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Freeway Performance Measurement System (PeMS) Version 4

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Freeway Performance Measurement System (PeMS) Version 4

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The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California. This report does not constitute a standard, specification, or regulation.

Final Report for Task Order 4301

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Freeway Performance Measurement System (PeMS), Version 4:

Final Report of MOU 4301

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Executive summary

PeMS 4 is the latest of four task orders devoted to research, development, and maintenance of the PeMS system. PeMS collects, processes, stores, and makes available online data from the six Caltrans districts (D3, 4, 7, 8, 11, 12), which include the major urban areas in California. The data are obtained from 23,237 loops, grouped into 7,359 vehicle detector stations (VDS). These loops cover 2,812 out of 30,726 miles of interstate and state highways in California.

PeMS began as a research project. As the research system evolved, Caltrans determined that the information it provided was very valuable, and significant resources were then directed towards the development of PeMS. This entailed production-level code development and system maintenance. Faculty, post-doctoral fellows, and graduate student researchers at U.C. Berkeley (UCB) conduct the 'research' element of the project. Berkeley Transportation Systems (BTS) is responsible for PeMS 'development' and 'maintenance' activities. The UCB and BTS groups meet weekly. There are periodic conferences with members of Caltrans Division of Traffic Operations. The project is co-managed by the PeMS PI and the Division of Traffic Operations.

The product of the research activity is reported in professional meetings and journals and in algorithms, and summarized in this report. The algorithms are incorporated into PeMS applications code as part of the development activity. The maintenance activity is concerned with database management, network troubleshooting, and providing PeMS access to users.

PeMS is accessed over a standard web browser via the Internet. The current PeMS user community comprises 956 individuals and 63 'value added resellers' or VARs. During October 2003, PeMS received an average of 4,000 'hits', generating 42 MB of data download, each day. Caltrans users account for 26 percent of hits, and UCB accounts for 12 percent. The remaining usage is by VARs, academic researchers around the country, and transportation professionals.

Under PeMS 4, the system changed significantly in three ways. First, the 'look and feel' that users experience has improved. Website navigation is more intuitive. Second, PeMS functionality increased with the incorporation of congestion reports, travel time reliability, loop detector diagnosis, and data correction.

Third, the database structure has been changed from a district-by-district orientation to a statewide orientation. As a result, statistics like travel times can be collected for routes that cross district boundaries.

The PeMS 4 statement of work lists eight specific tasks:

1. Operations and maintenance of PeMS;
2. Add new administrative capabilities;
3. System documentation;
4. Implement PeMS capability to support detector health initiative;
5. Develop congestion monitoring capability;
6. Provide traffic analysis capabilities useful for planners and engineers;
7. Support PeMS transition efforts;
8. Research issues associated with data integrity.

For each task, Caltrans names a person or group that determines whether the task has been satisfactorily carried out and recommends necessary changes.

Berkeley Transportation Systems (BTS) accomplished task 1.

For task 2, BTS developed a website that permits a PeMS administrator to (1) control access, (2) view usage of PeMS along several dimensions, e.g., total usage per day/week/month, and (3) monitor intensive users.

For task 3, BTS developed an extensive set of online 'help' pages. As a user navigates through the website, she can query what the various quantities mean, and how they are derived from the raw data.

For task 4, UCB developed an extensive set of diagnostic tools that determine (1) which loop detectors are functioning and which are not, and (2) the likely cause of detector malfunctions. The tools were checked in the field. A report was prepared on the 'health' of detector system in all six Caltrans districts from which PeMS receives data. Interaction with District 4 personnel led to an improvement of its detector system.

For task 5, UCB and BTS developed an automated facility that produces the HICOMP report for the state and for any district. For the first time, Caltrans staff has the ability to quickly prepare a comprehensive congestion report and discern congestion trends in the state.

For task 6, many new features have been added to PeMS. Caltrans users suggested these features. Examples of new features include calculation of travel time reliability and analysis of 'lane closures'.

For task 7, a version of PeMS was installed in Caltrans. However, the full transfer has been postponed pending the Caltrans deployment decision.

For task 8, UCB and BTS conducted an extensive statistical analysis of the data received from detectors to determine their validity. PeMS now incorporates a real time procedure that examines each data sample as it arrives, imputes 'reliable' values for samples that are missing or judged to be unreliable. PeMS now provides a complete data set, which greatly facilitates the development of new applications.

1. PeMS 4.1

The current PeMS release is PeMS 4.1 [1]. Access to PeMS is organized in a hierarchy of spatial aggregation levels: state, districts, counties, etc. Within each level there is a set of functional categories that organizes the data for that level. This organization is repeated at each spatial level; each spatial level has its own functional categories.

Figure 1 is a screen capture of the PeMS homepage—this is the topmost or ‘state’ level. The selection list on the left is divided in two parts. The upper part lists the spatial aggregations—California, Districts, Counties, etc. that are immediately ‘below’ this level. The lower part is the list of functional categories at the ‘state’ level. For example, selecting HICOMP and then selecting ‘year = 2002’, ‘vehicle-hours of delay $V_t = 60$ ’, and ‘draw plot’ returns the page shown in figure 2.

The quantity ‘Vehicle-hours of delay $V_t = 60$ ’ is the total vehicle-hours spent by drivers in excess of the time needed to travel the same number of vehicle-miles driving below 60 mph. The pie chart shows the share of this congestion delay. Other quantities that may be selected are vehicle-miles traveled and vehicle-hours traveled. Selecting ‘view table’ instead of ‘draw plot’ returns the table of values corresponding to the pie chart. The table can be imported into a spreadsheet for analysis or incorporation in a report.

Clicking on the ‘district’ level takes the user to the next level of spatial aggregation. For example, selecting D3 (District 3) and then selecting ‘vehicle miles traveled’, ‘group by freeway’ and displayed by ‘draw plot’ yields the pie chart of figure 3.

Typically, a user first selects the desired spatial level, then one or more quantities, the temporal (by 5 minutes, hour, day) or spatial grouping (postmiles of freeways) and the period (hours or days) of interest. These selections determine the data that needs to be displayed. Finally, the user chooses the form of display, typically a time series or contour plot, or a table of values from which the plot is made.

The online tutorial [2] provides a fairly complete description of how to navigate through the website and gives examples of useful information that can be obtained from the website.

2. New administrative capabilities

An important element in the design of PeMS 4.1 is to enhance and simplify ‘high level’ administration. The objective is to enable the manager responsible for controlling access to PeMS and tracking how well it is being used to carry out these responsibilities easily, without an expertise in database management. PeMS now provides a web interface that permits the manager to do that. A system administrator¹ can click on the ‘site management’ link to reach the page shown in figure 4.

The main page shows the status of data feeds from the six districts. Figure 4 indicates that on 10/31/2003, District 8 was reporting 50 percent of its 30-second samples, District 11 was reporting 90 percent, and the other districts were in between these two extremes.

¹ There are three classes of PeMS users, system administrator, registered user, and value added reseller. They have different levels of access. Only a system administrator can view the site management page.

The four functional categories available to the administrator are ‘data feeds’ (illustrated in figure 4), ‘usage reports’, ‘manage groups’, and ‘manage users’. The ‘data feeds’ and ‘usage reports’ give the administrator a view of system performance. For example, selecting ‘bytes served’, ‘group by day’, and ‘draw plot’ gives the page captured in figure 5. The table in the figure says that during October 2003, PeMS received on average 4,000 hits and served 44 MB per day. Other selections provide the number of unique visitors per day, the intensity of usage by user, etc.

The ‘manage groups’ and ‘manage users’ allow administrator add or delete user accounts.

The ‘user feedback’ page summarizes comments and questions that users provide. Every web page has a ‘feedback’ button that a user can click to pop up a window, which the user can fill out. This is a very valuable means for discovering ‘bugs’ and receiving suggestions for improvement.

3. Help pages

Every web page has a ‘help’ button. The help page accessible from the main is displayed in figure 6. This page provides links to general topics: system overview, which describes how PeMS collects, processes and stores data; system calculations, which explains the calculations PeMS performs; common analysis, which gives a step-by-step account; etc.

If the user selects ‘detector health’ at the ‘state’ level and asks for a ‘summary’, PeMS returns the page in figure 7. Upon clicking the ‘?’ button, PeMS returns the help page, which is also displayed. The page gives a description of the ‘detector health’ report, a summary of the meaning of the individual items in the report, followed by details of how the calculations are performed. Thus a user gains a complete understanding of the procedures that PeMS uses in constructing its detector health report.

Virtually all algorithms that PeMS uses in constructing its performance measures are explained in research publications, most of which can be accessed from the PeMS ‘Resources’ link.

4. Detector health

With more experience with loop detector data it was realized that these data are contaminated. There are two major types of contamination: missing data samples, and erroneous data samples. In a 24-hour day, a loop should report $24 \times 60 \times 2 = 2880$ samples. Figure 4 shows that on October 31, 2003, the sample-reporting rate in different districts varied between 50 and 90 percent. PeMS calculates the reporting rate by counting the number of samples it receives.

A reported sample could still be erroneous because of malfunctioning detectors. To figure out whether a loop detector is malfunctioning, PeMS conducts an elaborate statistical test, based on a time series of samples from the same loop.

The statistical tests were based on field studies² to determine the most likely type of malfunction. The studies revealed four common symptoms: ‘occupancy = 0’, ‘occupancy > 0, flow = 0’, ‘high occupancy’, and ‘low entropy’. The first three symptoms are self-explanatory and indicate a detector stuck ‘high’ or ‘low’. The ‘low entropy’ statistical test means that the sample values (over one day) show very little variability, indicating very low sensitivity. For a detailed discussion of the tests, see [6].

PeMS runs these tests once a day. And produces a daily ‘health status’ report of all loop detectors. Figure 7 is the report for October 31, 2003, aggregated by district. It says that of 16, 501 mainline/HoV loops, only 10,391 loops, or 63 percent, were considered ‘good’, i.e. functioning properly. Of the 6,110 loops that are ‘bad’, 2,908 or 48 percent, had problems with the communication link between the stations and the TMC, 1,764 or 29 percent had the detector card off, 325 or 5 percent of the loops showed the symptom ‘high occupancy’, 598 or 10 percent gave intermittent samples, 231 or 4 percent showed constant or ‘low entropy’ symptom.

More detailed information about loop detector health, down to the level of each loop, can be obtained by exploring lower levels of spatial aggregation. This PeMS ‘detector health’ application is the first one of its kind reported in the literature.

The detector health report can be an invaluable tool in Caltrans’ Detector Fitness Program. A confidential report³ was submitted to the Division of Traffic Operations and circulated for comment among the districts. A detailed report⁴ was prepared for the Bay Area, District 4, followed by many meetings with district staff. Many errors were diagnosed and subsequently corrected.

In current practice, Caltrans dispatches field crews to inspect all loops on selected freeways. This practice has three deficiencies. The selection of freeways and which loops to inspect seem not to be related to any estimate of the detector health. Thus significant resources are inefficiently used. Second, field inspection is not followed by a check to determine whether a defective loop or station was in fact ‘fixed’. Lastly, the field crew apparently is not responsible for correcting defective communications, which accounts for half of ‘bad’ loops.

The PeMS health reports reveal a structural problem in Caltrans loop health maintenance. San Diego, District 11, maintains its loop detector system in excellent health, other districts are much worse by comparison. Evidently, in these other districts detector health has low priority or their procedures for health maintenance are not as effective.

² C. Chen and A. Sharafsaleh, “Trip report: Inspecting loop detectors, April 24-25, 2002, on I-10 in Los Angeles, Caltrans District 7,” April 26, 2002, submitted to Caltrans.

³ C. Chen, J. Kwon and P. Varaiya, “The quality of loop data and the health of California’s freeway loop detectors,” September 30, 2002.

⁴ J. Kwon and P. Varaiya, “Quality of loop detectors in the San Francisco Bay Area (D4),” October 23, 2002.

5. Congestion monitoring

Each year Caltrans publishes its Highway Congestion Monitoring Program or HICOMP Report. The report estimates the extent of congestion delay and the sections of freeway that are congested. Drivers traveling over selected portions of the freeway once or twice a year and measuring the delay they experience provide the primary data. This is a very unsatisfactory procedure and the report based on it is unreliable for two reasons.

First, the samples of congestion delay gathered in this way are unrepresentative. Congestion is a statistical phenomenon with enormous fluctuations. Figure 8 shows the congestion delay on 32 miles of I-5N in San Diego. The plot gives for each hour the vehicles-hours of delay incurred driving below 60 mph. The data are for weekdays during the month August 25-September 25, 2003. The three plots give the maximum, minimum and average delay. As can be seen, at 16:00 the minimum delay was almost 0, the maximum was 2,200, and the mean delay was 1,000 vehicle-hours. Evidently, the delay experienced by one driver traveling on this section of freeway at 16:00 would be unrepresentative. More importantly, this example shows that a meaningful report of congestion must indicate the statistical fluctuations.

Second, labor cost involved in manual driving only permits coverage of a small fraction of the state's freeways. As a result changes in trends and detection of emerging sections of congestion will be missed. Furthermore the decision of what sections to monitor by manual driving will be arbitrary and subjective.

The congestion monitoring application eliminates the need for manual driving and provides an instantaneous report on freeway congestion for any period and any freeway section or route. Moreover, trends are immediately detected. The application provides an indispensable tool to measure the effectiveness of any congestion mitigation effort, and can be used to direct resources aimed to alleviate congestion.

6. Traffic analysis capabilities

Based on feedback from PeMS users and from Division of Traffic Operations, PeMS 4.1 offers many applications to assist traffic analysis. Some representative illustrations below are extracted from the more complete discussion in [2].

Spatial analysis

Figure 9 uses the PeMS spatial analysis functions to display contour plots of flows, occupancy and delay on US-50W (postmiles 5 to 20) in Sacramento during 06:00-21:00 on April 4, 2003. The contour plots clearly reveal an increase in density and a slowdown in speed between postmiles 5 and 10 in the afternoon (15:00-17:00). The analyst can within minutes examine the plots for different days to determine if this depends on day of week or if there is a difference between weekdays and weekends. Attempting to conduct such an analysis without PeMS would be prohibitively costly in terms of the analyst's time.

Time series at a single loop

Based on the analysis of figure 9, the analyst may decide to carry out a quantitative study based on a time series of data from an individual detector station. Figure 10 illustrates what such a study might yield. The top two charts in the figure give the speed and travel time for each lane across the segment corresponding to VDS 312188 on US-50W. The

plots reveal two dips in speed and increased travel time at 16:00 and 17:00. The bottom two plots give the profile of ‘g-factors’ that PeMS uses to calculate speed from the raw occupancy and flow data [7].

Quantity relationships

Figure 11 displays the relation between flow and speed at the same VDS station to reveal how the breakdown in traffic flow occurs. It also shows that before breakdown occurs, aggregate flow reaches 700 vehicles per 5-minutes or 8,400 vehicles/hour across the four lanes at a speed between 65 and 70 mph. Moreover, once breakdown occurs, the speed rapidly drops to below 30 mph, and the flow drops to 6,000-7,200 vehicles/hour.

PeMS has permitted an extensive study of traffic flow Districts 7, 12 reveals this characteristic pattern: traffic moves at a maximum flow at 60 mph and once breakdown occurs, it takes a long time to restore free flow [3], [4]. An important conclusion of these studies is that freeways are operated most inefficiently precisely during periods of peak demand. An inescapable conclusion is that prevention of traffic breakdown (by ramp-metering, for example) could dramatically increase freeway ‘productivity’.

Travel time reliability

Congestion delay measures aggregate or system-level freeway performance. Freeway users experience congestion in the form of long and variable travel times. A major new application in PeMS 4.1 is the automatic calculation of travel times and travel time fluctuations along any route that the user selects.

Figure 12 illustrates the application. The user selects a route along 99-N from Elk Grove via 51-N to Junction 80. The four plots displays data in different forms for one month 4/5/2003 to 5/4/2003. The top left gives the time series; the top right displays the mean, max and min travel times by departure time; the bottom left gives the travel time on 5/1/2003 vs. the monthly average; and the plot on the bottom right compares the mean, 25th and 75th percentiles.

The plots offer reveal different information. For example, the bottom right plot implies that on 25 percent of the days, if one leaves at 17:00, this trip would take at least 34 minutes and on 25 percent of the days it would take at most 20 minutes.

A detailed study of travel time reliability is available in [5].

Other applications

The ‘lane closure’ application allows the user to gauge the impact of a lane closure in terms of delay caused and queue lengths. The ‘incident impact’ application permits a user to estimate the delay caused by an incident in the past. The ‘bottleneck’ application can be used to determine the drop in flow following the activation of a bottleneck and the resulting delay. The ‘travel time’ application may be used to predict travel times in the future. These are all illustrated in [2]. PeMS was used to measure recurrent and non-recurrent congestion [8] and to estimate truck volumes [9].

7. Deployment

PeMS is currently located at the University of California, Berkeley. It has a steadily growing number of users to whom it provides valuable analysis capabilities that are

unmatched. Its users include Caltrans personnel, transportation professionals, value added resellers, and academic researchers.

PeMS thus serves a dual role. On the one hand, it is an experimental system upon which users rely for their analysis of freeway traffic, for calibrating their models, and for testing various hypotheses of traffic behavior. Scores of publications have relied on PeMS for support of empirical research. Value added resellers have come to rely on PeMS as part of their business process.

Caltrans management views PeMS as the foundation of a performance monitoring system upon which a reliable, customer-responsive freeway system can operate. However, to serve the needs of operations and businesses, PeMS should be run as a 'production' system that provides a 24×7 reliable service. A version of the PeMS software has been installed on Caltrans computers. However, the decision to deploy PeMS as a production system has not yet been made.

8. Data reliability

As we have seen, almost 40 percent of samples are missing or unreliable because of malfunctioning detectors. If imputed samples were not substituted for these, virtually every time series would have incorrect or missing values. It is not possible to write applications that work on such time series. For this reason, PeMS developed an elaborate statistical procedure to impute reliable values for missing or unreliable samples.

Figure 13 illustrates the imputation procedure for the 2-lane VDS 312134 on US 5-N. The plots on the top right and bottom right show the observed 5-minute flows (red) on lanes 1 and 2, respectively and the imputed flow (green). In lane 1, most samples are missing, but most samples are present in lane 2. From the lane 2 plot, one can see that the imputed flows match the observed flows well, inspiring confidence on the imputations for lane 1. The plots on the left explain how the imputations are carried out.

An imputed sample value is inferred from other (reliable) sample values. The inference depends on how 'close' in space and time the reliable values are.

Local neighbors This method uses linear regression based on the local neighbors. PeMS pre-computes the relationship between each loop and each of its neighbors. Then, when a data sample is missing, we use these relationships to compute what the value should have been from each of its neighbors. We then take the median of the resulting values. For this method to be used, we need to have the data samples from the neighbors available. So when the data feed goes down and there aren't any samples, we can't use this method.

Global Neighbors/Coefficients This method is similar to the Local Neighbors method above, but it covers the case when the loop data for a particular loop is always missing and hence it was never possible to compute the regression coefficients for its neighbors. In this case, we model the relationship between the general classes of neighbors over the entire district (or globally). We get global regression coefficients that can then be used in the same manner as the Local Neighbors method.

Temporal Medians If neither of the two above methods can be used, then we attempt to impute by using the temporal median for this specific location and time of week. This means that when a data sample is missing at a particular loop detector at a particular time

of the week, we fill it in by taking the median over the previous four weeks at that location at that time of week. So if we miss a sample at Wednesday at 5:05pm then we take the median of the last four Wednesdays at 5:05.

Global/District Medians When the loop detector never reports data, we can't even substitute in the temporal median. In this case, we substitute in the median value across all loops in the district for this class of freeway (meaning the number of lanes in the freeway), for this lane of the freeway for this time of the week.

None This category shows up on the Imputation Methods plot when everything else has failed. This is an indication of some sort of misconfiguration in the loop detector tables that should be investigated. For example, in cases where the only loops at a particular station are marked as being in lanes 3 and 4 but there is no 4-lane freeway in the district. In that case, we can't get district median values to use for our imputation method of last resort (because there aren't any other locations with 3 lanes). In that case, there is nothing that can be done and those particular loops should be investigated for configuration errors.

Returning to the left plots in figure 13, for lane 1, most of the imputed values are based on 'local neighbors' and a few are based on 'temporal medians'; for lane 2, 'temporal medians' are used for the small number of missing sample values.

9. Conclusion

PeMS is a unique product in several respects. It offers an unequalled access to freeway data, with applications that are useful to Caltrans management, engineers and planners; value added resellers; general public; and the research community. It has succeeded because of joint management by academic researchers and staff of Caltrans' Division of Traffic Operations. The former have maintained the highest research standards, seen for example in the many publications in archival journals and presentations at major conferences and meetings. The latter has kept the project focused on current and emerging needs of Caltrans. However, PeMS is far from realizing its potential as a daily tool that transportation professionals use. This is in part because Caltrans has yet to determine how it is to transform itself from an agency primarily devoted to capital projects to one whose main emphasis is on operational efficiency and delivery of service to the public.

PeMS has received considerable external attention. The appendix gives three examples: an extract from the Legislative Analyst's Office Report of 2001; a Newsweek story in its October 20, 2003 issue on traveler information; and a Los Angeles Times story of October 23, 2003 on the impact of the transit strike.

Acknowledgements

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The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views of or policy of the California Department of Transportation. This report does not constitute a standard, specification or regulation.

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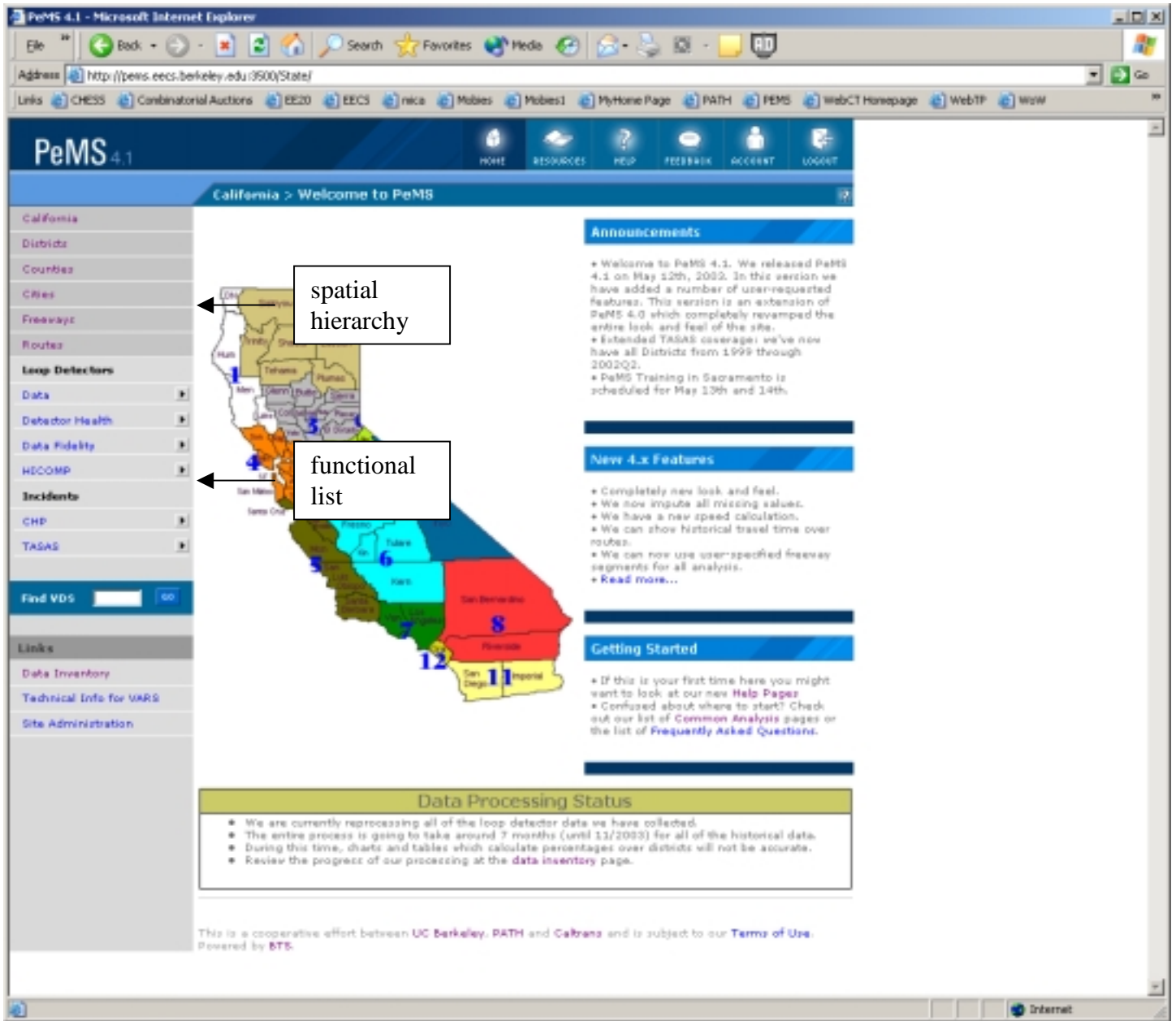


Figure 1 PeMS home page

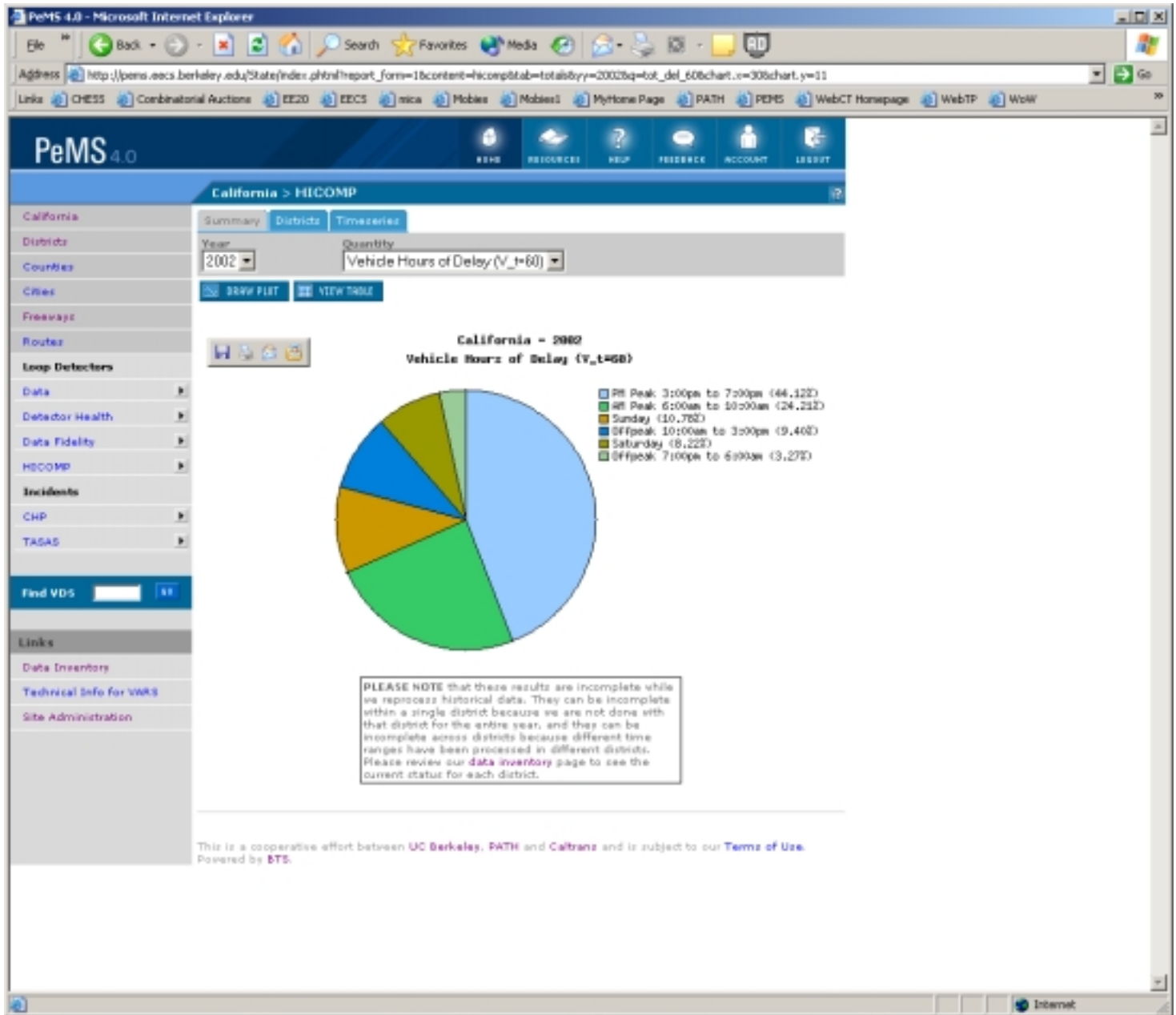


Figure 2 HICOMP-vehicle hours of Delay (V_t=60)

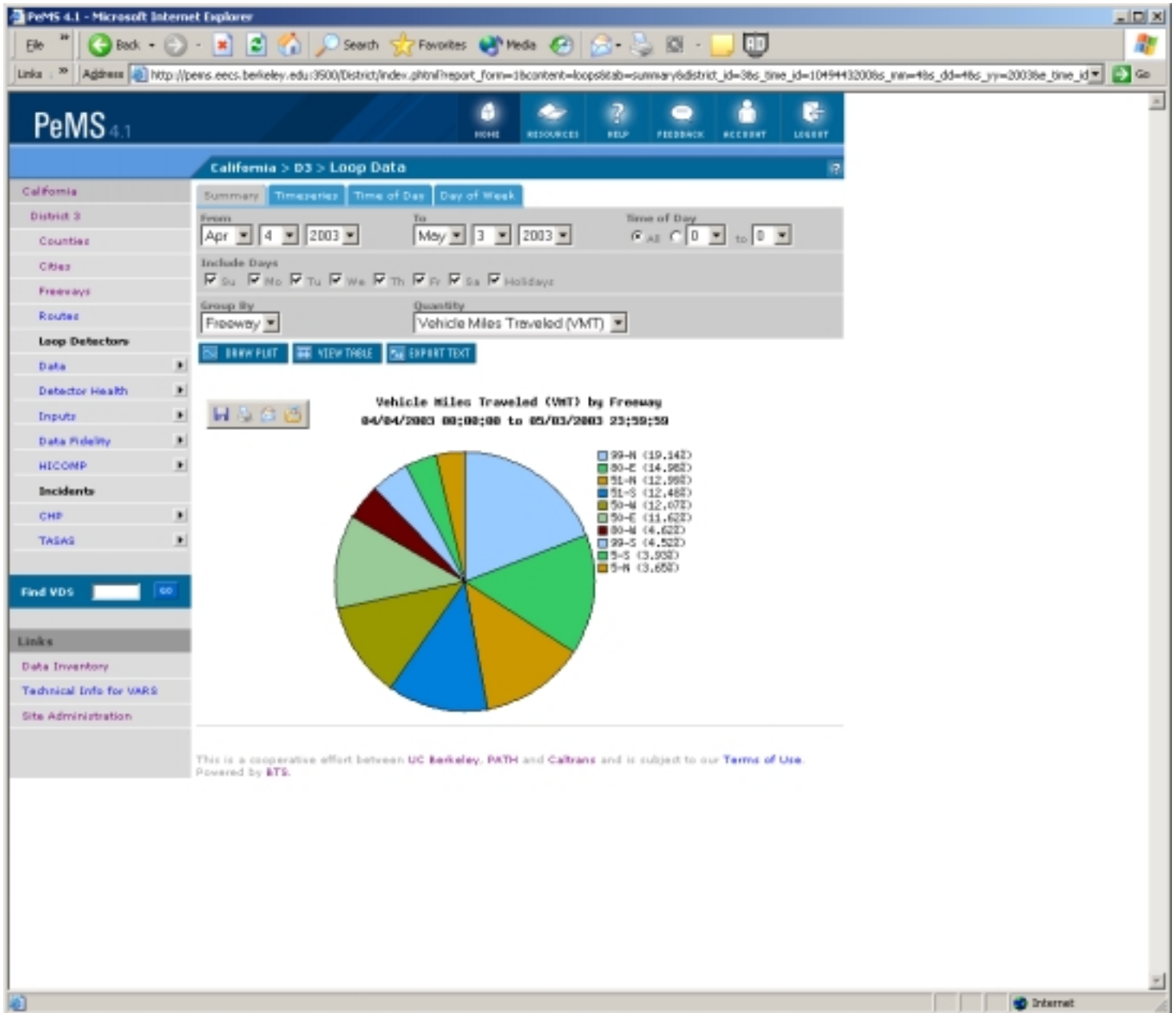


Figure 3 Vehicle miles traveled in District 3, grouped by freeway

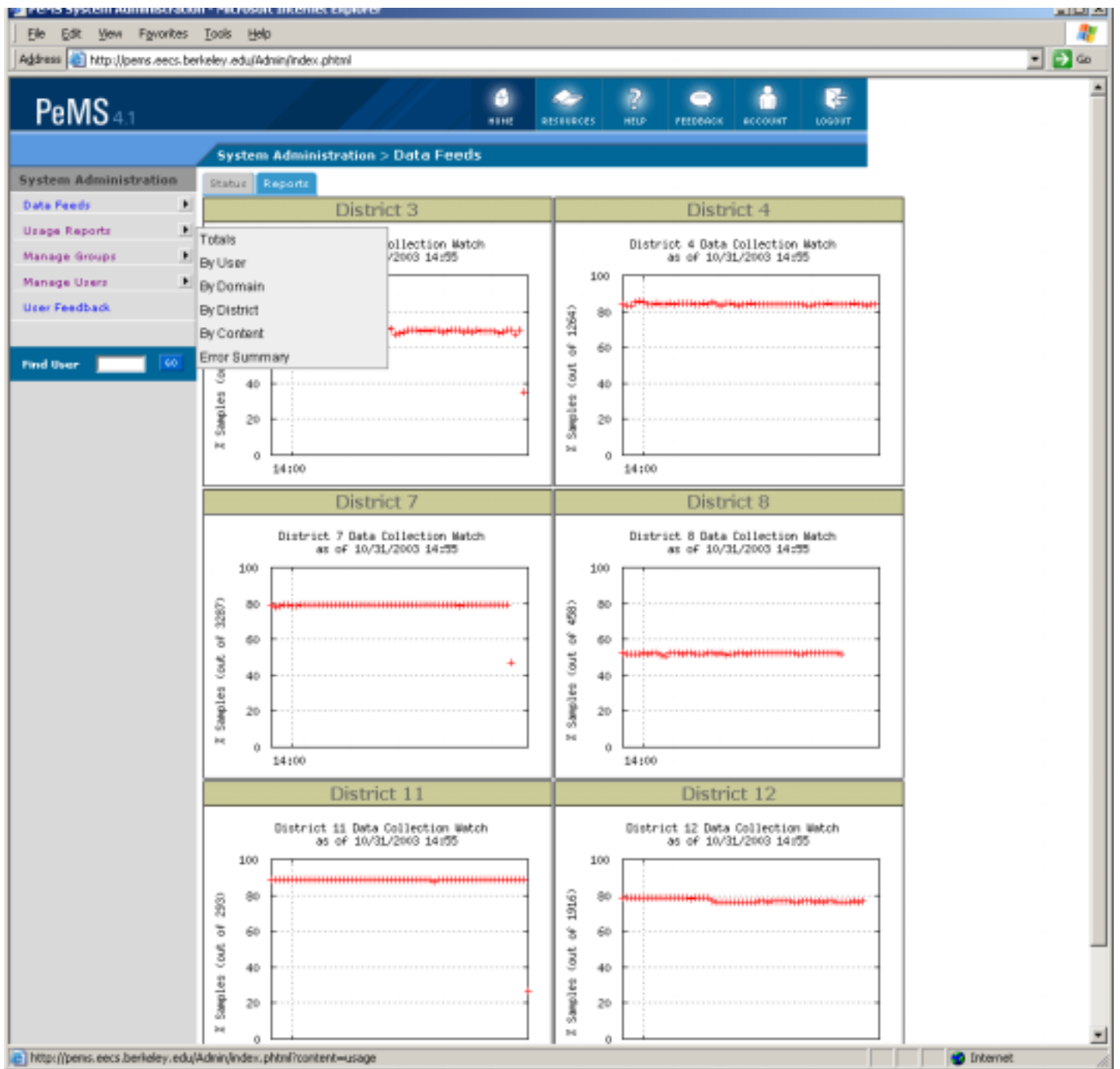


Figure 4 The System Administration page

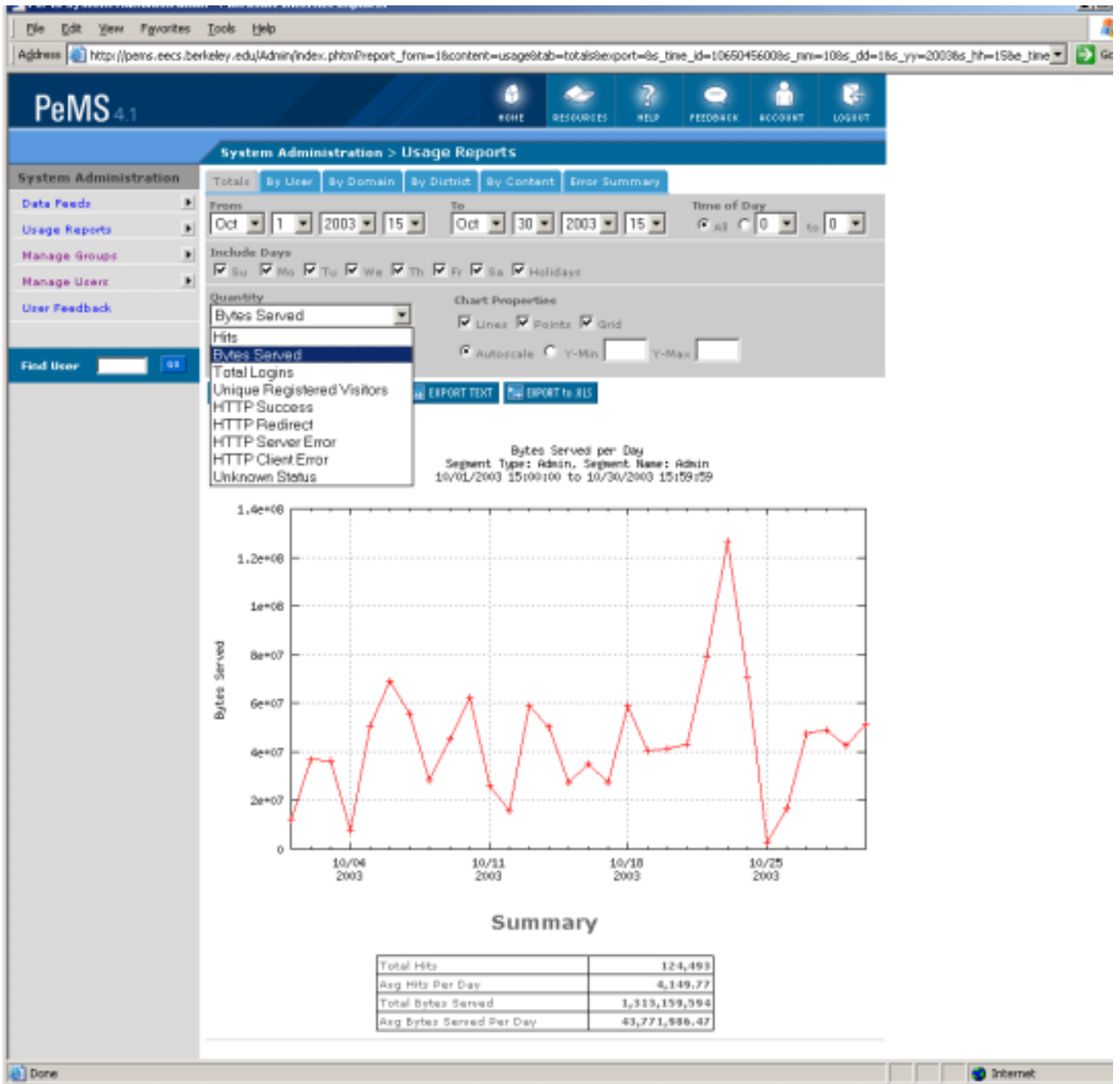


Figure 5 System usage



Figure 6 The main help page

PeMS 4.1 - Microsoft Internet Explorer

Address: http://pems.eecs.berkeley.edu/State/index.php?context=detector_health

PeMS 4.1

California > Detector Health

Summary | Timeseries | Samples Collected

Date: Oct 31 2003 Group By: District

VIEW TABLE

No Warning

Good (62,375)
Bad (137,938)

Suspected Errors

Come Down (47,892)
Card Off (26,073)
High Occ (3,328)
Intermittent (9,792)
Constant (3,708)
Other (4,652)

	# HL/WV	#		Suspected Error					
		Good	Bad	Come Down	Card Off	High Occ	Intermittent	Constant Value	Other
3	677	451	226	141	27	6	3	4	29
4	4,682	2,713	1,969						
7	3,284	3,864	1,990						
8	969	313	595						
11	1,050	964	193						
12	3,264	2,196	1,108						
total	28,281	28,281	8,128						

This is a cooperative effort between UC Berkeley, sponsored by B75.

PeMS HELP

Detector Health Reports

The detector health reports allow users to examine in detail which loop detectors have been determined to be bad by the diagnostic algorithms. Every day the PeMS system makes a determination as to whether each individual loop in the system is good or bad. It does this by subjecting the loops to a number of different tests. Depending on the results of these tests, it declares that the loop is good or bad and it makes a guess as to the cause. For more details please refer to the [Calculations](#) page in the Help section of the web site and the reference given there.

The various reports that users can perform on the loops are:

Summary

The summary report lets the user see how many loops are good or bad for a particular day. It does this with a simple pie chart. In addition, for the bad points, it gives a breakdown as to what the diagnostic algorithm thinks the problems are in a pie chart as well. Note that these percentages are for individual loops (ie) for each lane.

There is also a table below the pie charts which shows the number of loops which are bad for a given geographic region. The breakdown by geographic region is selected by

Taskbar: Start | Inbox - Microsoft Outlook | FinalReport | FinalReport | Karaya, Prash P - Oct... | YnskeporPQU4306.doc... | PeMS 4.1 - Microsoft Int... | PeMS Help > State > ... | H 12:06 AM

Figure 7 The detector health help page

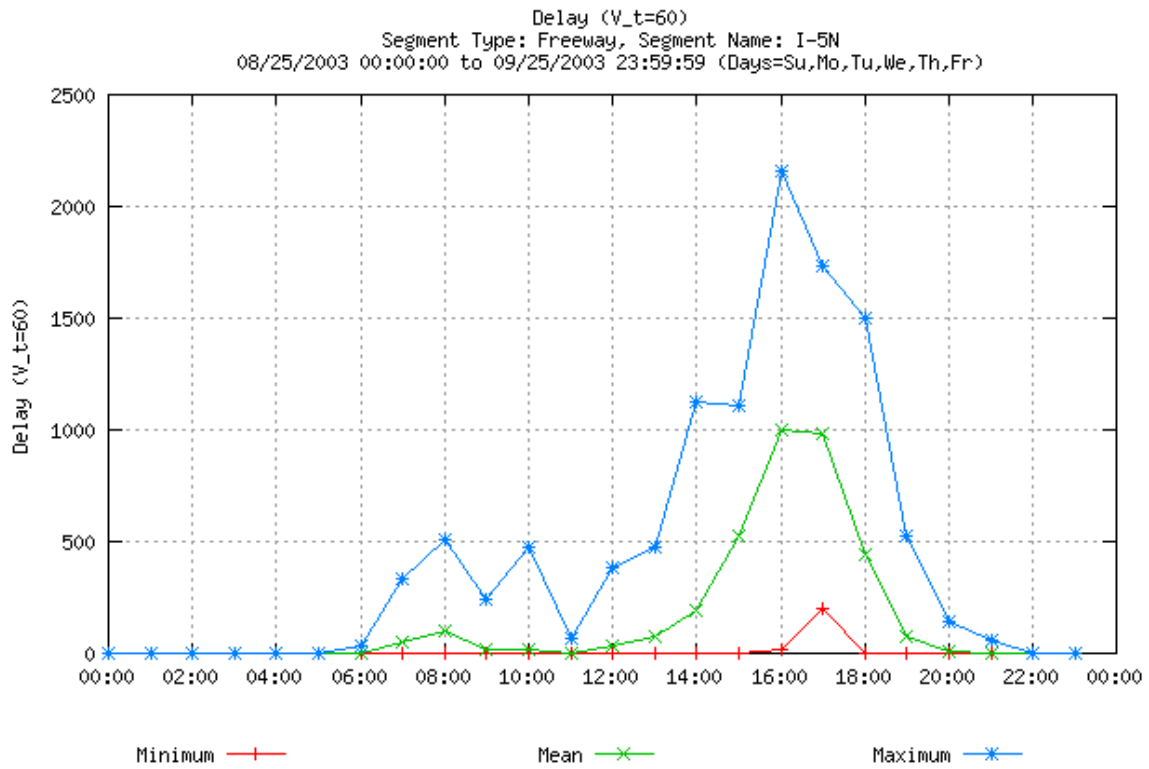
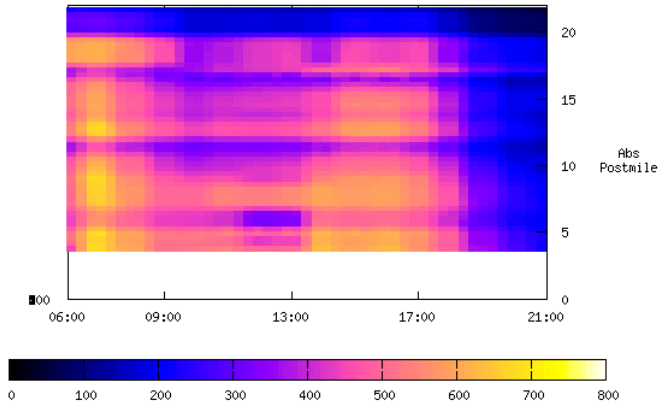
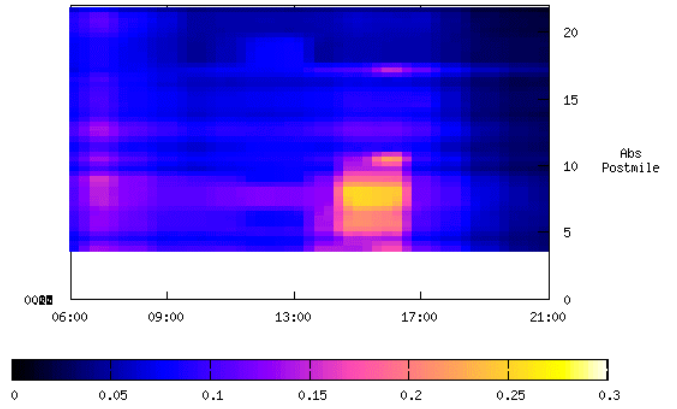


Figure 8 Congestion delay on I-5N, San Diego, 8/25/2003-9/25/2003 by time of day

Aggregated Flow (Veh/5-min) for US-50W
04/04/2003
Traffic Flows From Top to Bottom



Aggregated Occupancy (%) for US-50W
04/04/2003
Traffic Flows From Top to Bottom



Aggregated Speed (mph) for US-50W
04/04/2003
Traffic Flows From Top to Bottom

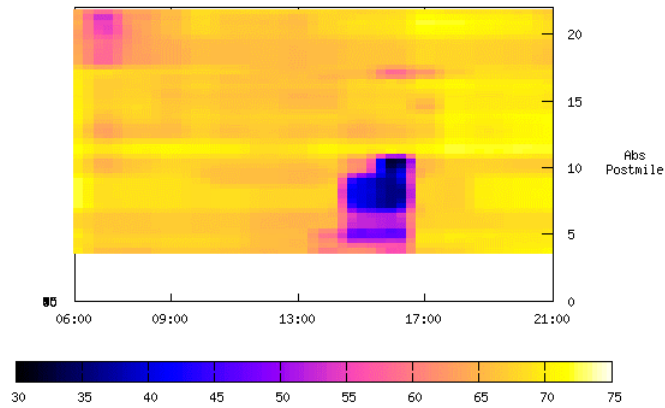


Figure 9 Spatial analysis of traffic on US-50W in Sacramento, 4/4/2003

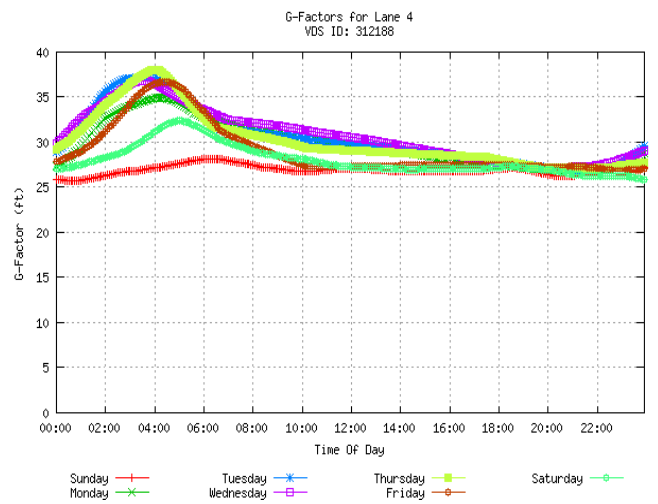
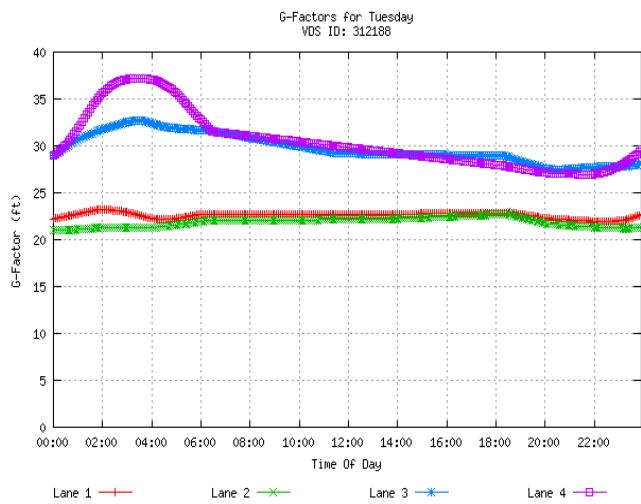
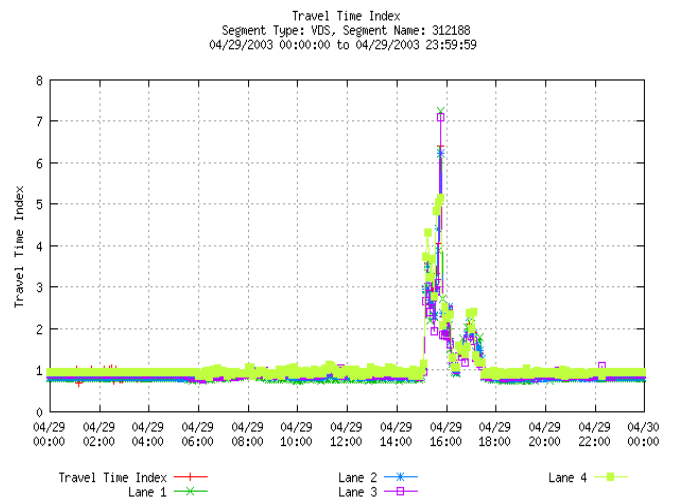
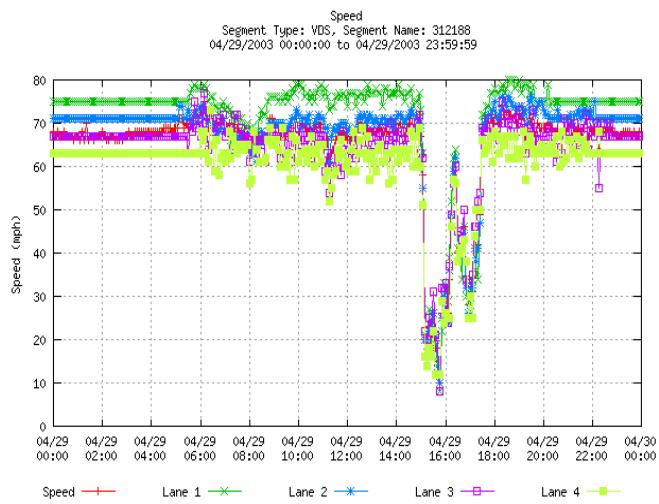


Figure 10 Time series analysis of speed and travel time at a loop on US-50W, Sacramento

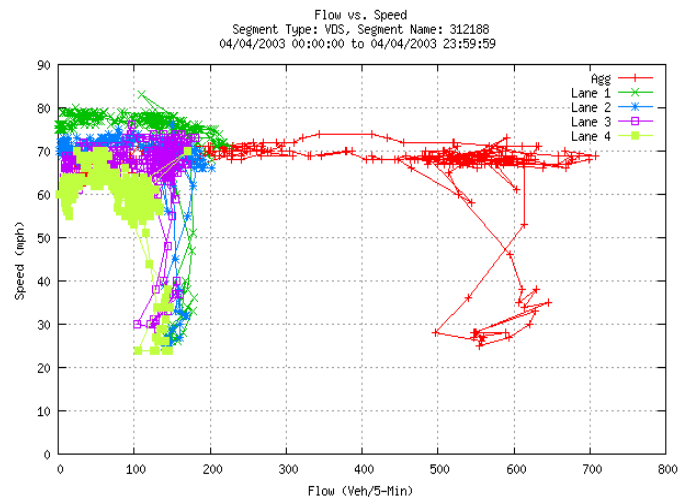
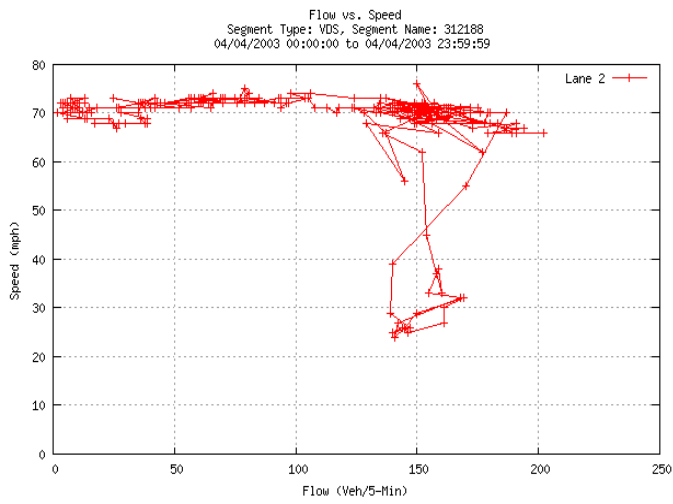
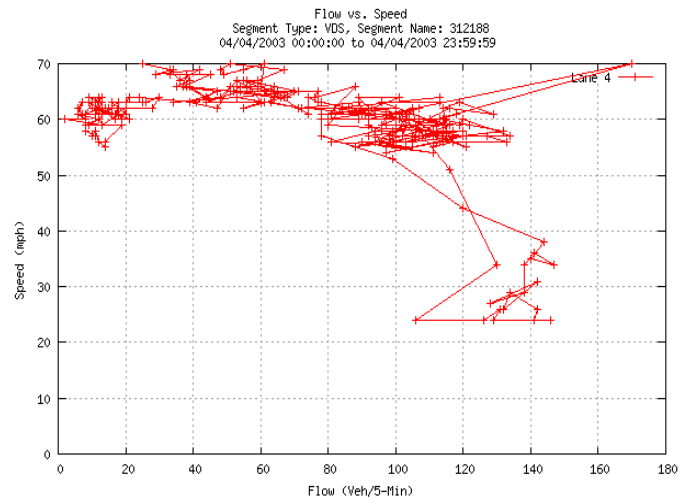
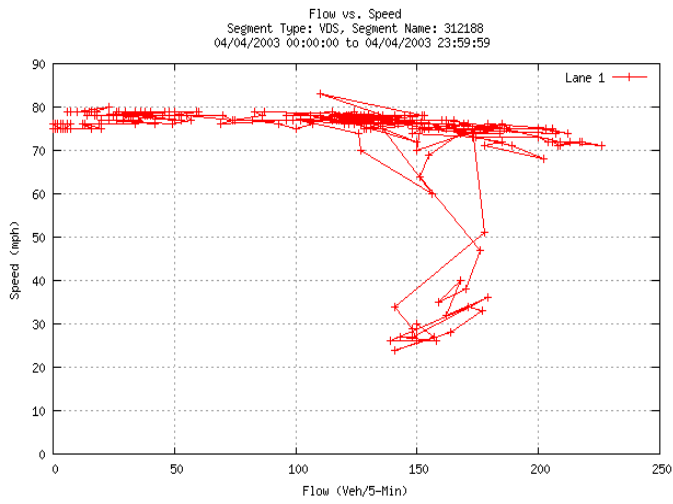


Figure 11 Speed vs. flow on VDS 312188

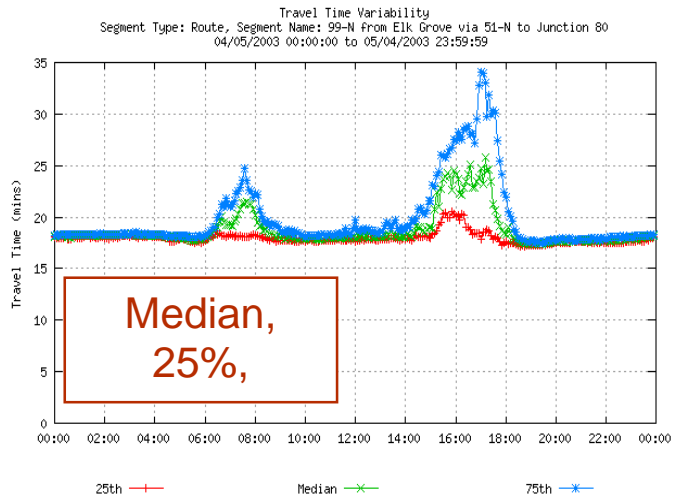
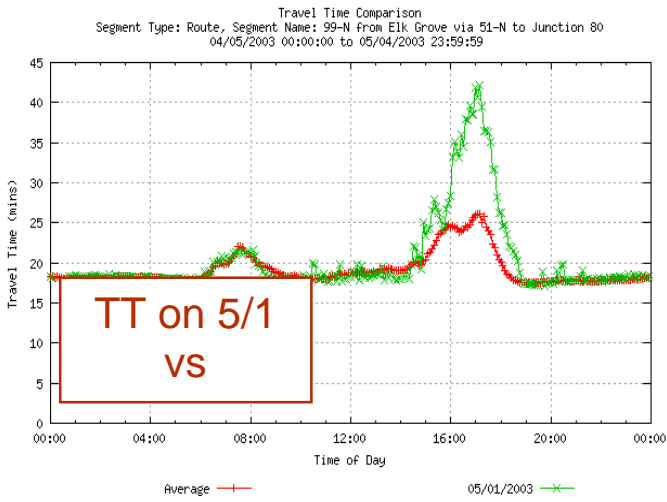
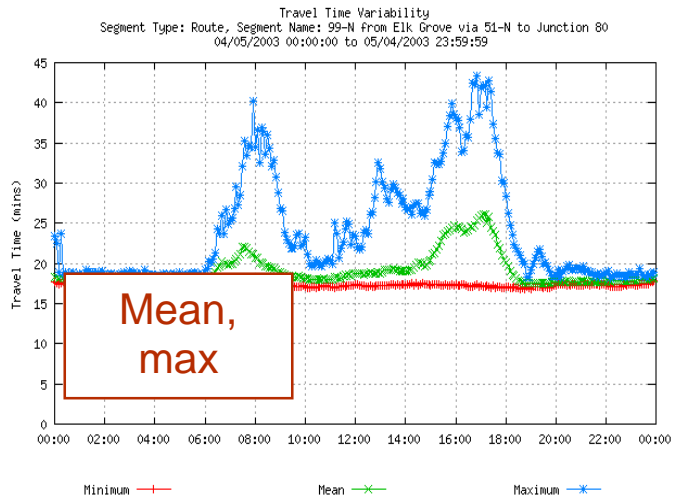
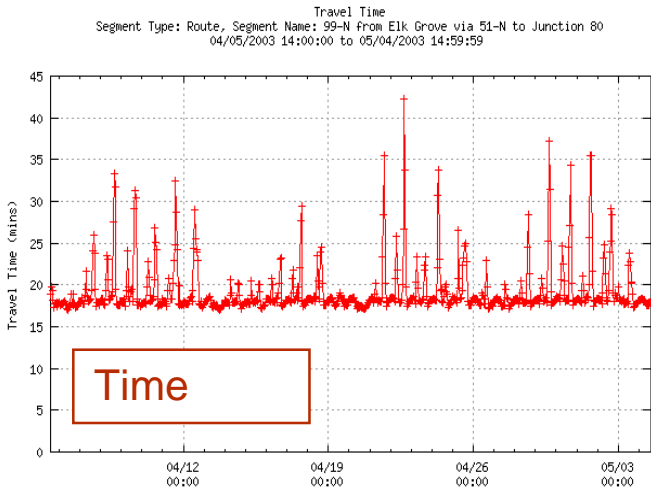


Figure 12 Travel time analysis

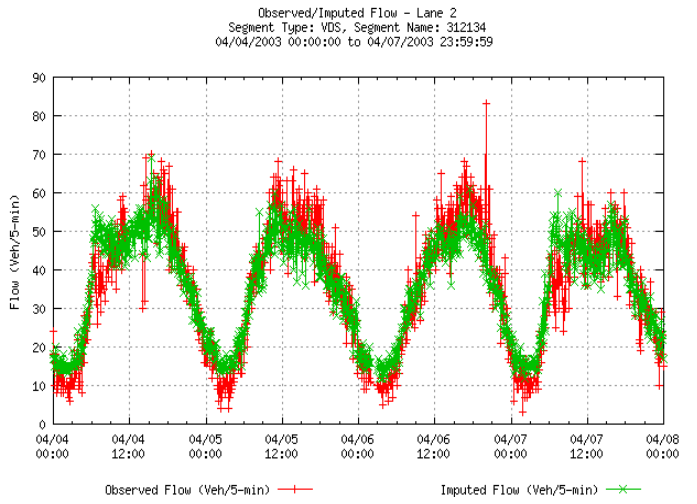
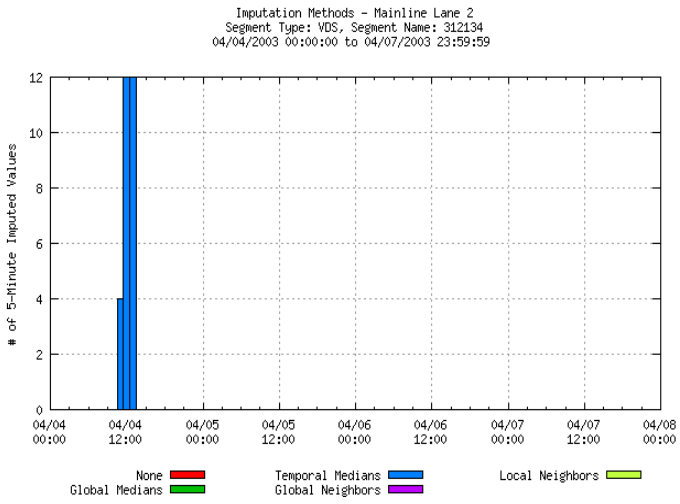
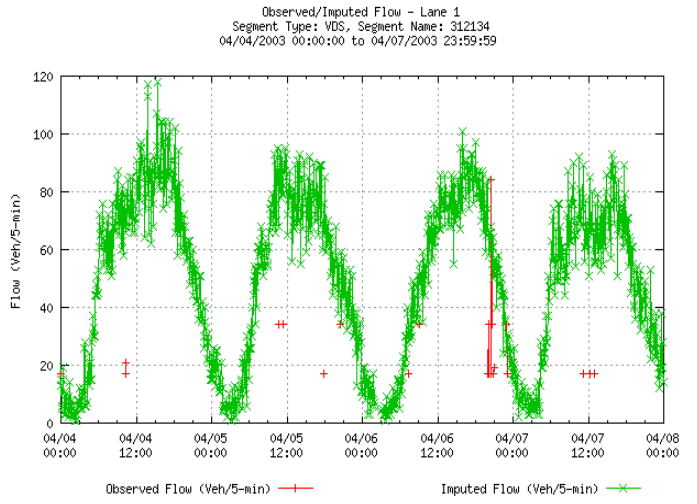
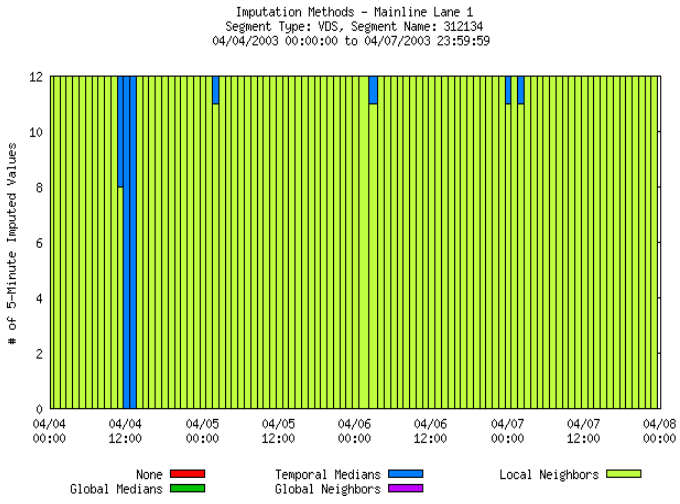


Figure 13 Data fidelity

Appendix

Statewide Strategy for Traffic Information Systems Needed

We recommend the adoption of budget bill language to require the Department of Transportation to convene a steering committee to determine how the department should use traffic information available from the Advanced Traffic Management System.

Just as the department needs a coordinated strategy for the development of ATMS software and TMCs, it also needs a coordinated, statewide strategy for how it will use and disseminate traffic information. To date, Caltrans has focused on using the information from ATMS to improve the internal operation of TMCs. While this was the original goal of ATMS, opportunities exist to use the data for many additional uses related to the department's ultimate goal of improving mobility.

Traffic Management Software Provides New Opportunities. The information that ATMS can provide is of tremendous value to transportation planners and engineers, as well as the general public. For example, Caltrans could provide a more accurate and detailed congestion monitoring report than it does at present. Currently, the department provides an annual report on highway congestion in the state's urban areas. The report relies primarily upon vehicles equipped with a device (known as a tachometer) to measure speed. Because this is a costly and labor-intensive method, the department limits its data collection to two days per year.

The ATMS system, however, provides the department with much more detailed highway performance information for *every day* of the year. For example, data are available on the daily volume of traffic in *each* lane on *every* freeway covered by the system. These data could be used not only to better assess the levels of congestion in each region, but also to conduct detailed before and after studies to determine the benefits of specific transportation projects, such as a new high occupancy vehicle lane or a new interchange.

Additionally, the ATMS system could enable the department or the private sector to provide reliable, real-time traffic information to the public. Finally, it could allow the department to incorporate performance measures, such as travel time and reliability, into policy and funding decisions, a goal that the department has been working towards for several years.

Pilot Project Successful. Caltrans has begun exploring the opportunities provided by ATMS, through the development of a pilot project, in coordination with the National Science Foundation and the Partners for Advanced Transit and Highways (PATH) program. The goal of the project was to develop an application that converts raw data from ATMS into user-friendly traffic information. Known as the **Performance Measurement System (PeMS)**,

the software, operated by UC Berkeley, can provide real-time freeway information accessible via the web or cell phone including:

- Current speeds and freeway incidents by freeway segment.
- Hours of delay on specific freeway corridors.
- Amount of delay that can be reduced via ramp metering.
- Number of vehicles using carpool lanes.
- Travel time predictions one hour ahead of time.
- Condition of loop detectors.


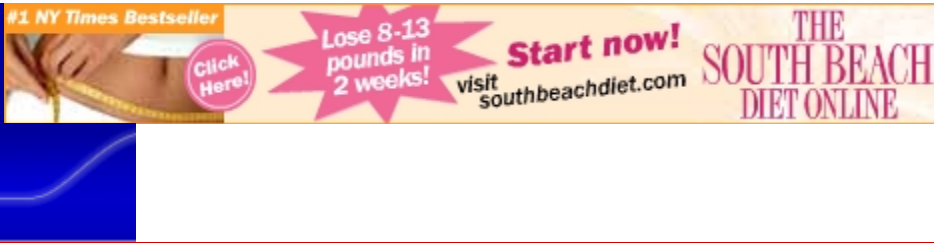
Currently Los Angeles is the only district that is sending its ATMS data to UC Berkeley's PeMS project, although other districts that have ATMS could do so relatively easily. The PeMS software is operational and has been extensively tested, but is not yet accessible to the public.

Analyst's Recommendation. The department needs a strategy for how to take advantage of the new traffic information data that are being made available through ATMS. The PeMS offers a glimpse into the many benefits that can be gained from the data. In order to ensure that the department uses a statewide approach to reaping the full benefits of this technology, we recommend the following budget bill language in Item 2660-001-0042:

The Department of Transportation shall establish a steering committee to: (1) determine how the department should take advantage of the Advanced Traffic Management System data for congestion monitoring purposes; (2) develop recommendations for how this data could be used to improve the department's various business practices, including but not limited to planning, design and engineering, maintenance, and traffic operations; and (3) develop a departmentwide approach for how the information should be disseminated to the public. The committee shall include, but not be limited to, a representative from each of Caltrans Traffic Operations, Planning, and Highway Program, the Information Systems and Service Center, UC Berkeley's PATH program and the California Chamber of Commerce. The committee shall provide a report to the Chair of the Joint Legislative Budget Committee, the chair of the fiscal committee in each house, and the chair of the transportation policy committee in each house by December 1, 2001.

INTERCITY RAIL PROGRAM

The intercity rail program was established to provide motorists traveling long distances with a safe, efficient, and cost-effective transportation alternative to the automobile. Currently, the state supports and funds


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Get a Move On

Led by Tokyo, cities are turning to wireless technology to untangle their traffic jams

By Anna Kuchment
NEWSWEEK

Oct. 20 issue — Before leaving to meet his friend for dinner the other night, Sakae Fujimoto checked the local traffic report. Instead of flipping stations on the radio, he booted up his in-car navigation system.

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“WHERE WOULD YOU like to go?” a computerized female voice inquired. Fujimoto specified an address in Shinagawa, a Tokyo district 16 miles north of his apartment. When a map appeared on his monitor, red arrows showed that a traffic jam was blocking one of the main roads into the city. The voice came back to warn him that there had been a car accident 500 yards ahead; Tokyo-bound traffic was slowing to a crawl. But there was good news, too: the screen displayed five quick alternate routes into town, with estimates of how long each would take. He chose one, and 30 minutes later was sitting down over Korean barbecue with his friend.

Traffic has been the bane of city living for more than 2,000 years. When the streets of ancient Rome grew jammed with carts, vendors and oxen, the caesars banned daytime deliveries altogether—only to have residents complain of being kept awake at night. In the early 1900s, streetcars were buried underground to make way for automobiles and, more recently, cities binged on road building to speed travel from downtown areas to the suburbs and back. Now road congestion has reached a new crisis point. A 2001 report from the World Business Council for Sustainable Development in Geneva estimated that urban residents in developed countries spend double and triple the amount of time in traffic that they did 20 years ago. The average annual delay for American drivers climbed from 11 hours in 1982 to 36 hours in 1999, according to the Texas Transportation Institute.

City planners are attacking this age-old problem with a 21st-century tool: wireless communication. “Building streets is expensive and we don’t have the space for it in our modern cities anymore,” says Bernd Leitsch, an engineer who is helping to roll out a system in Berlin similar to Tokyo’s. “We have to use what we have and make traffic flow better. That can only be done through technology.”

Cities from Berlin to Los Angeles are pinning their hopes on so-called advanced traveler-information systems, much like the one Fujimoto uses. They rely on thousands of sensors embedded in the asphalt, attached to street signs and hidden in traffic lights that record data on traffic flows and density and deliver it, wirelessly, to computer servers. Computers then combine this information with police dispatches on accidents or emergencies and deliver it to users who can access it on PDAs, mobile phones and the Internet. In

Japan, 10 percent of drivers rely on such systems, and that number is growing rapidly.

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Berlin's system is likely to be the most advanced of all.

Developed over the past 10 years at a cost of \$16 million by the city government and corporate giants DaimlerChrysler and Siemens, the Traffic Management Center—or VMZ in its German initials—will not only give a snapshot of road delays but also predict what traffic conditions will be like in several hours. It gathers live data from 125 infrared

sensors posted at major streets and 40 Webcams at key intersections. It combines these data with past patterns, including speed, flow, construction sites, road closings, temperature and precipitation, and feeds them into a battery of computers. The machines then tell city drivers the quickest way to get from point A to point B. "It's like a weather forecast, only more exact," says Leitsch, the VMZ's director.

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Los Angeles, which has some of the most congested roads in North America, has a similar pilot program in place. Called PEMS

(Performance Evaluation and Monitoring System), it receives information from loop detectors, electrical wires buried beneath the pavement that send traffic data every 30 seconds to a computer server at the University of California, Berkeley. City officials hope the system will eventually be able to tell travelers exactly when they should leave home in order to reach their destinations on time.

These information systems alone are unlikely to make a large dent in traffic patterns worldwide. They don't encourage drivers to leave their cars behind, for instance, unlike London's widely praised congestion tax, where drivers are fined for entering the city center during peak hours. But city planners hope that a combination of such innovative approaches will restore to drivers something that traffic jams take away: the

freedom to roam.

With Hideko Takayama in Tokyo and Stefan Theil in Berlin

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Strike Clogs Traffic Even More

Studies find more cars on the roads and an increase in rush-hour delays on major L.A. freeways.

By Caitlin Liu and Joel Rubin, Times Staff Writers

Traffic on Los Angeles streets and freeways has increased since the transit strike began 10 days ago, according to transportation records, significantly worsening congestion and delays throughout the city.

A report by the Los Angeles Department of Transportation, which sampled 11 major intersections and freeway ramps for three days last week, found a 4.4% jump in traffic volume overall, clogging roads from Westwood to Hollywood to Woodland Hills.

Experts said even such a modest jump in traffic volume can cause major problems on already congested streets.

"Just a 5% increase during our peak hours can send us into a tizzy," said Wayne Tanda, general manager for the Transportation Department. "A few more cars getting into a freeway can send it into total gridlock."

Motorists said the commute is getting worse by the day.

"It's absolutely terrible," said Brent Phillips, whose 45-minute morning drive from Encino to downtown Los Angeles has doubled since MTA workers went on strike. "From the moment I get onto the freeway until I get to work, it's like a parking lot."

The 101 Freeway, which Phillips drives every day, appears to be especially hard hit. The Hollywood Freeway portion of the 101 runs above the Red Line subway, and the Ventura Freeway segment runs parallel to the Metro Rapid bus line. Before the strike, the Red Line and Ventura Boulevard Metro Rapid buses accounted for 70,000 daily trips.

Since the transit shutdown, the Hollywood Freeway's Highland Avenue exit in the Cahuenga Pass registered a 4.5% increase in traffic volume,



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according to the city report.

"Traffic is very easily disturbed. If you're near capacity ... a very small disturbance is all you need to create a very serious traffic jam," said Asha Weinstein, assistant professor of urban and regional planning at San Jose State University. "If you add a small percentage of vehicles ... it can be just enough to push you over the edge."

There are also signs that traffic is worsening as more transit users turn to alternatives. Last Wednesday, the day after the Metropolitan Transportation Authority's mechanics went on strike, citywide traffic grew by 3.7% compared with the previous Wednesday. By Friday, traffic volumes were up by 5.9%, according to the report.

A separate analysis of traffic data by the UC Berkeley Institute of Transportation found that commuters on major Los Angeles freeway corridors saw a 37.5% increase in rush-hour delays since the start of the strike.

The analysis, performed for The Times, compared several weeks of Tuesday-to-Thursday traffic patterns from freeways feeding into downtown, including Interstates 5, 10 and 110 as well as California 60 and U.S. 101. It measured increases in commuter delays. A delay was defined as the extra time congestion added to a normal drive when traffic is clear, said researcher Chao Chen, who examined data from the institute's Freeway Performance Measurement System, a project sponsored by the California Department of Transportation.

The study found that motorists on these routes suffered a total of 12,600 hours of delays on an average day before the strike. But after the transit shutdown, the cumulative delays grew to 17,300 hours a day.

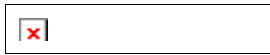
The southbound 101 recorded the biggest increase in delays — 70%, according to the Berkeley analysis.

Before the strike, transit trips accounted for at least 5% of all travel within Los Angeles County, according to MTA's latest estimates. On an average weekday, Angelenos took 580,000 trips by bus and 100,000 trips by rail.

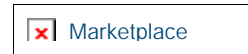
By removing those riders from freeways and roads, the region's bus and train network was saving the average resident 9.8 hours a year by reducing delays, according to a 2003 study by the Texas Transportation Institute.

Now, many riders are either driving again or paying someone to ferry them around.

Since the strike began, ridership in franchised taxicabs has jumped 30%, according to the Transportation Department report. Bandit taxis — or illegal car or van service — also have been proliferating. Even when people carpool, drivers typically travel extra miles to pick up and drop off



passengers.



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"The last strike [in 2000], it didn't appear this bad," said Jimmy Price, chief of LADOT's parking enforcement and traffic control unit, after it took him 30 minutes to drive two blocks through the downtown's fashion district.

Holding up her white-gloved hands at the intersection of Figueroa and 6th streets Wednesday afternoon, Traffic Officer April McCarthy said she senses growing frustration among motorists. "Just two seconds ago, a guy drove by and flipped me off!" she said. "But that's just part of the job."

"It's TMC — too many cars," added Rod Bernsen, a reporter for Fox 11 News .

Bernsen, who has surveyed the region's freeways from a helicopter in the sky before and after the strike began, said the stop-and-go conditions and miles of backups reminded him of traffic snarls on rainy days.

"There's a lot more congestion. It's noticeable," Bernsen said.

Motorists aren't the only ones unnerved by the increased traffic.

"It's gone pretty crazy, man," said Carlos Garcia, a bike messenger from East Los Angeles. "When the strike started I was happy because the buses would be gone, but then [the streets] were just packed with cars. It gets worse and worse every day."

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