON/SB MICKL	JCT 215/60 SEP	1/29/03	A	13	5:47	9:46	18	12.8	-	75	49	Moderate	II
2003	Elink-g	8	SBD	10	E	9.940	18.180	JCT 15/10 SEP	EB OFF/ CEDAR	5/28/03	P	12	15:00	18:49	19	8.3	-	75	40	Moderate	II
2003	Nlink-e	8	SBD	215	N	4.050	9.920	CL 10-215 IC	E ST OFF GORE	5/29/03	P	15	15:00	18:36	14	5.9	-	72	43	Moderate	II
2002	NLINK-M	8	SBD	15	N	9.850	17.410	NB ON/ SUMMIT	NB OFF/KENWOOD	11/1/02	P	18	14:39	20:26	19	7.9	-	75	44	Moderate	II
2003	Nlink-h	8	SBD	215	N	43.270	47.960	JCT 215/60 SEP	NB OFF/WASHING	1/29/03	P	15	14:20	18:46	18	2.7	-	75	49	Moderate	II
2003	Slink-h	8	SBD	215	S	47.880	43.270	WASHINGTON ON	JCT 215/60 SEP	1/29/03	P	15	14:18	19:00	19	2.5	-	75	49	Moderate	II
2004	7	10	SJ	99	N	-	8.180	NB 99 on ramp from Austin Rd	SB 5 off ramp to Manthy Rd	1/21/04	A	14	5:04	8:16	14	1.1	8	62	43	Moderate	II
2004	2	10	SJ	205	E	-	13.810	EB 205 Mt. House Pkwy onramp	EB 120 off ramp to Yosemite Ave	1/27/04	P	19	13:59	20:24	20	11.0	-	75	43	Moderate	II
2003	4	10	SJ	4	E	-	9.240	EB 4 onramp from Fresno Ave	NB 99 Morada Lane off ramp	11/18/03	P	7	14:44	18:12	30	4.0	-	74	44	Moderate	II
2004	7	10	SJ	99	N	-	8.180	NB 99 on ramp from Austin Rd	SB 5 off ramp to Manthy Rd	1/22/04	A	15	4:24	7:57	14	1.1	14	59	47	Moderate	II
2004	2	10	SJ	205	E	-	13.810	EB 205 Mt. House Pkwy onramp	EB 120 off ramp to Yosemite Ave	1/29/04	P	20	14:16	19:36	16	11.0	-	75	48	Moderate	II
2003	4	10	SJ	99	N	-	9.240	EB 4 onramp from Fresno Ave	NB 99 Morada Lane off ramp	11/18/03	P	7	14:48	18:18	30	5.3	1	75	48	Moderate	II
2003	10	10	SJ	4	W	-	9.840	WB 4 onramp from Stanislaus St	NB 5 off ramp to Eight Mile Rd	11/20/03	P	9	14:54	18:16	23	1.3	-	69	48	Moderate	II
2004	7	10	SJ	120	W	-	8.180	NB 99 on ramp from Austin Rd	SB 5 off ramp to Manthy Rd	1/21/04	A	14	5:05	8:23	14	6.7	-	73	48	Moderate	II
2004	1	10	SJ	205	W	-	13.930	WB 120 Yosemite Ave onramp	WB 205 off ramp to Mt House Pkwy	1/27/04	A	16	4:03	7:58	15	11.1	-	75	48	Moderate	II
2003	3	10	SJ	99	S	-	9.190	SB 99 Morada Lane onramp	WB 4 off to Fresno Ave	11/18/03	A	16	4:44	8:35	14	5.2	-	75	49	Moderate	II
2003	N88002T8	4	ALA	880	N	-	20.010	Great Mall On	Route 92 Off	10/24/03	A	3	1:18	4:42	68	19.1	-	69	34	High	III
2004	ORA091EB	12	ORA	91	E	11.499	19.794	EB IMPERIAL ON	GREEN RIV OFF	6/9/04	P	3	15:57	19:13	65	8.2	-	73	15	High	III
2002	ORA091EB	12	ORA	91	E	0.023	7.751	CARMENITA POC	EAST ST. OFF	11/20/02	P	1	14:08	14:17	9	2.6	-	47	17	High	III
2004	ORA405SB	12	ORA	405	S	25.060	15.475	STEARNS ON	HEIL PED OC	6/2/04	A	2	7:00	8:44	52	9.8	-	73	22	High	III
2004	ORA405SB	12	ORA	405	S	15.475	10.282	HEIL AVE POC	RTE 73/405 SEP	6/1/04	A	1	8:41	8:53	12	5.2	-	60	26	High	III
2004	ORA091EB	12	ORA	91	E	1.167	7.451	EB ON FR GR RV	I 15 JCT	6/8/04	P	3	15:40	18:29	56	6.3	-	71	28	High	III
2002	Slink-k	8	RIV	71	S	7.730	11.530	SB OFF/EUCLID	JCT 91 SEP	12/4/02	A	3	5:46	7:52	42	3.0	-	47	20	High	III
2003	N88004T9	4	ALA	880	N	2.000	19.500	Route 84 On	Coll/66th Off	5/8/03	A	4	5:58	10:16	65	16.8	-	72	51	Low	III
2003	N88002T8	4	ALA	880	N	-	20.010	Great Mall On	Route 92 Off	10/8/03	A	3	6:16	9:54	73	19.2	-	67	55	Low	III
2003	N88004T9	4	ALA	880	N	2.000	19.500	Route 84 On	Coll/66th Off	5/22/03	A	4	5:58	10:14	64	16.8	-	67	56	Low	III
2003	S88005T6	4	ALA	880	S	-	18.800	Rte 92 On	Great Mall Off	10/23/03	P	6	15:27	18:56	35	19.0	-	75	57	Low	III
2002	S88008TS	4	ALA	880	S	-	17.278	7Th St. On	Rte 92 Off	6/12/02	A	5	5:49	9:31	44	16.8	2	69	57	Low	III
2003	N88002T8	4	ALA	880	N	-	20.010	Great Mall On	Route 92 Off	5/1/03	A	6	5:44	9:44	40	18.8	-	68	58	Low	III
2002	N88006TO	4	ALA	880	N	-	26.464	RTE 92 ON	7TH ST OFF	6/12/02	A	6	5:31	9:49	43	16.7	13	69	58	Low	III
2003	S88005T6	4	ALA	880	S	-	18.800	Rte 92 On	Great Mall Off	10/14/03	P	4	14:59	19:18	65	19.1	16	69	59	Low	III
2003	S88004TS	4	ALA	880	S	4.000	18.800	Fremont On	Great Mall Off	6/4/03	P	5	14:45	19:09	53	13.7	18	69	60	Low	III
2003	S88008TS	4	ALA	880	S	-	17.278	7Th St. On	Rte 92 Off	5/8/03	A	1	6:39	6:56	16	16.7	16	69	61	Low	III
2003	S88008TS	4	ALA	880	S	-	17.278	7Th St. On	Rte 92 Off	5/21/03	P	5	15:17	19:40	53	28.3	-	75	71	Low	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	9/12/02	A	3	7:08	8:10	21	10.3	4	70	54	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	4/25/02	P	4	16:13	17:54	25	11.0	1	75	55	Low	III

2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	9/10/02	A	4	6:58	8:20	21	9.5	2	74	56	Low	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	9/11/02	A	4	6:59	8:24	21	10.3	-	73	57	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	3/19/02	A	3	6:41	7:47	22	9.5	-	73	57	Low	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	10/3/02	A	4	6:49	8:13	21	10.4	-	75	58	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	10/9/02	P	4	16:03	17:44	25	11.1	2	75	58	Low	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	4/4/02	A	4	6:51	8:15	21	10.4	3	71	58	Low	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	5/1/02	A	3	6:49	7:49	20	10.3	5	75	58	Low	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	10/1/02	A	4	6:53	8:17	21	10.5	2	75	59	Low	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	9/10/02	P	4	16:21	17:43	21	10.4	6	73	60	Low	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	3/19/02	A	3	6:56	8:07	24	11.1	-	74	60	Low	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	5/2/02	A	4	6:55	8:17	20	10.4	5	75	60	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	10/8/02	P	4	16:05	17:43	25	11.0	10	73	60	Low	III
2002	FRE168SB	6	FRE	168	S	4.813	0.993	WILLOW AVE OC	MCKINLEY AV UC	4/16/02	A	7	6:48	8:15	12	3.9	-	75	60	Low	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	4/3/02	P	5	16:03	17:47	21	10.5	11	73	60	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	10/3/02	P	5	15:59	17:49	22	10.5	8	75	60	Low	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	9/19/02	A	3	6:31	8:14	34	11.0	-	72	61	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	3/20/02	P	4	16:03	17:42	25	11.0	4	74	61	Low	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	4/2/02	P	4	16:08	17:29	20	10.4	21	72	61	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	4/23/02	P	4	16:00	17:37	24	11.0	4	75	61	Low	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	10/8/02	A	3	6:58	8:09	24	11.1	-	75	61	Low	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	10/9/02	A	4	6:52	8:30	25	11.1	-	75	61	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	9/19/02	P	4	16:12	17:51	25	11.0	17	71	61	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	4/24/02	P	4	16:08	17:53	26	11.0	11	75	61	Low	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	4/25/02	A	3	7:09	8:18	23	10.3	3	75	61	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	9/12/02	P	4	16:14	17:34	20	10.3	12	75	61	Low	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	10/10/02	A	3	6:51	8:00	23	11.1	8	75	62	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	9/18/02	P	4	16:16	17:52	24	11.0	2	74	62	Low	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	9/18/02	A	3	6:32	8:13	34	11.0	7	74	62	Low	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	3/21/02	A	2	7:09	7:48	20	11.0	11	74	62	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	4/2/02	P	5	15:57	17:41	21	10.4	5	75	62	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	4/4/02	A	4	6:40	8:03	21	10.4	9	69	62	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	4/3/02	P	5	15:51	17:36	21	10.4	5	71	62	Low	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	4/23/02	A	3	7:05	8:14	23	11.1	5	75	62	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	9/10/02	P	4	16:10	17:32	20	10.4	10	72	63	Low	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	9/12/02	P	4	16:26	17:46	20	10.2	8	72	63	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	9/12/02	A	4	6:52	8:22	22	10.6	3	75	63	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	9/11/02	P	4	16:11	17:33	21	10.5	13	72	63	Low	III
2002	FRE168SB	6	FRE	168	S	4.813	0.993	WILLOW AVE OC	MCKINLEY AV UC	10/16/02	A	6	6:42	8:12	15	3.9	-	72	63	Low	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	9/5/02	A	4	6:53	8:31	24	11.1	26	75	63	Low	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	9/11/02	P	3	16:22	17:21	20	10.3	28	71	63	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	4/30/02	P	5	15:55	17:41	21	10.5	7	73	63	Low	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	3/20/02	A	3	6:58	8:06	23	11.1	23	74	63	Low	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	4/30/02	P	5	16:11	17:52	20	10.3	-	74	63	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	9/11/02	A	4	6:47	8:12	21	10.5	9	74	63	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	9/10/02	A	4	6:47	8:12	21	10.5	27	74	64	Low	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	4/24/02	A	3	7:05	8:14	23	11.0	17	73	64	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	4/4/02	P	4	15:58	17:18	20	10.5	8	72	64	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	3/21/02	P	4	15:58	17:41	26	11.0	15	75	64	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	5/1/02	A	4	6:39	7:55	19	8.8	2	75	64	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	5/1/02	P	5	16:00	17:44	21	10.7	-	75	64	Low	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	9/19/02	P	3	16:28	17:38	23	11.0	8	74	64	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	10/3/02	A	5	6:37	8:25	21	10.1	16	75	64	Low	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	4/4/02	P	4	16:12	17:30	19	10.4	9	75	64	Low	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	10/2/02	P	4	16:22	17:39	19	10.5	17	74	64	Low	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	4/23/02	P	3	16:15	17:24	23	11.1	4	75	65	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	3/19/02	P	4	16:01	17:38	24	11.0	7	73	65	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	4/25/02	A	3	6:54	8:05	24	11.6	4	73	65	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	10/2/02	P	5	16:11	17:50	20	10.5	21	74	65	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	9/19/02	A	3	6:44	8:26	34	11.1	16	75	65	Low	III
2002	FRE168SB	6	FRE	168	S	4.813	0.993	WILLOW AVE OC	MCKINLEY AV UC	4/16/02	P	8	16:02	17:38	12	3.9	22	74	65	Low	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	10/3/02	P	4	16:11	17:37	22	10.5	7	73	65	Low	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	4/25/02	P	4	16:00	17:40	25	11.2	6	75	65	Low	III
2002	FRE168SB	6	FRE	168	S	4.813	0.993	WILLOW AVE OC	MCKINLEY AV UC	10/16/02	P	6	16:07	17:50	17	5.6	-	75	65	Low	III
2002	FRE168NB	6	FRE	168	N	0.999	4.813	MCKINLEY AV UC	WILLOW AVE OC	4/16/02	P	8	15:56	17:33	12	3.8	14	72	66	Low	III

2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	5/2/02	P	5	15:59	17:36	20	10.5	26	75	66	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	10/1/02	A	4	6:41	8:04	21	10.6	4	75	66	Low	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	3/19/02	P	4	16:16	17:53	24	11.1	20	75	66	Low	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	10/8/02	P	3	16:21	17:29	23	11.1	10	75	66	Low	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	5/1/02	P	4	16:13	17:32	20	10.3	23	75	66	Low	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	5/2/02	P	4	16:10	17:47	24	10.3	2	75	66	Low	III
2002	FRE168NB	6	FRE	168	N	0.999	4.813	MCKINLEY AV UC	WILLOW AVE OC	10/16/02	P	6	16:01	17:34	16	3.9	17	73	66	Low	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	9/18/02	P	4	16:03	17:39	24	11.1	21	75	66	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	5/2/02	A	4	6:37	8:05	22	10.5	15	75	66	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	4/23/02	A	3	6:50	7:59	23	11.1	5	74	66	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	3/21/02	A	3	6:54	8:01	22	11.0	15	75	66	Low	III
2002	FRE180WB	6	FRE	180	W	60.367	56.775	MAPLE AVE. UC	H ST. OH	10/17/02	A	9	6:39	8:00	9	3.7	8	75	66	Low	III
2002	FRE180WB	6	FRE	180	W	60.367	56.775	MAPLE AVE. UC	H ST. OH	10/17/02	P	9	16:05	17:27	9	3.7	3	74	66	Low	III
2002	FRE99NB	6	FRE	99	N	17.645	28.102	ORANGE AV OC	SHAW AV OC	4/3/02	A	1	6:43	6:52	10	10.7	8	74	66	Low	III
2002	FRE180EB	6	FRE	180	E	56.775	60.367	H ST. OC	MAPLE AVE. OC	10/17/02	P	9	16:00	17:22	9	3.5	3	72	67	Low	III
2002	FRE168NB	6	FRE	168	N	0.999	4.813	MCKINLEY AV UC	WILLOW AVE OC	4/16/02	A	7	6:42	8:10	12	3.8	15	75	67	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	9/18/02	A	3	6:45	8:26	34	11.1	25	75	67	Low	III
2002	FRE168NB	6	FRE	168	N	0.999	4.813	MCKINLEY AV UC	WILLOW AVE OC	10/16/02	A	6	6:36	8:06	15	3.9	20	75	67	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	10/9/02	A	4	6:36	8:14	25	11.1	10	75	67	Low	III
2002	FRE180EB	6	FRE	180	E	56.775	60.367	H ST. OC	MAPLE AVE. OC	10/17/02	A	9	6:34	7:53	9	3.5	12	73	67	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	10/10/02	A	4	6:36	8:12	24	11.0	17	75	67	Low	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	3/20/02	A	4	6:43	8:21	25	11.0	7	75	68	Low	III
2002	KER58EB	6	KER	58	E	52.332	60.450	ROUTE 99/58SEP	VINELAND RD OC	9/24/02	P	3	16:28	17:07	13	6.2	5	73	60	Low	III
2002	KER178WB	6	KER	178	W	5.641	1.702	OSWELL ST OC	END FREEWAY	4/10/02	P	8	15:54	17:35	13	3.9	4	72	63	Low	III
2002	KER99NB	6	KER	99	N	18.526	30.532	HOSKINS RD OC	7TH STAND OC	9/23/02	P	4	16:18	17:50	23	11.9	20	74	63	Low	III
2001	KER99NB	6	KER	99	N	18.526	30.532	HOSKINS RD OC	7TH STAND OC	4/18/01	P	5	16:03	18:00	24	11.9	33	71	64	Low	III
2002	KER178EB	6	KER	178	E	1.702	5.641	BEGIN FREEWAY	OSWELL ST OC	4/10/02	P	8	15:46	17:28	13	4.1	3	74	64	Low	III
2002	KER58EB	6	KER	58	E	52.332	60.450	ROUTE 99/58SEP	VINELAND RD OC	4/9/02	P	4	16:14	17:22	17	8.1	3	73	64	Low	III
2002	KER178EB	6	KER	178	E	1.702	5.641	BEGIN FREEWAY	OSWELL ST OC	9/26/02	P	6	16:29	17:42	12	3.9	6	70	64	Low	III
2002	KER178EB	6	KER	178	E	1.702	5.641	BEGIN FREEWAY	OSWELL ST OC	9/26/02	A	8	6:39	8:15	12	3.9	8	75	65	Low	III
2002	KER178EB	6	KER	178	E	1.702	5.641	BEGIN FREEWAY	OSWELL ST OC	4/11/02	A	7	6:44	8:07	12	3.9	29	75	65	Low	III
2002	KER178WB	6	KER	178	W	5.641	1.702	OSWELL ST OC	END FREEWAY	9/26/02	P	6	16:36	17:50	12	3.9	20	72	65	Low	III
2002	KER58WB	6	KER	58	W	60.450	52.332	VINELAND RD OC	ROUTE 99/58SEP	9/24/02	P	3	16:17	17:03	15	8.2	5	74	66	Low	III
2002	KER58WB	6	KER	58	W	60.450	52.332	VINELAND RD OC	ROUTE 99/58SEP	4/9/02	P	5	16:04	17:37	19	8.2	13	75	66	Low	III
2002	KER58WB	6	KER	58	W	60.450	52.332	VINELAND RD OC	ROUTE 99/58SEP	9/25/02	P	6	16:05	17:50	17	8.1	3	75	66	Low	III
2002	KER178WB	6	KER	178	W	5.641	1.702	OSWELL ST OC	END FREEWAY	9/26/02	A	8	6:46	8:24	12	3.9	11	74	66	Low	III
2002	KER58EB	6	KER	58	E	52.332	60.450	ROUTE 99/58SEP	VINELAND RD OC	9/25/02	P	5	16:14	17:40	17	8.1	23	74	66	Low	III
2002	KER99NB	6	KER	99	N	18.526	30.532	HOSKINS RD OC	7TH STAND OC	9/24/02	A	4	6:48	8:28	25	11.9	12	75	67	Low	III
2002	KER178WB	6	KER	178	W	5.641	1.702	OSWELL ST OC	END FREEWAY	4/11/02	A	7	6:51	8:14	12	3.9	12	75	68	Low	III
2002	KER58EB	6	KER	58	E	52.332	60.450	ROUTE 99/58SEP	VINELAND RD OC	9/25/02	A	5	6:49	8:13	17	7.6	7	75	68	Low	III
2002	KER58WB	6	KER	58	W	60.450	52.332	VINELAND RD OC	ROUTE 99/58SEP	9/25/02	A	6	6:41	8:23	17	7.7	12	75	69	Low	III
2002	KER58EB	6	KER	58	E	52.332	60.450	ROUTE 99/58SEP	VINELAND RD OC	4/10/02	A	4	7:09	8:09	15	8.1	18	75	70	Low	III
2002	KER58WB	6	KER	58	W	60.450	52.332	VINELAND RD OC	ROUTE 99/58SEP	4/10/02	A	5	7:01	8:20	16	8.2	2	75	70	Low	III
2002	MAD99NB	6	MAD	99	N	8.722	14.222	AVE 13 OC	AVE 17 OC	4/18/02	A	7	6:28	8:07	14	5.5	1	74	65	Low	III
2002	MAD99SB	6	MAD	99	S	14.222	8.722	AVE 17 OC	AVE 13 OC	10/23/02	P	6	16:04	17:48	17	5.7	3	75	65	Low	III
2002	MAD99NB	6	MAD	99	N	8.722	14.222	AVE 13 OC	AVE 17 OC	10/23/02	P	6	15:58	17:37	17	5.9	1	72	65	Low	III
2002	MAD99SB	6	MAD	99	S	14.222	8.722	AVE 17 OC	AVE 13 OC	4/18/02	A	7	6:34	8:13	14	5.5	4	74	66	Low	III
2002	MAD99NB	6	MAD	99	N	8.722	14.222	AVE 13 OC	AVE 17 OC	10/23/02	A	6	6:33	8:13	17	4.8	8	72	68	Low	III
2002	MAD99NB	6	MAD	99	N	8.722	14.222	AVE 13 OC	AVE 17 OC	4/18/02	P	6	16:04	17:29	14	5.5	3	75	68	Low	III
2002	MAD99SB	6	MAD	99	S	14.222	8.722	AVE 17 OC	AVE 13 OC	4/18/02	P	6	16:10	17:35	14	5.7	14	75	68	Low	III
2002	MAD99SB	6	MAD	99	S	14.222	8.722	AVE 17 OC	AVE 13 OC	10/23/02	A	6	6:43	8:22	17	5.7	17	75	69	Low	III
2004	ORA405NB	12	ORA	405	N	15.475	25.200	HEIL PED OC	PALO VERDE OFF	6/2/04	A	3	6:21	9:09	56	9.7	-	73	53	Low	III
2004	ORA091EB	12	ORA	91	E	11.499	19.794	EB IMPERIAL ON	GREEN RIV OFF	6/9/04	A	2	6:40	8:05	42	8.1	-	75	55	Low	III
2004	ORA091WB	12	ORA	91	W	19.811	11.788	GREEN RIV ON	IMPERIAL OFF	6/9/04	A	3	5:54	8:47	58	7.9	-	72	55	Low	III
2004	ORA405SB	12	ORA	405	S	15.475	10.282	HEIL AVE POC	RTE 73/405 SEP	6/1/04	P	5	15:18	23:33	99	5.3	-	75	55	Low	III
2004	ORA405SB	12	ORA	405	S	25.060	15.475	STEARNS ON	HEIL PED OC	6/2/04	P	3	15:38	18:26	56	9.6	23	69	56	Low	III
2004	ORA005NB	12	ORA	5	N	7.116	21.304	RAMBLAS RTE 1	5/405 SEP BRIDGE	11/17/04	A	5	6:19	9:13	35	13.9	19	75	60	Low	III
2004	ORA005SB	12	ORA	5	S	21.304	6.972	5/405 SEP BRIDGE	SB OFF RTE 001	11/17/04	A	4	7:00	8:55	29	13.9	29	75	61	Low	III
2002	ORA091WB	12	ORA	91	W	7.810	0.023	EAST ST ON	CARMENITA POC	11/20/02	P	1	14:18	14:25	7	7.9	20	75	67	Low	III
2002	SB51AM	3	SAC	51	S	8.602	1.637	RTE 244 ON	E ST OFF	5/23/02	A	5	6:29	8:38	26	7.0	-	72	53	Low	III
2002	TUL198EB	6	TUL	198	E	5.760	13.737	SHIRK ROAD	ROAD 156 UC	10/24/02	A	5	6:44	8:21	19	7.9	14	75	64	Low	III
2002	TUL198EB	6	TUL	198	E	5.760	13.737	SHIRK ROAD	ROAD 156 UC	10/24/02	P	5	16:04	17:53	22	8.0	10	75	64	Low	III
2002	TUL198WB	6	TUL	198	W	13.737	5.760	ROAD 156 UC	SHIRK RD OC	5/7/02	A	5	6:39	8:15	19	8.1	5	70	64	Low	III
2002	TUL198EB	6	TUL	198	E	5.760	13.737	SHIRK ROAD	ROAD 156 UC	5/7/02	A	5	6:29	8:04	19	8.1	28	70	65	Low	III

2002	TUL198WB	6	TUL	198	W	13.737	5.760	ROAD 156 UC	SHIRK RD OC	10/24/02	P	5	16:15	18:03	22	8.0	15	75	65	Low	III
2002	TUL198WB	6	TUL	198	W	13.737	5.760	ROAD 156 UC	SHIRK RD OC	10/24/02	A	5	6:55	8:32	19	8.0	3	74	66	Low	III
2002	TUL198WB	6	TUL	198	W	13.737	5.760	ROAD 156 UC	SHIRK RD OC	5/7/02	P	5	16:06	17:41	19	8.0	7	74	68	Low	III
2002	TUL198EB	6	TUL	198	E	5.760	13.737	SHIRK ROAD	ROAD 156 UC	5/7/02	P	5	15:56	17:30	19	7.9	23	73	68	Low	III
2003	S88007T0	4	ALA	880	S	23.000	6.210	66th Ave On	Thorton On	10/28/03	P	3	15:14	17:52	53	17.4	-	66	42	Moderate	III
2003	S88005T6	4	ALA	880	S	-	18.800	Rte 92 On	Great Mall Off	10/23/03	A	4	5:26	10:08	71	19.2	-	70	45	Moderate	III
2003	S88007T0	4	ALA	880	S	23.000	6.210	66th Ave On	Thorton On	10/7/03	P	4	14:48	18:57	62	15.3	-	67	47	Moderate	III
2003	N88006TO	4	ALA	880	N	-	26.464	RTE 92 ON	7TH ST OFF	5/21/03	P	5	14:54	19:22	54	16.6	-	71	48	Moderate	III
2003	S88007T0	4	ALA	880	S	23.000	6.210	66th Ave On	Thorton On	5/22/03	A	4	6:16	10:32	64	17.0	-	68	49	Moderate	III
2003	N88004T9	4	ALA	880	N	2.000	19.500	Route 84 On	Coll/66th Off	10/7/03	P	4	14:28	18:46	65	17.1	-	68	50	Moderate	III
2002	FRE99SB	6	FRE	99	S	28.102	17.645	SHAW AV OC	ORANGE AV OC	4/3/02	A	1	6:53	7:02	9	6.4	-	75	43	Moderate	III
2002	ORA405SB	12	ORA	405	S	25.060	11.675	STEARNS ON	HARBOR BL OFF	10/21/02	P	1	15:21	15:29	8	4.8	-	72	35	Moderate	III
2004	ORA405NB	12	ORA	405	N	10.282	15.475	RTE 73/405 SEP	HEIL AVE POC	6/1/04	P	5	15:56	0:05	98	5.4	-	72	40	Moderate	III
2004	ORA091EB	12	ORA	91	E	0.230	7.751	CARMENITA POC	EAST ST. OFF	11/8/04	P	2	13:55	14:39	22	4.3	-	73	46	Moderate	III
2002	ORA405NB	12	ORA	405	N	11.438	25.200	N/B HARBOR ON	PALO VERDE OFF	10/21/02	P	1	15:10	15:19	9	7.3	-	63	46	Moderate	III
2002	ORA405NB	12	ORA	405	N	0.230	11.268	5/405 JUNCTION	HARBOR BL OFF	10/21/02	P	1	14:39	14:49	10	7.5	-	63	47	Moderate	III
2004	ORA405NB	12	ORA	405	N	15.475	25.200	HEIL PED OC	PALO VERDE OFF	6/2/04	P	3	17:37	19:10	31	9.6	0	68	49	Moderate	III
2002	ORA405SB	12	ORA	405	S	11.292	0.230	NB HARBOR ON	5/405 JUNCTION	10/21/02	P	1	14:32	14:38	6	5.0	-	72	49	Moderate	III
2002	NB51PM	3	SAC	51	N	0.769	8.449	P ST ON	RTE 244 OFF	6/11/02	P	3	16:54	18:05	24	7.7	-	71	39	Moderate	III
2002	SB51PM	3	SAC	51	S	8.602	1.637	RTE 244 ON	E ST OFF	6/11/02	P	6	14:56	17:55	30	7.0	-	72	46	Moderate	III
2003	n88006t0	4	ALA	880	n	-	26.464	RTE 92 ON	7TH ST OFF	5/8/03	A	2	6:19	7:20	30	12.9	35	67	61	None	III
2001	FRE180WB	6	FRE	180	W	60.367	56.775	MAPLE AVE. UC	H ST. OH	5/9/01	P	6	16:14	17:54	17	3.6	35	71	62	None	III
2001	FRE180EB	6	FRE	180	E	56.775	60.367	H ST. OC	MAPLE AVE. OC	5/9/01	P	7	16:09	17:48	14	3.2	45	72	63	None	III
2001	FRE180WB	6	FRE	180	W	60.367	56.775	MAPLE AVE. UC	H ST. OH	5/9/01	A	6	6:57	8:08	12	3.6	44	70	63	None	III
2001	FRE180EB	6	FRE	180	E	56.775	60.367	H ST. OC	MAPLE AVE. OC	5/9/01	A	6	6:50	8:02	12	3.3	50	72	63	None	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	3/21/02	P	3	16:22	17:29	22	11.0	45	75	64	None	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	10/9/02	P	3	16:18	18:00	34	11.1	36	74	65	None	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	3/20/02	P	3	16:21	17:28	23	11.1	43	75	65	None	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	9/5/02	A	3	7:06	8:15	23	11.1	51	75	66	None	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	4/24/02	A	3	6:50	7:58	22	11.0	37	73	66	None	III
2002	FRE41NB	6	FRE	41	N	21.113	32.165	JENSEN AVE OC	AUDOBON DR OC	10/8/02	A	4	6:42	8:21	25	11.1	50	75	66	None	III
2002	FRE41SB	6	FRE	41	S	32.165	21.113	AUDUBON DR	JENSEN AVE OC	4/24/02	P	3	16:25	17:40	25	11.1	38	75	67	None	III
2001	KER99NB	6	KER	99	N	18.526	30.532	HOSKINS RD OC	7TH STAND OC	4/18/01	A	4	6:56	8:27	23	11.8	46	75	64	None	III
2001	KER99SB	6	KER	99	S	30.532	18.526	7TH STAND OC	HOSKINS RD OC	4/18/01	A	4	6:42	8:14	23	12.0	49	75	64	None	III
2002	KER99SB	6	KER	99	S	30.532	18.526	7TH STAND OC	HOSKINS RD OC	9/23/02	P	4	16:00	17:37	24	12.3	35	75	65	None	III
2001	KER99SB	6	KER	99	S	30.532	18.526	7TH STAND OC	HOSKINS RD OC	4/18/01	P	5	15:49	17:46	24	12.0	44	74	66	None	III
2002	KER99SB	6	KER	99	S	30.532	18.526	7TH STAND OC	HOSKINS RD OC	9/24/02	A	4	6:35	8:15	25	12.0	37	75	68	None	III
2002	ORA091WB	12	ORA	91	W	19.811	10.272	GREEN RIV ON	LAKEVIEW OFF	11/26/02	P	10	14:59	19:07	25	9.5	39	75	64	None	III
2002	ORA073SB	12	ORA	73	S	27.728	23.737	ON FR FAIRVIEW	BISON OFF	10/16/02	P	13	15:00	19:05	19	3.9	37	75	65	None	III
2004	ORA091WB	12	ORA	91	W	7.451	1.137	I 15 JCT	WB OFF GR RIVR	6/8/04	A	2	7:00	8:26	43	6.3	46	72	61	None	III
2004	ORA091EB	12	ORA	91	E	1.167	7.451	EB ON FR GR RV	I 15 JCT	6/8/04	A	3	6:18	9:06	56	6.3	52	75	65	None	III
2004	ORA091WB	12	ORA	91	W	7.451	1.137	I 15 JCT	WB OFF GR RIVR	6/8/04	P	4	15:01	19:06	61	6.3	53	75	66	None	III
2004	ORA091WB	12	ORA	91	W	19.811	11.788	GREEN RIV ON	IMPERIAL OFF	6/9/04	P	3	15:20	18:20	60	8.0	43	75	66	None	III
2004	ORA073SB	12	ORA	73	S	27.728	23.737	ON FROM FAIRVIEW	BISON OFF	9/23/04	P	1	23:49	23:52	4	4.0	35	75	67	None	III
2004	2	10	SJ	5	N	-	13.810	EB 205 Mt. House Pkwy onramp	EB 120 off ramp to Yosemite Ave	1/29/04	P	20	14:27	19:37	16	1.3	46	75	59	None	III
2004	1	10	SJ	5	S	-	13.930	WB 120 Yosemite Ave onramp	WB 205 off ramp to Mt House Pkwy	1/29/04	A	15	4:00	7:36	14	1.6	44	74	61	None	III