Intellimotion

Research Updates in Intelligent Transportation Systems

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Advances in Performance Measurement

PATH – Partners for Advanced Transit and Highways – is a collaboration between the California Department of Transportation (Caltrans), the University of California, other public and private academic institutions, and private industry.

PATH's mission: applying advanced technology to increase highway capacity and safety, and to reduce traffic congestion, air pollution, and energy consumption.

CALIFORNIA PATH

Platoon Travel Saves Fuel…How Much?

Fred Browand, Mark Michaelian, Aerospace & Mechanical Engineering, USC

At 6:30 AM, Los Angeles' elderly, conservative Pasadena Freeway resembles a stock car track—all that's missing are the numbers painted on the sides of the cars. Sunup in the Silicon Valley is met by squealing brakes and belching exhaust as commute traffic screeches from freeway speed to a dead stop, then lurches forward again. People follow closer and drive faster than ever before, and those who try to drive at a safe speed and a safe separation may only infuriate other drivers. Refusal to play the "close-following" game can unfortunately result in additional hazards. Perhaps this reflects our harried lifestyle, as well as our frustration with the high levels of congestion we often encounter. But like it or not, close-following is a part of the urban driving scene.

Although fitting more vehicles on existing roads, rather than building new ones, is certainly Caltrans' goal, anarchic, hazardous, disorderly vehicular behavior is hardly the way to achieve it. But orderly close-following, as PATH's platoon demonstrations have repeatedly proved (see *Intellimotion* 6.3, 1997), offers potential relief from current and projected high levels of freeway congestion, relief that seems essential for the economic health of our major metropolitan areas. Relief from vehicular pollution has become a public health imperative as well. Smoothing the flow of traffic would translate directly into less fuel consumed and less pollution created per mile traveled. Such beneficial reductions in fuel consumption (and pollution) arise from two distinct sources. First, using automatic control systems and other safety features could eliminate stop-and-go driving in favor of an orderly traffic flow at a higher, more efficient travel speed. A second benefit, the subject of our research, arises from reducing aerodynamic drag, the air resistance encountered by a moving vehicle. The key effect is that the average drag of several vehicles in a close-following formation is considerably less than the drag of the same number of vehicles traveling apart. Less drag means less fuel needed to propel a vehicle forward. It is this second benefit that we are interested in quantifying.

How Close is Close?

Do people drive closely enough now to achieve any significant fuel savings? How closely must cars travel to realize fuel saving? Caltrans and PATH wanted to know the answer. We searched the literature and could find nothing. There are inferences from cycle racing, where racers travel in a

Three-Lumina platoon in the Dryden wind tunnel at USC. A portion of the ground plane has been removed to show the support mechanism below.

pack, suggesting that drag is greatest for the cyclist in front of the pack, and less for the following cyclists, who are "drafting" the leader and each other. A similar consensus hails from high speed stock car racing; here it is acknowledged that a close-following trailing car "gets a free ride" from the car in front, and that two closely matched and closely spaced cars can travel faster together than either one singly. It is also common knowledge that an even greater speed benefit can be achieved if more than two vehicles cooperate, but this situation, of course, is difficult to establish and to maintain. While such qualitative information is interesting, it has little engineering value. What are needed are quantitative estimates of fuel savings and quantitative estimates of drag savings, and the relationships between drag savings and fuel savings. We desire this information for vehicle spacings on the order of a car length and less.

Since we could find no useful information in the open literature, we undertook extensive wind tunnel tests using scale models of Chevrolet Lumina minivans. In the wind tunnel, drag was measured separately for as many as four vehicles in tandem, as a function of separation distance between the vehicles. The results show drag savings of a few percent even at spacings of five to ten car lengths. But at spacings on the order of one car length, potential fuel savings become significant. At one car length, we measured average drag savings of 12 percent, 20 percent, and 23 percent respectively for two, three, and four vehicles in tandem (Zabat, Stabile, Frascaroli and Browand 1995). Potential fuel savings were estimated from the drag savings by use of the Environmental Protection Agency (EPA) Highway Driving Schedule, a federal test procedure (as outlined by Sovran 1983). At a one-car-length separation, fuel savings were estimated as respectively 6 percent, 8 percent, and 9.5 percent for the two- three- and four-vehicle platoons (Zabat, Stabile, and Browand 1995).

On the Desert Floor at El Mirage

Strictly speaking, these numbers apply only to Lumina vans following the EPA Highway Driving Schedule, but we felt they would be representative for a variety of minivan vehicles traveling at moderate (90-100 kph, or 55-60 mph) highway speeds. To provide additional confidence, we performed a series of field tests at El Mirage Dry Lakebed, about 100 kilometers (60 miles) northeast of the University of Southern California campus, over the San Gabriel Mountains. El Mirage is delightful in the spring and fall, with cool mornings and warm afternoons; unfortunately we were usually there in the heat of summer. When we recall El Mirage now, we think of heat and dust.

The field tests utilized two Ford Windstar vans connected by means of a custom-made, variable length flexible connection capable of measuring the force between the vehicles. A series of intricate speed-up and coast-down maneuvers allowed the estimation of the drag separately for each van. After considerable effort—field tests are far more difficult to orchestrate than wind tunnel tests—we did verify the drag savings obtained earlier in the laboratory (Hong, Marcu, Browand and Tucker 1998).

We Can Now Measure Fuel Consumption Directly

Because platoon travel reduces aerodynamic drag on each vehicle in the platoon, a platoon vehicle will need less fuel to cover a given distance over a road than for the same vehicle traveling the same path alone. Since PATH maintains eight fully automated Buick LeSabres, it occurred to us that with just a little more effort, we could measure fuel consumption for each car in a platoon directly! We got a chance to try our proposal during the summer of 1999, using up to four LeSabres at a time operating on the Interstate 15 High-Occupancy Vehicle (HOV) lanes north of San Diego, where Demo '97 took place (Michaelian and Browand 2000).

For a particular vehicle, fuel expenditure at cruise depends primarily upon vehicle speed, vehicle weight, and the up or downgrade of the roadway. Vehicle speed determines the power expended to overcome aerodynamic drag and rolling resistance; speed, weight and road grade determine the power expended to lift the vehicle against gravity. In virtually all modern cars, electronic fuel injection is used to efficiently deliver the correct amount of fuel to each engine cylinder. The vehicle's Power Control Module (PCM, a fancy name for computer) constantly monitors the state of engine performance, including engine rpm, manifold pressure, and throttle position, and computes how much fuel is required. The PCM then generates a train of pulses instructing each fuel injector to open and to remain open for the duration of the pulse. The quantity of fuel delivered per fuel injector pulse is linearly proportional to the pulse duration (PD). Our goal was to record the fuel injector pulse duration, as well as other data signals generated by the PCM, in order to later calculate the amount of fuel used by the engine at any time during the experiment. We form an expression to mathematically describe the instantaneous fuel expenditure, expressed in milliliters per kilometer traveled, as follows

$$\frac{ml}{km} = C_2(PD)\frac{rpm}{v}$$

where C_2 is a proportionality constant (made up of a calibration constant supplied for the specific model of fuel injector, and unit conversions), PD is the fuel injector pulse duration, rpm is the engine revolutions per minute, and v is the vehicle speed. For our fuel consumption calculation, the computer sampled and stored injector pulse duration, engine rpm, and forward speed, at a rate of 100 samples per second. The digital data for each run was stored on the computer hard drive, and later transferred for safe-keeping to a second computer in the vehicle cabin. At the end of each day, the data was transferred to Zip disks, and carried to USC for later processing. The total data set comprised approximately 200 MB.

Test Site

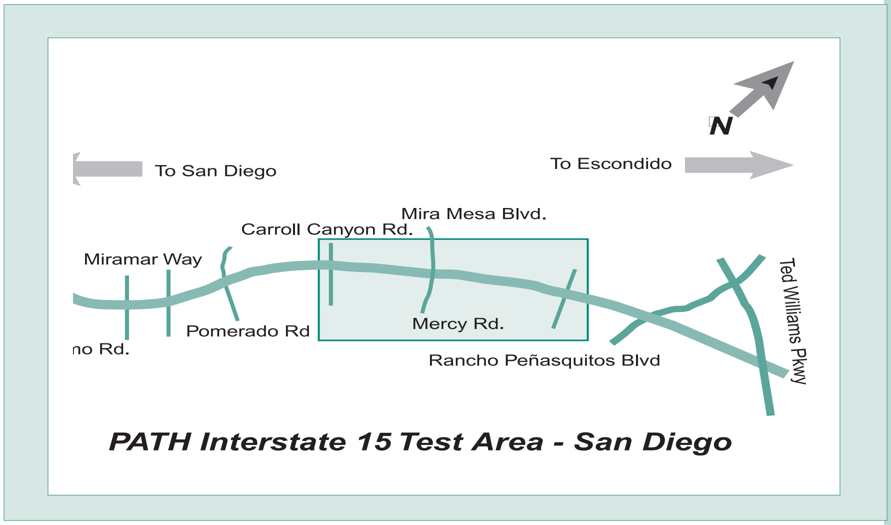
All tests were performed north of San Diego on a 12-kilometer portion of Interstate 15 that contains two limited-access HOV lanes operated by Caltrans. The two HOV lanes and two shoulder lanes are situated in the center of I-15, sandwiched by concrete dividers between four lanes of northbound and four lanes of southbound traffic. They were made available to PATH personnel for platoon testing between 9:30 AM and 1:30 PM.

During the platoon maneuvers, the Buick LeSabres were operated under fully automatic lateral and longitudinal control using the PATH Magnetic Guidance System (see *Intellimotion* 7.4, 1998). A computer in the trunk of each car recorded sensor outputs and other diagnostic engine parameters, and maintained the desired vehicle spacing and lane-keeping with errors of the order of several centimeters. Our platoon fuel economy tests began at a point three kilometers north of the south terminus and extended approximately six kilometers to Ted Williams Parkway (Route 56). A central 2.4-kilometer section was chosen for the fuel consumption calculations. Within this interval the vehicles had established their proper platoon configuration, and were traveling at the target speed of 96.6 kph (60 mph).

Just after daybreak at El Mirage Dry Lakebed, researchers Patrick Hong (l) and Bogdan Marcu (r) perform a final safety inspection. The vans will accelerate to 125 kph (80 mph, see photo on p. 1), coast to a low speed, turn, and repeat the procedure.

Test Participants, Test Protocol

The platoon tests were a combined effort by PATH, Caltrans, and USC. PATH drivers taking part were Bénédicte Bougler, Dan Empey, Pushkar Hingwe, Xiao-Yun Lu, David Nelson, and Han-Shue Tan. Caltrans operations were overseen by Larry Baumeister. USC personnel included undergraduate students David Lazzara and Glen Landreth, and former graduate student Patrick Hong, in addition to ourselves. Everyone helped



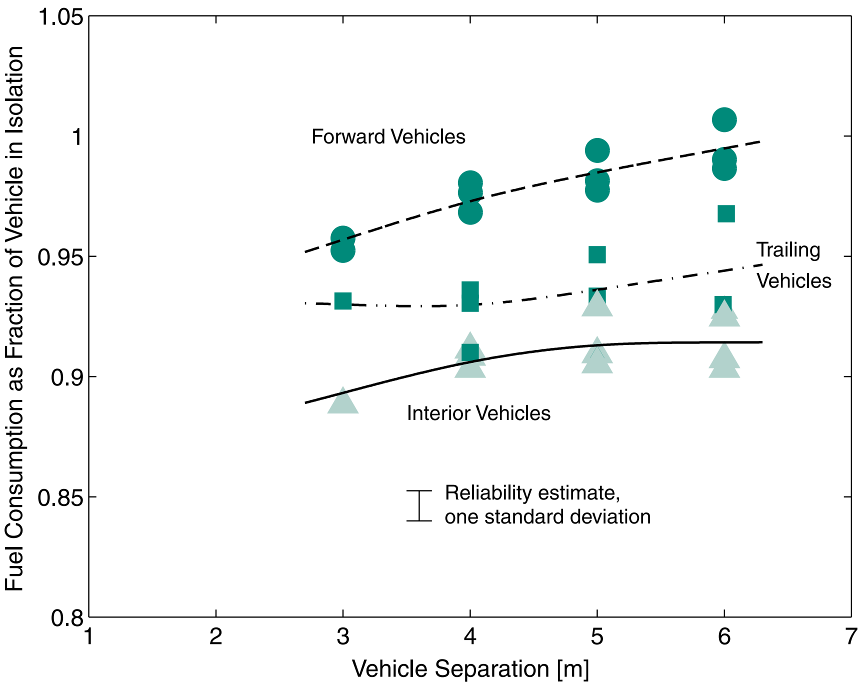
San Diego I-15 area with limited access HOV lanes. Fuel consumption tests were done in area shown by box.

Test platoon operating at 4-meter spacing on limited access position of I-15 north of San Diego.

make the test program a success, but a large measure of credit must go to the test drivers for their dedication and driving skill.

A total of 43 runs were completed over the three-day period from July 6-8, 1999. Data sufficient to determine the instantaneous fuel consumption were continuously recorded for platoons of two, three, and four vehicles, as well as for each vehicle in isolation. Since vehicle spacing is the most important variable affecting drag (and fuel consumption), the platoon testing was performed for spacings of 6 meters, 5 meters, 4 meters, and 3 meters, although the four-vehicle platoon was not tested at the 3 meter spacing. Each separate test, or run, consisted of driving the vehicle or platoon of vehicles from south-to-north or from north-to-south over the prescribed test course. Throughout most of the test period, winds were variable, up to 2-3 meters per second from the north. To minimize the effect of wind, and to account for changes in roadway elevation, separate south-to-north and north-to-south runs were combined into a single test result. Whenever possible, tests were repeated several times to provide a more reliable average.

Figure 1. Fuel consumption for close-following relative to fuel consumption for a single vehicle over the same 2.4 kilometer round trip. All results for 2- 3- and 4-vehicle platoons are plotted.
● – lead vehicles
▲– interior vehicles
■ – trailing vehicles



Fuel Consumption Results

Instantaneous fuel consumption—as determined from the previous algebraic expression—was evaluated for each vehicle in each run. Average fuel consumption values for each vehicle were then determined by integrating the instantaneous values over the same 2.4 km round-trip. Whenever two runs were available over a short time interval, the variation in fuel consumption values was within several tenths of a percent—a remarkable level of accuracy. Over the three-day test period, fuel consumption values were reproducible within about one per cent. (These larger errors probably reflect the observed changes in wind speed.)

The benefit to be derived for each vehicle while close-following is the ratio of the fuel expended in close-following divided by the fuel expended by the same vehicle traveling the same path in isolation. Whenever close-following reduces drag and fuel consumption, the resulting benefit ratios will be smaller than unity: the greater the reduction, the smaller the ratio. One way to present the results is shown in Figure 1, where all vehicles are grouped in one of three categories—either as lead vehicles (●), interior vehicles (▲) or trailing vehicles (■). (Note the two-car platoon does not have an interior vehicle.) The plotted results are the benefit ratios expressed as a function of vehicle spacing within the platoon. It is possible to draw several general conclusions from the plot. Over the range of spacings tested—and probably at shorter spacings—the interior vehicles have the least fuel consumption and thus benefit most from close-following. Trailing vehicles are intermediate in benefit, and leading vehicles benefit least. The values for fuel savings are significant—at 3 meters' spacing, the savings range from 5 percent to 12 percent depending upon position in the platoon.

The three lines drawn in Figure 1 are cubic-spline smoothed fits for the three data groups. The smoothed fits, as well as the data, tell us that the spacing between vehicles in platoon configurations is quite important. Additional fuel savings are projected for shorter vehicle spacings. In this regard, it is interesting to note that the savings for trailing vehicles levels off at about 0.93 (7 percent fuel saving), while the leading vehicles and interior vehicles would continue to benefit from shortened spacing. In fact, it is quite possible that leading vehicle savings will overtake trailing vehicle savings at a spacing of about two meters. Since a typical car is about 5 meters long, a two-meter spacing would represent 0.4 car lengths—a short, but still possible, separation.

Combining Resources: Wind Tunnel Data and Field Data

In 1995, we predicted fuel expenditure for minivan platoons of various lengths based upon the drag savings we measured in our wind tunnel at USC, by incorporating these drag savings into the simple dynamical model of Sovran for travel over the EPA Highway Driving Schedule. At the time, no other data were available for comparison purposes. Now we have acquired high quality field data for platoons of passenger cars, and one must naturally inquire how the present data compares with earlier predictions—and what may be learned from such a comparison.

First, all the qualitative aspects displayed in Figure 1 are entirely consistent with and predictable from the early wind tunnel drag measurements. (See Zabat, Stabile, Frascaroli and Browand 1995 for the particulars.) Quantitative comparisons of fuel consumption for wind tunnel and field data are shown in Figure 2. This figure presents the same platoon test data in a slightly different format. The savings in fuel consumption is plotted on the vertical axis, expressed as a percentage of the isolation value and averaged over all vehicles within the platoon. Field test results for two-, three-, and four-vehicle platoons are plotted with large marker symbols (● – 2 cars; ▲ – 3 cars; ■ – 4 cars). The separation between vehicles—the horizontal axis—is now measured in units of the square root of vehicle frontal area,$\sqrt{\mathbf{A}}$. It is reasonable to suppose that the aerodynamic influence of one vehicle upon another will scale with the cross sectional area (or frontal area) of the vehicle. Thus the minivan, with its blunt rear end and large frontal area, should have a greater influence than a passenger car at the same physical separation. Scaling separation by $\sqrt{\mathbf{A}}$ is an attempt to bring the results for passenger cars and for minivans into as close agreement as possible. The curves with open marker symbols (❍ – 2 vans; □ – 3 vans; Δ– 4 vans) in Figure 2 represent the predicted fuel savings for minivans driving the EPA Highway Driving Schedule, based upon our wind tunnel drag measurements. The curve denoted by Xs is an averaged result for two minivans in the four possible orientations with respect to one another and to the airstream direction. This curve is referred to as the two-vehicle, "geometrically-averaged vehicle" result.

The predictions derived from wind tunnel data for three- and four-vehicle minivan platoons overestimate the actual fuel consumption savings experienced by the Buick LeSabres by about 30 percent. This may be due in part to uncertain use of the EPA Driving Schedule, but it is more likely due to real differences in geometry other than frontal area between vans and passenger cars. Notice that the geometrically-averaged vehicle result for two vehicles lies in the gray band between the two-vehicle platoon Buick field data and the two-vehicle platoon Lumina wind tunnel data.

The two results taken together, passenger car field data and wind tunnel minivan data, probably bracket the results for most other vehicle geometries. We would anticipate car-like geometries to fall near the result for the Buick LeSabres, and the more bluff vehicle shapes—vans and SUVs—to fall nearer the minivan result.

continued on page 11

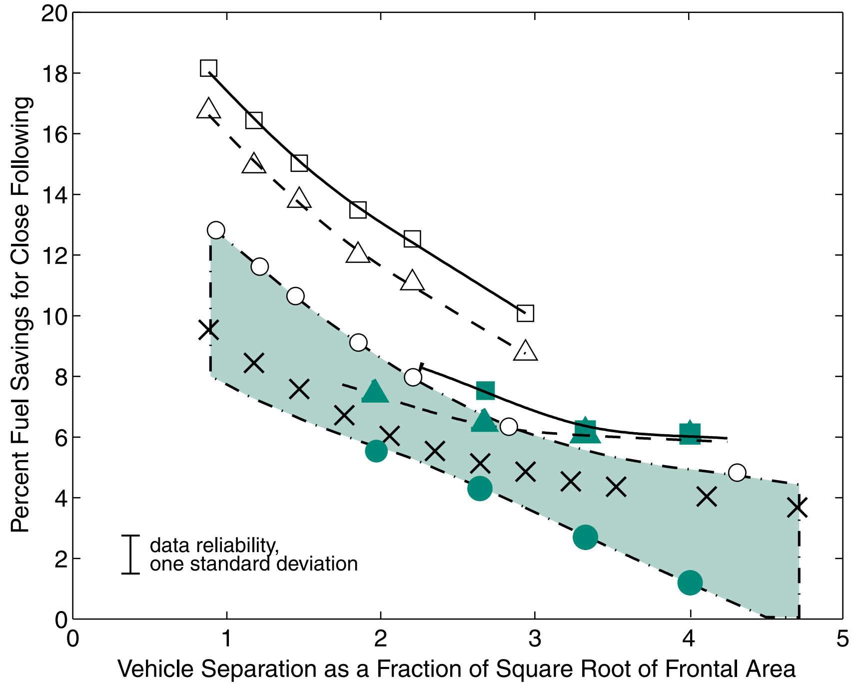


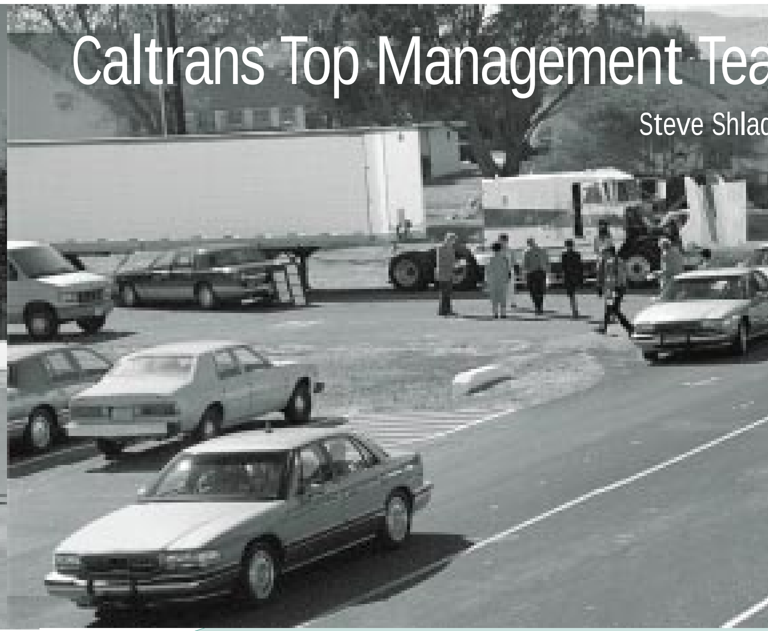
Figure 2. Fuel savings for platoons of Buick LeSabres (1999 field tests), and fuel savings for platoons of minivans derived from windtunnel drag.

Field tests: ● – 2 cars
▲– 3 cars
■ – 4 cars

Wind tunnel tests:
❍ – 2 vans
□ – 3 vans
Δ– 4 vans

Caltrans Top Management Tea

Steve Shlad



Caltrans Director Jeff Morales was sufficiently impressed by his summer visit to PATH with the ITS America Coordinating Council to bring his entire top management team back for a repeat performance in the Fall.

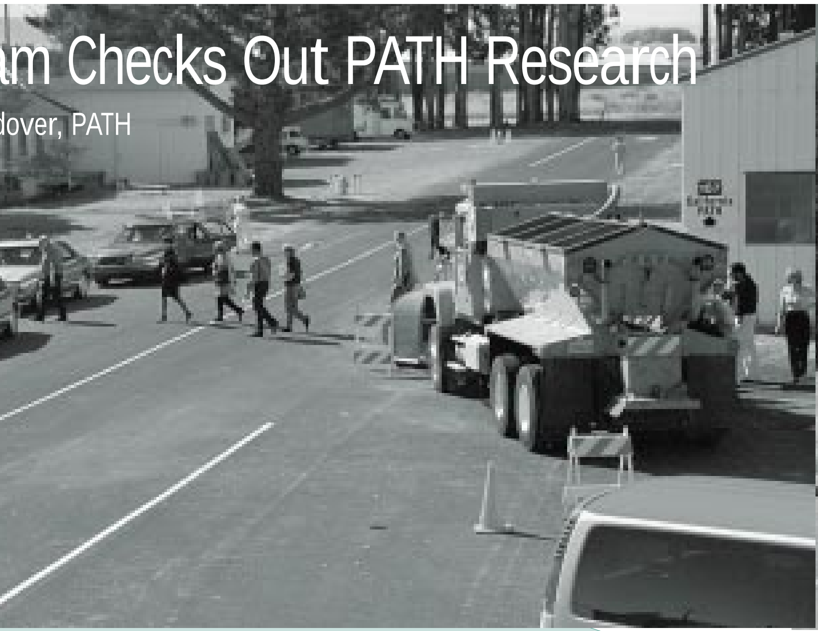
The September Caltrans Directors meeting was held at the District 4 headquarters in Oakland on the 19th and 20th and the participants spent the afternoon of September 19 observing PATH research at the Richmond Field Station, as well as touring the Pavement Research Center.

PATH projects on display included:

- Freeway Performance Measurement System (PeMS), to diagnose congestion problems (see article, page 8)
- ATMS Testbed and traffic simulation capabilities at UC Irvine
- CarLink car-sharing program
- Automated Freightliner truck

am Checks Out PATH Research

dover, PATH



• Advanced Snowplow and its guidance display
• Sensor-friendly vehicles and roadways
• Automated merging and precision docking vehicle demonstrations.

Visitors included Deputy Directors, District Directors, and other key managers from Caltrans, many of them primary decision makers who will be instrumental in deploying the results of PATH research. We received very favorable feedback; indeed, after the visit, Caltrans Chief Deputy Director Tony Harris said, "I enjoyed it and look forward to aggressively pursuing implementation of some of the items." Their experience here can only help to enhance their perception of the value of the work we do, which should translate into better future working relationships and, we can hope, funding as well.

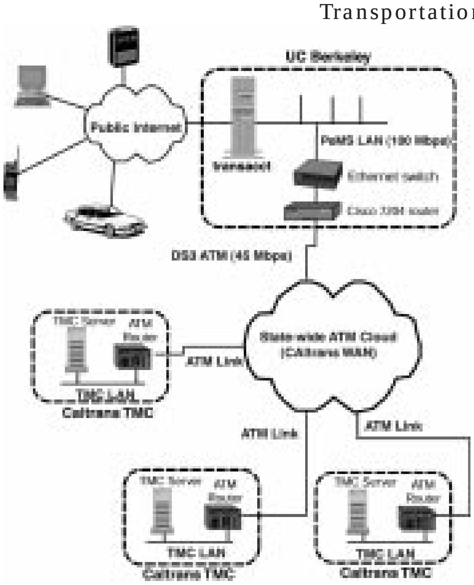
Freeway Performance Measurement System (PeMS) Shows Big Picture

Chao Chen, Zhanfeng Jia, Karl Petty, Jun Shu, Alexander Skabardonis, Pravin Varaiya, UC Berkeley

PATH researcher Chao Chen accepts PeMS award for Best California Research Project/Facility Award for 2000 from California Alliance for Advanced Transportation Systems Board Chairman Harry Voccola.

The Freeway Performance Measurement Project, a joint effort between PATH and Caltrans, collects real-time flow and occupancy data from loop detectors embedded in California's freeways and makes it available for transportation management, research, and commercial use. The project's freeway Performance Measurement System (PeMS) provides five-minute, per-loop averages of occupancy and flow, speed, and congestion. PeMS also extracts traffic information from real-time and historical data and presents it in low-cost, easy-to-use forms to assist managers, traffic engineers, planners, freeway users, researchers, and transportation information service providers (ISPs). Managers can use PeMS to get the "big picture" of how well their systems are working; engineers to get detailed traffic analyses, and spot bottlenecks or malfunctioning equipment; planners to evaluate management strategies; travelers to find the quickest or shortest routes for their trips; and ISPs to package travel-time information with other services.

PeMS physical architecture.



PeMS relies on the facilities at Caltrans District Transportation Management Centers (TMCs) to actually collect the data. Caltrans' front-end processors transmit data over a high-speed link directly to the PeMS database. The PeMS system itself consists of the link from the Caltrans District TMC, an Oracle database, a lot of processing routines, and a set of web pages. A major research aim of this project is to examine the trends of freeway measures over a significant period of time (two to three years), for research purposes.

PeMS is easy to use; built-in applications are accessed through a Web browser (http://transacct.eecs.berkeley.edu). PeMS creates a map of the entire freeway network for each five-minute interval, with each link color-coded according to speed or any of the other computed measures. An "animation" application can play back these maps in sequence over any time interval. The animation vividly shows how congestion starts and spreads. PeMS brings large benefits. Caltrans managers can instantaneously obtain a uniform and comprehensive assessment of the performance of their freeways. Traffic engineers and planners can base their operational decisions on knowledge of the current state of the freeway network, and determine whether bottlenecks can be alleviated by minor capital improvements. Traffic control strategies (ramp-metering and changeable message signs) can be optimally placed and evaluated. Travelers can obtain the current shortest route and travel time estimates. PeMS can serve to guide and assess deployment of intelligent transportation systems (ITS).

PeMS is also easy to deploy. The PeMS software architecture is modular and open. New applications are added as need arises. A new Caltrans district can be added on-line with six person-weeks of effort, with no disruption of the district's TMC. Data from new loops can be incorporated as they are deployed. Although a prototype, PeMS has been in stable operation for eighteen months, and can serve as the blueprint for a 24/7 production system.

A district TMC and PeMS collect data as follows. A front-end processor (FEP) at the TMC, receiving data from freeway loops every 30 seconds, formats this data and writes it both into the TMC database and the PeMS database. PeMS maintains a separate instance of the database for each district. Caltrans' 12 districts together generate two gigabytes (GB) of data each day. District 7, Los Angeles, now on-line in real-time, accounts for one GB daily. The PeMS database currently has over 400 GB of data.

As data arrives in real time, PeMS software:

- aggregates 30-second values of flow and occupancy to lane-by-lane, 5-minute values
- calculates the speed for each lane from the flow/occupancy data
- Aggregates the lane-by-lane value of flow, occupancy, and speed across all lanes at each detector station
- Computes the basic performance measures – VMT (Vehicle-miles of travel), VHT (vehicle-hours of travel), and delay (time a vehicle spends on a freeway section relative to the time it would spend if traveling at a user-specified speed–default is 35 mph).

PeMS Architecture

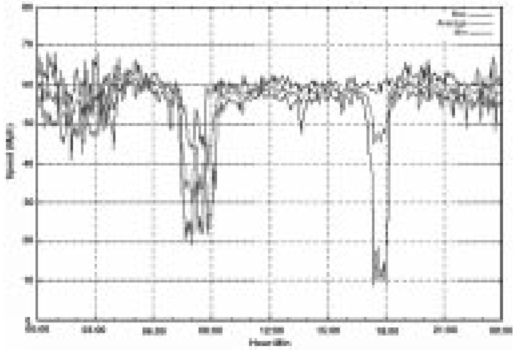
The PeMS computer, transacct, is located at the University of California at Berkeley. Users access PeMS over the Internet. Transacct also has a 45 Mbps link to the Caltrans ATM wide area network (WAN). The WAN is used to transfer data from Caltrans districts to PeMS. An individual Caltrans district is connected to PeMS over a permanent ATM virtual circuit. To establish such a circuit the routing tables at the two ends must be configured, which is done remotely from Caltrans Headquarters in Sacramento.

PeMS uses commercial off-the-shelf products for communication and computation. Detector data are retrieved over the Caltrans ATM wide area network to which all districts are connected. The 45 Mbps link connecting PeMS to this network costs $2000/month. The PeMS computer is a four-processor SUN 450 workstation with one GB of RAM and a terabyte of disk space, using a standard Oracle database for storage and retrieval.

Uses Of PeMS

Users can run various applications through their Web browsers. The following scenarios illustrate the use of PeMS by transportation managers, engineers, travelers, VARs, and researchers.

• **Manager**–"If you can't tell how your system performed yesterday, you can't expect to manage it today." A manager can bring up PeMS on her Web browser to compare the performance of her district's freeways with previous days (e.g., the average travel speed on a section of freeway over a three week time period). The manager observes that on a certain day the speed fell below thirty mph. She could initiate an inquiry calling up all instances whenever the speed fell below thirty mph. She also could compare the performance of other freeways in her district, and allocate resources towards improving the worst performers.

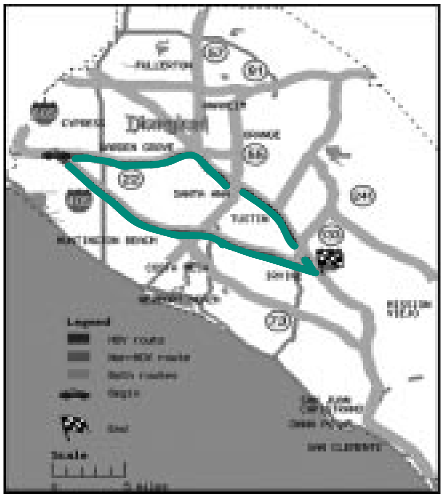


• **Engineer**–In response to the manager's inquiry, the engineer asks PeMS to display a contour plot of speed for the 24-hour period of the specific day over the freeway section. From that plot, the engineer identifies the location of the choke point, as well as the spatial and temporal extent of congestion. The engineer also uses a set of plots generated by PeMS to verify whether the loop detectors at the study section are working properly.

• **Traveler/Travel Information Service Providers (ISPs)**–PeMS provides trip time estimates and shortest routes. The PeMS web site displays your district freeway map: when you click on an origin and destination, PeMS highlights the two shortest routes, depending on whether or not you can use the HOV lanes, and a caption with the corresponding travel times.

If you were stuck in a traffic jam, you would want to know how much longer your trip would take, and whether you should reschedule an appointment or cancel it altogether. In the near future, an ISP could enable you to access PeMS via cell phone to find out. The ISP could also send you alerts during your trip if the traffic situation changed. PeMS has already developed a prototype for a Web-enabled cell phone.

• **Planner/Researcher**–Delay on any section of freeway can be estimated using PeMS, as well as how much delay on that section could be saved through ramp metering (or through other traffic management strategies) and how much of the delay remains due to excess traffic demand.



Travel Time Estimates and Routing

From	To	Estimated Time	Distance
I-405	I-5	55 min	23.0 miles
		22 min using HOV lane	23.0 miles (HOV)

PeMS Web site displays: above, 24-hour contour plot of speed for a specific section of freeway; below, district freeway map showing best routes and travel times to a selected destination.

continued on page 12

PATH on Paper

An Updated List of Recent PATH Sponsored Research Publications

PATH publications (which include research reports, working papers, technical memoranda, and technical notes) can be obtained from:

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A searchable database of PATH publications is available via the PATH World Wide Web site at: http://www.path.berkeley.edu

Automated Travel Time Measurement Using Vehicle Lengths From Loop Detector Speed Traps, Benjamin Coifman, Michael Cassidy, August 2000, 78 pp., $15, UCB-ITS-PRR-2000-12*

The Costs and Benefits of Telecommuting: A Review and Evaluation of Micro-Scale Studies and Promotional Literature, Kevan R. Shafizadeh, Patricia L. Mokhtarian, Debbie A. Niemeier, Ilan Salomon, August 2000, 60 pp., $15, UCB-ITS-PRR-2000-13*

Field Experiments Demonstrate Fuel Savings for Close-Following, Mark Michaelian, Fred Browand, August 2000, 28 pp., $10, UCB-ITS-PRR-2000-14*

Nonlinear Longitudinal Controller Development and Real-time Implementation, Xiao-Yun Lu, Han-Shue Tan, Dan Empey, Steven E. Shladover, J. Karl Hedrick, September 2000, 38 pp., $10, UCB-ITS-PRR-2000-15*

Modeling, Design and Implementation of Longitudinal Control Algorithm for Automated Vehicle Merging, Xiao-Yun Lu, Han-Shue Tan, Steven E. Shladover, J. Karl Hedrick, September 2000, 33 pp., $10, UCB-ITS-PRR-2000-16*

Studies of Collisions and Control Strategies in Vehicle Following Operations by Two-Dimensional Impact Simulation, Ching-Yao Chan, September 2000, 39 pp., $10, UCB-ITS-PRR-2000-17*

Safety Evaluation of Vehicle Following Operations by Fault Tree and Sensitivity Analysis, Ching-Yao Chan, September 2000, UCB-ITS-PRR-2000-18*

Model of Human Vehicle Driving – A Predictive Nonlinear Optimization Approach, Günther Prokop, October 2000, UCB-ITS-PRR-2000-19

A Cost-Benefit Analysis of Home-Based Telecommuting, Kevan R. Shafizadeh, November 2000, 137 pp., $20, UCB-ITS-PRR-2000-20*

Study of Freeway Traffic Near an Off-Ramp, Michael J. Cassidy, Shadi B. Anani, John M. Haigwood, August 2000, UCB-ITS-PWP-2000-10

A New Methodology for Evaluating Incident Detection Algorithms, Karl Petty, Michael Ostland, Jaimyoung Kwon, John Rice, Peter J. Bickel, August 2000, 17 pp., $5, UCB-ITS-PWP-2000-11*

New Aggregation Strategies to Improve Velocity Estimation From Single Loop Detectors, Benjamin Coifman, Zu-Hsu Lee, August 2000, 18 pp., $5, UCB-ITS-PWP-2000-12*

Experimental Characterization of Multi-Lane Freeway Traffic Upstream of an Offramp Bottleneck, Juan Carlos Muñoz, Carlos Daganzo, August 2000, 64 pp., $15, UCB-ITS-PWP-2000-13*

Incident Dispatching, Clearance and Delay, Randolph Hall, August 2000, UCB-ITS-PWP-2000-14

INCISIM: Users Manual, Heng Liu, Randolph Hall, August 2000, 35 pp., $10, UCB-ITS-PWP-2000-15*

Productivity Benefits and Cost Effeciencies from ITS Applications to Public Transit: The Evaluation of AVL, David Gillen, Elva Chang, Doug Johnson, September 2000, 88 pp., $15, UCB-ITS-PWP-2000-16*

Measuring the Aggregate Productivity Benefits from ITS Applications: The California Experience, David Gillen, Matt Haynes, September 2000, 105 pp., $20, UCB-ITS-PWP-2000-17*

Travel Time Estimation on the San Francisco Bay Area Network Using Cellular Phones as Probes, Jean-Luc Ygnace, Chris Drane, Y.B. Yim, Renaud de Lacvivier, September 2000, 56 pp., $15, UCB-ITS-PWP-2000-18*

PATH ATMIS: State of the Research Annual Report Fiscal Year 1999/2000, Robert Tam, October 2000, 36 pp., $10, UCB-ITS-PWP-2000-19*

Operations at Regional Traveler Information Centers: The Case of the TravInfo Field Operational Test – Final Results, Mark A. Miller, Dimitri Loukakos, September 2000, 52 pp., $15, UCB-ITS-PWP-2000-20*

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Platoon Travel Saves Fuel–How Much?

continued from page 5

Conclusions

As a closing remark, we surmise that large trucks (Class 8) and buses may display a different dependence outside these limits. Trucks are longer and more bluff than minivans and SUVs, and might be expected to produce greater fuel savings for the same non-dimensional spacings—that is, to lie above the curves presented here. There is commercial interest in platooning two trucks at short headway, and we are currently making measurements to document drag behavior. Statistics taken from California Department of Transportation literature show that approximately 7.5 billion five-axle truck (Class 8) vehicle-miles were logged on state highways during 1997 (Caltrans 1999). Undoubtedly, the number is larger today. Our latest preliminary experiments in the wind tunnel have shown that a 25-30 percent decrease in drag might be realized for a two-truck platoon (see also Bonnet & Fritz 2000). The resulting fuel saving would be of the order of 12-15 percent. If the average five-axle truck achieves six miles per gallon, the projected fuel saving is of the order of 200 million gallons of diesel fuel per year in California alone.

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Performance Measurement System (PeMS) Gives Big Picture

continued from page 9

Conclusions

The state cannot afford to build additional freeways to relieve congestion. It must improve the productivity of its freeways through the use of information technology (IT). The key question is: by how much can IT reduce congestion? PeMS can help answer this question.

Caltrans is currently evolving a strategy for ITS deployment, founded on a performance evaluation system. PeMS can help managers, planners, and engineers accurately estimate current performance; discover locations where improvements are likely to be most effective; evaluate in advance the benefits of suggested investments; and, after those investments are made, measure the resulting benefits. Such a system should be part of daily operations, just as production, cost, sales and revenue figures are essential in the daily operations of a private corporation. PeMS can be a key element of the Caltrans performance evaluation system.

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