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### Author

Tam, Robert

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**PATH ATMIS/Systems  
State of the Research Annual Report:  
Fiscal Year 1997/1998**

**Robert Tam**

**California PATH Working Paper  
UCB-ITS-PWP-98-32**

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**PATH ATMIS/Systems  
State of the Research  
Annual Report  
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**Robert Tam**

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## 1. Introduction

This report summarizes PATH ATMIS and Systems research for fiscal year 1997-1998. In each of the brief project descriptions we state the objectives of the project and outline its status and some of its principal results. These descriptions are not intended to be comprehensive or complete, but rather to present a picture of the main thrusts of each of the reported projects. References are provided for more detailed information about particular projects. Taken together, the collection of project descriptions should also give a reader an overview of the entire program. In general we have described only projects which are completed or have produced specific results and reports, and thus a number of projects in progress are not cited.

The report is organized into the following research topics:

- **Surveillance Systems**
- **Traffic Management Systems**
- **Traffic Modeling**
- **Traveler Information Systems**
- **Public Transportation Systems**
- **System Integration and Benefit/Cost Analysis**

## 2. Surveillance Systems

### *MOU 211 - Advanced Image Sensing Methods for Traffic Surveillance and Detection*

Arthur MacCarley, Cal Poly San Luis Obispo

Existing electronic imaging methods utilize conventional video cameras, and rely on human perception of information in the visible electromagnetic spectrum. This is adequate for most highway surveillance applications. A Traffic Management Center (TMC) operator may rely upon these video images for visually monitoring traffic conditions, or these video signals may be used by a computer vision system to detect traffic flow parameters.

Exceptions exist however: reasonably clear atmospheric conditions and an adequate level of natural or artificial visible-spectrum illumination are required. In conditions of dense fog, snow, rain or airborne particles (smoke or dust), and at times of low natural illumination, visible light sensing methods may be inadequate. Yet, it is precisely in these low-visibility conditions that the greatest need exists for reliable traffic monitoring, especially if the objective is the recognition of impending dangerous traffic situations

This project studies alternative imaging technologies for traffic surveillance and detection which have superior ability to "see through" fog and particles, which do not depend on

natural visible-spectrum illumination, and which may contain additional information of potential value in traffic management. The most probable candidates are infrared (IR) sensitive cameras and passive millimeter-wave radiometric imaging. While commercial product offerings for each of these technologies may be expensive at the present time, recent advances are expected to reduce system costs, possibly to the point of cost-effectiveness in specialized monitoring situations.

State-of-the-art examples of these alternative imaging technologies are evaluated in the context of traffic surveillance and detection applications. Evaluation criteria include: information content of image, standard video performance metrics, technical advantages and limitations, and human interface factors. Extensive field test data is acquired over a range of traffic and environmental conditions. A suite of metrics are developed for objective comparison of the image information content of traffic imagery acquired with each device. A suite of computer vision applications were developed and used to compare all videotaped or digitally-stored imagery from field work using these metrics. Results were ranked based upon spectral band, scene conditions, and individual camera. The merits and limitations of advanced imaging sensors as inputs to traffic detection computer vision systems are discussed. Recommendations are made regarding the usability and cost effectiveness of these technologies for a range of traffic surveillance and detection applications.

Overall the research team concluded that the long wave Infrared (8-12  $\mu$  m infrared), short wave Infrared (3-5  $\mu$  m) and millimeter wave (94 GHz) bands have some intrinsic advantage under combined conditions of darkness and fog. However, the devices tested for imaging in these bands were generally impractical for highway use, due to limited mean time before failure and high cost. The characteristics of very near infrared(VNIR) images are so close to those of monochromatic visible spectrum images, that there appears to be no identifiable advantage for traffic monitoring, other than possibly covert surveillance with artificial VNIR illumination. Chromatic (frequency-specific) information is available only in the visible band - made possible by the highly developed human eye. We found that color surveillance information is of significant value in traffic management operations.

### ***MOU 352 - Automated Travel Time Measurement Using Vehicle Lengths From Loop Detector Speed Traps***

Michael Cassidy, University of California, Berkeley

A University of California, Berkeley team headed by Professor Mike Cassidy has developed three reidentification algorithms (Basic, Subsampling, Approximation) for consecutive loop detector stations on a freeway, whereby a vehicle's length measurement made at a downstream detector station is matched with the vehicle's corresponding length measurement at an upstream station. The algorithms use dual loop speed traps. These detectors are quite common, often placed at half mile spacings or less on urban freeways. The work is also transferable to other detectors capable of extracting a reproducible vehicle measurement, i.e. a vehicle signature, such as video image processing.

The Basic Algorithm attempts to find an exact match for every vehicle. This property is particularly desirable during congestion, when travel times are likely to change rapidly due to disturbances propagating through the traffic. Using 60 Hz speed trap data, the algorithm works well for freeway traffic moving slower than 40 mph. Under free flow traffic conditions, the vehicle length measurement resolution degrades, making it difficult to differentiate between common vehicles. It should be feasible to apply this algorithm during all traffic conditions with higher resolution length data, e.g., using a higher sampling frequency.

The Subsampling Algorithm works well under all traffic conditions, but it only attempts to match the long trucks (up to 20 percent of all vehicles). This algorithm is intended for free flow conditions, when local velocity measurements at the detector stations should be representative of the entire link. The trucks serve as a good diagnostic for the onset of congestion and thus, can signal the need to switch to the Basic Algorithm. With more advanced vehicle detection systems, it should be possible to subsample vehicles based on other features, such as vehicle color measured from a video image processing system.

The Approximation Algorithm also works well under all traffic conditions. It attempts to find an approximate match for every vehicle, but it does not provide an exact match. Compared to the Subsampling Algorithm, this algorithm can provide more information during transitions from free flow to congestion (or vice versa) because it incorporates information from all vehicles. To find exact matches during these transitions, the Approximation Algorithm can be used to estimate a small range of possible matches for a vehicle. Then, the Basic Algorithm can be applied to this small range to find the exact match.

The Basic Algorithm was tested over a 0.35 mile segment of I-80 in Berkeley during congested conditions. Velocities ranged between 0 and 40 mph. Comparing the travel times as measured by the algorithm against the true travel times, the algorithm and the ground truth were very similar. The algorithm matched approximately 60% of the vehicles that passed during the 70 minute study period. Travel time ranged between 50 sec. and 130 sec. while the maximum error by the algorithm was under 5 sec. The average travel time measurement error was 2.4%.

The Subsampling Algorithm was tested over a two mile segment of State Highway 99 in Sacramento during free flow conditions. The algorithm attempted to match trucks in the outside lane. There were two on ramps and one off ramp between the detector stations. Velocities were on the order of 60 mph. The algorithm matched approximately 60% of the trucks that passed during the 25 minute study period. Travel time ranged between 100 sec. and 135 sec. while the maximum error by the algorithm was under 3 sec. The average travel time measurement error was 0.69%.

The Approximation Algorithm was tested over a 1.5 mile segment of I-80 in Berkeley during the transition from free flow to congestion. Initially, the traffic was moving about



60 mph, velocities dropped to 20 mph as a downstream queue overran the segment, and then, towards the end of the two hour sample, the velocities dropped further to about 15 mph. Comparing the travel times as measured by the algorithm against the true travel times, the algorithm and the ground truth were very similar. The algorithm found an "approximate" match for all of the vehicles that passed during the two hour study period. Travel time ranged between 70 sec and 260 sec while the maximum error by the algorithm was under 30 sec. The larger error by this algorithm reflects an error of about 15 vehicles and it is to be expected due to the fact that this is an approximation method. The maximum error is not representative of the matching results during most of the run. The average travel time measurement error was 4.8%.

### ***MOU 336 - Section-Related Measures of Traffic System Performance: Field Prototype Implementation***

Stephen Ritchie, University of California, Irvine

This project is developing an important component of intelligent surveillance systems by investigating a new set of advanced traffic surveillance techniques based on pattern recognition technology. The approach uses standard inductive loops and transforms them into intelligent sensors that have the capability of reidentifying individual vehicles from one loop detector station to the next. One of the components that make this intelligent surveillance system possible is a high-speed (1-12 millisecond scan rate) scanning inductive loop detector card that has the capability of outputting inductance counts. The other critical component is the vehicle signature processing and correlation algorithm developed in this project that is capable of solving the vehicle reidentification problem. The correlation algorithm was formulated and solved as a lexicographic optimization problem. The lexicographic optimization formulation is a preemptive multi-objective formulation that combines goal programming, classification, and Bayesian analysis techniques.

The solution of the vehicle reidentification problem has the potential to yield reliable section measures such as travel times, speeds and densities. It also enables the measurement of specific dynamic origin/destination demands as well as the development of new algorithms for ATMIS (Advanced Transportation Management and Information Systems) implementations using conventional surveillance infrastructure.

Freeway inductive loop data from SR-24 in Lafayette, California, demonstrated that robust results could be obtained under different traffic flow conditions. For moderate traffic flow (1000 vphpl), the estimated travel time was within 1.88% of the true travel time manually computed from video tapes. For congested traffic flow (1800 vphpl), the results had an average error of 3.24%. A small sample was analyzed to determine if this technique could work with single loops instead of double loops. With single loops, the speed of the vehicle must be estimated. Normally, this is done by assuming an average vehicle length. This method can lead to large errors if the variance of the vehicle lengths is great. A new method uses the vehicle signature and approximates speeds by using the waveform slew rate. The slew rate measures how fast the mass of the vehicle covers the entire loop, and is proportional to the speed. The initial results are promising, having a

speed error from 0.0% to 5.6%. Introducing this speed error, the reidentification was recomputed under moderate flow data. Even with a 5 mph speed variance, the algorithm still managed to match over 50% of the vehicles, resulting in good travel time estimation.

The system is being further developed and is undergoing a prototype field implementation at a major signalized intersection in Irvine, California, with communication of real-time results to the City of Irvine Traffic Management Center. The use of existing surveillance infrastructure coupled with this approach could allow development of widespread applications in Intelligent Transportation Systems (ITS).

### ***MOU 350 - Video-Based Signature Analysis and Tracking (V<sup>2</sup>SAT) System***

Arthur MacCarley, Cal Poly San Luis Obispo

This project investigates a possible means for non-intrusively tracking individual vehicles on freeways for data collection purposes. The operational concept involves the use of a computer vision method to make simple measurements of external dimensions, points of optical demarcation, and predominant colors of each vehicle. A conventional color video camera serves as the primary sensor in a self-contained detection module including a dedicated image processing computer and wireless communications components. Detection modules are placed directly above traffic lanes on an overcrossing or similar support structure, with one detector for each lane. For each passing vehicle, a Video Signature Vector (VSV) is measured and transmitted by the detection module to a central correlation computer. The correlation computer continuously receives VSV's asynchronously transmitted by all detection modules, and attempts to match VSV's to re-identify each vehicle at each detectorized site, in order to determine the progress of the vehicle through the freeway network.

If proven accurate and cost-effective, V<sup>2</sup>SAT is potentially useful as a means for tracking the progress of individual vehicles in freeway traffic for such purposes as traffic flow model validation, generation of origin-destination data and travel time estimation. Potential advantages are low cost in widespread deployment, simplicity and reliability of detection, minimal bandwidth and storage requirements for transmission of the signature vector, and reasonable identification ability without violation of privacy rights.

In Phase 1 work, completed in 1997, the effectiveness of the VSV for reliable detection and discrimination of vehicles was verified from field data. A 17 minute period of traffic flow was evaluated under moderate traffic conditions on Highway 101 in San Luis Obispo. Detectors were located above the number one lanes about 1800 feet apart. The system matched 81% of the vehicles correctly and yielded an average travel time which differed by 0.72% from the hand calculated values.

Limitations of the method were adequate ambient lighting was required for accurate detection, and image artifacts such as shadows could be problematic in a computer vision mechanization of the method. It was concluded that the problems associated with the exclusive use of ambient lighting are insurmountable, especially for system operation at

night or under conditions of harsh shadows. We have devised a high power pulsed VNIR illuminator which is activated upon detection of the vehicle (via ambient illumination) in the detection window. The IR power output of the illuminator is approximately 200 Watts during each 10 millisecond pulse (one pulse per vehicle). The net energy dissipation of this illuminator is small. The illuminator functions as a fill-flash (reducing shadows) during daylight operation, and as the primary source of illumination during night operation

The packaging and communication of the VSV from detection modules to the correlation computer was examined. The most cost effective means for detector/processor communications is socket-based Ethernet communications over wireless modems. We have used a commercial wireless Internet service provider in the San Luis Obispo Area, MetriCom Inc., which offers continuous 33 KB wireless network connectivity at a cost of \$30 per month per channel. We have fully implemented and tested the socket-based communications protocols over a hard-wire LAN.

***MOU 351 - Development of a Real-Time Laser-Based Detection System for Measurement of True Travel Time on the Highway***

Harry Cheng, University of California, Davis

The primary objective of this research project is to develop a non-intrusive detection system for measurement of true travel time of a platoon of vehicles. The key task in the measurement of true travel time is to acquire unique or semi-unique information on vehicles and then re-identify them downstream. Over the past year, the research team has continued their research in the development of a laser-based vehicle identification system which can obtain high-resolution reproducible site-independent delineations of vehicles.

Two prototypes have been developed: one prototype used inside the laboratory for software and algorithm development and the other for outdoor testing with vehicles. The indoor prototype has been modified for measurement of the vehicle length. A second laser and detector were added to the laboratory system allowing for velocity measurements and the calculation of vehicle length. In addition, the software was modified to support two detectors and to calculate vehicle length. The window comparator acts as a detector by producing a binary state based on the sensor signal in relation to two thresholds. Compensation for signal bias and threshold level calibration is performed automatically during system calibration. The effects of rapid detector transitions caused by noisy signals were reduced by using an envelope near the two threshold levels. The detector only changes states when the signal passes completely through the envelope near each threshold area.

Significant progress has been made in developing the full-scale outdoor prototype system. It now uses a multi-element photodiode array, instead of a single photodiode, in the receiving unit of the detection system. The photodiode array is the receiving sensor to be used for field applications. A sensor circuit for two elements of the array was created based on the previous circuit design for a single element. A new infrared laser, a

Powerspectra POS 850 diode laser, was purchased. The new laser gives a much higher quality laser line than the previous laser. During indoor testing of the outdoor prototype system, each of the 25 sensor elements of the array was tested to verify the size of the field of view and location of each element. By examining the testing data in detail, it was shown that the measured field of view of each element along the length of the laser line was approximately 5 inches. The laser line thickness and sensor field of view perpendicular to the laser line were both less than 1 inch in width at a distance of about 20 feet, which is in agreement with our theoretical calculation. The system has been tested outdoors under a variety of lighting conditions and has proven to work well during day and night. During outdoor testing, it was shown that the minimum detectable object height, is about 17 inches, slightly better than our desired value.

Currently, the research team is making a sensor circuit to accommodate four sensor elements. They are also planning to construct a second detection system, similar to the first one, so the velocity and length of a vehicle can be measured outdoors.

***MOU 347 - Use of Los Angeles Freeway Service Patrol Vehicles as Probe Vehicles***  
James Moore, University of Southern California

The objective of this research project is to translate probe vehicle data from Los Angeles Freeway Service Patrol (FSP) trucks into level of service (LOS) information, comparison of this approach to other sensing technologies, and combination of this data with loop detector information. The research focuses on empirically estimating the ambient speed of the freeway traffic based on FSP truck data from the Automatic Vehicle Locator (AVL) terminal connected to the CHP Computer Aided Dispatch (CAD) Level II console located in the Caltrans District 7 Transportation Management Center (TMC). The work determines whether probe information can be gathered in sufficient quality and quantity to measure level of service on the traffic network, and how this data might best be used to supplement the LOS information provided by single trap loop detectors. Operational, technical, and institutional constraints that might limit use of the Los Angeles FSP fleet as probe vehicles will be identified.

The first phase of the study focused on a comprehensive review of related research literature, interviews with FSP system operators, analysis of FSP operational statistics, and field observations of FSP trucks. The principal investigator and research assistants signed standard non-disclosure agreement with the software vendor for the CAD/AVL systems. In June 1997, Division level permission was received from CHP to access its CAD computer in the Los Angeles Communications Center (LACC) and the Caltrans District 7 TMC. This permission included Department of Justice background checks. However, this permission was withdrawn shortly afterwards. In June 1998, clearance was received from CHP Headquarters Office of Special Projects to access the AVL terminal connected to the CHP CAD terminal at Caltrans District 7 TMC. Personnel at Caltrans District 7 were very helpful in familiarizing the research assistants with the MODCOMP computer. The MODCOMP computer is used for generating and storing loop detector data for the Los Angeles freeway system.

The current research focuses on:

- simultaneous data collection from three sources - FSP data from AVL terminal, loop detector data from the MODCOMP computer, and other probe vehicle speed data;
- fusing historic (but recent) loop detector data and AVL data for improved level of service measures; and
- accounting for differences among loop detector outputs, FSP data from AVL log files, and outputs generated by other probe vehicles.

The FSP speed data available from the AVL terminal are not strict, real-time measures. Instead, the AVL provides pseudo-real time information on several aspects of the FSP truck's status, e.g., location, a confidence interval for speed, and working status. The polling frequency for the AVL system limits the feasibility of simultaneously estimating system-wide real time speeds for many probes.

### **3. Traffic Management Systems**

#### ***MOU 356 - Developing and Using Surveillance Data for Research***

Joy Dahlgren, PATH

This project will utilize video cameras mounted on a tall apartment building adjacent to the I-80 in Emeryville coupled with loop detectors on I-80 for a variety of PATH/Caltrans projects. There will be 12 fixed video cameras providing views of the entire freeway for over a mile in each direction. These video cameras will be connected to video tape recorders. There will also be 2 remotely controlled moveable video cameras, which will transmit data via modem to Caltrans District 4 headquarters and the Berkeley campus. The project will initially support development of machine vision methods for traffic surveillance, travel times forecasts, incident detection methods, methods for visualizing traffic conditions, vehicle matching methods, and analysis of the effects of changes in travel time on travel behavior. A library of video film will be generated, which will provide a wealth of material for future research into traffic dynamics and ITS strategies to maximize flow and increase safety. PATH researchers have been working with the building management, Caltrans, equipment vendors and fabricators to determine the equipment setup, get the necessary equipment fabricated, and negotiate an agreement for use of the building. It is expected that the project will be operational early in 1999. The initial agreement will be for one year.

#### ***MOU 354 - Incident Management: Process Analysis and Improvement***

Randolph Hall, University of Southern California

Incident management is important due to its direct effect in saving life, property and the environment and due to its indirect effect on the entire highway system, including

congestion and travel time. By responding to or clearing incidents more quickly, or maximizing the roadway capacity during incidents, both the economic cost of congestion and the associated aggravation are reduced. The result is more reliable travel, shorter trips, and an ability to accommodate more trips within the existing roadway infrastructure.

The objective of this study is to examine how technology can be used to improve the processes and procedures of incident management. The study is being completed in two parts. The first part (completed in 1998) has documented processes used in Los Angeles County, California, and identified opportunities for improvement. The second part will quantitatively evaluate the effect of new procedures and technologies on incident related delay.

Information was collected on the individual agencies through a combination of three methods:

- (1) Document Review: Incident procedure manuals, dispatching plans, Internet web pages and other documents were obtained and reviewed.
- (2) Interviews: A questionnaire was developed to obtain information on incident response procedures and technologies. Interviews were administered in person, usually on a one-on-one basis.
- (3) Observation: Ride-alongs were completed with CHP officers, FSP trucks, and Caltrans Maintenance to observe how incidents are handled, and to obtain further information through interviews. Additional observations were completed at the Caltrans District 7 TMC and CHP Southern Division's Communication Center.

Technologies available for incident management were also documented by contacting manufacturers and reviewing articles in transportation and policing publications.

As a general conclusion, efficient dispatching plays a critical role in effective incident management. This includes being able to dispatch the appropriate crew and equipment, having that appropriate crew and equipment available close to the incident scene, and being able to determine which crew can be dispatched most quickly to the scene. A high level of efficiency depends on having the resources to ensure sufficient staffing, and it depends on the dispatching process itself. The latter might be improved through improved assessment of the incident prior to dispatching crews, and improved awareness of crew locations, which might be achieved through vehicle tracking systems.

***MOU 358 - Implementation of Advanced Techniques for Automated Freeway Incident Detection***

Baher Abdulhai, PATH

This project extended existing freeway incident detection research conducted under both PATH and under the ATMS Testbed Research Program, by operationalizing its principal findings. The probabilistic neural network (PNN), was integrated into the UCI testbed for on-line operation on the testbed network in Southern California.

The PNN incident detection system was re-coded in Java, to facilitate network communications and platform-independent operation. A Java-based graphical user interface has been developed. The GUI components include a display of the PNN, the current input to the PNN, a sliding window display of the output (the computed incident probability.) and a sliding button to allow the user to specify the desired misclassification cost ratio. The GUI code is in the form of a Java Applet object and has a modular structure that makes it easier to incorporate possible future modifications and extensions. The PNN algorithm itself was then translated from C to Java as a stand alone application object and was interfaced to the GUI applet running on the same host. The GUI display is updated each time a new output is computed by the PNN. The PNN algorithm and the GUI display update run as separate threads of control in Java; this concurrency leads to better utilization of CPU resources. A new module for computing the principal component transformation was developed to replace the use of statistical packages for this transformation. This was needed for maximum portability and independence of the overall system. Another module for computing volume and occupancy Averages for different Times and Locations (ATLs) was also developed to prepare the ATLs from real freeway data. The PNN and GUI were tested and correct operation was confirmed with sample inputs from data files.

The whole package was interfaced to a remote C++ CORBA client program that acquires online Caltrans traffic data from a CORBA server in the Testbed. Communication modules were added to the CORBA client program as well as to the PNN to enable on-line volume and occupancy data from different freeway sections to be sent from the CORBA client to the PNN at a specific rate (once every 30s). The data are sent to the PNN using a reliable TCP/IP streams sockets connection. An on line retraining module was developed as well. This module enables the TMC operator to initiate retraining on recently captured incident data, on-line without disturbing the operation of the system.

The PNN was then operated on-line on a 5 mile section of the 405 freeway, for on-line monitoring and testing. The overall on-line operation of the PNN was demonstrated to Caltrans engineers from D12. Currently, efforts are in progress to expand the network coverage to enhance the odds of capturing incidents. On-line evaluation will be performed next.

#### **4. Traffic Modeling**

*MOU 208 - Effects of Highway Capacity Increases on Travel Behavior*

Joy Dahlgren, PATH

A possible impediment to the implementation of ITS or any other improvement that will increase highway capacity is the perception that increasing capacity is futile—use will simply increase to absorb the additional capacity, creating negative environmental effects in the process. The construction of the HOV lanes on Route 80 between the Carquinez and Bay bridges and the reconstruction of the Cypress connector between I-80 and I-880 promised to provide an opportunity to investigate the truth of this perception. PATH has acquired most of the volume, travel time, and vehicle occupancy data that Caltrans has collected in this corridor since 1991. PATH also collected data on the corridor. It is clear from an analysis of this data that 1) travel times and volumes are quite variable, and therefore a fairly large volume of data will be required to make valid comparisons between time periods; 2) large volumes of data are not routinely collected; and 3) most of the loop detectors on I-80 have not been connected to equipment that records flows. The loop detectors at the Emeryville site (see discussion of MOU 356 in previous section) will provide large volumes of data, which will allow development of frequency distributions of vehicle volumes by time of day during the congested periods. This will be used to assess the probabilities that the limited “before” data collected in 1994, before the freeway expansion began, is from the same distributions. Another component of this research will be a survey administered to travelers on the newly reconstructed Cypress connection. The connection should reduce their travel time substantially. The survey is designed to determine how much time they think the new connection has saved; the route by which they made their trip before the connection was rebuilt; how the connection has affected or will affect their decisions regarding when, how much, and where to travel; and if the connection is likely to affect their job or housing choices in the future. The survey is planned for Spring 1999.

***MOU 359 - Subjective Evaluation of ITS-Capable Microscopic Traffic Simulators with Case Study on Paramics***

Baher Abdulhai, PATH

In this research, a comprehensive list of requirements for a microscopic traffic flow simulator to successfully model ITS was compiled, then applied to Paramics, a promising microscopic traffic simulator. The subjective evaluation was then followed by a calibration/validation study to objectively evaluate the performance of Paramics.

The subjective evaluation template covered (1) supply/control aspects, (2) demand/behavior aspects, (3) environmental-related aspects, and (4) simulator-performance aspects. The template was applied to Paramics, version 1.5. The evaluation revealed Paramics' capabilities and limitations as an ITS modeling tool. It was concluded that Paramics is an excellent ‘shell’ or ‘framework’ for a comprehensive and extensive transportation simulation laboratory. Paramics offers two very important and unprecedented features: high performance and scalability. To our knowledge, this is the most promising approach to handle realistic real word traffic networks under ITS. Also, Paramics offers very plausible detailed modeling for many components of the envisioned ‘ideal’ simulator. Nevertheless, several limitations were also found. Improving such



limitations requires both direct modifications in the software itself, and maturation of the Application Programming Interface (API), offered by Paramics. The API is regarded to be the most important capability of the software. A truly comprehensive API would be the gateway for researchers to the heart of the software, without having to deal with the underlying proprietary code. The API should have a dual role: (1) to allow researchers to override the simulator's default models such as car following, lane changing, route choice models and the like, and (2) to allow them to interface complementary modules to the simulator. Complementary modules could be any ITS application such signal optimization, adaptive ramp metering, incident detection and management and any other important ITS application.

The second phase of the project involved calibration and validation of Paramics. The Irvine network was coded, an effort that included several field visits for refining the geometry of the network's model. Dynamic Origin/Destination data generated from an independent project (M. G. McNally, ITS, UCI) was reformatted and used to drive the simulator. Paramics was then calibrated on a small freeway section in Orange County. The objective was to test and modify the car following and lane use parameters, without errors from O/D inaccuracies associated with full networks. Both reaction time and average headway have been calibrated using real data from the Testbed. Validation results under different traffic levels were found encouraging compared to real data from the Testbed, matching with 6% mean error in lane by lane flows. The calibrated parameters were then applied to the whole Irvine networks. Simulation outputs were acceptably close to real data from throughout the network, matching within 20% mean error in detector counts. Headway distributions and flow-density curves from both the simulator and the real data also showed acceptable match.

### ***MOU 337 - Identification and Prioritization of Environmentally Beneficial Intelligent Transportation Technologies***

Daniel Sperling, University of California, Davis

Intelligent transportation technologies have long been promoted as a solution to the environmental impact of transport systems. While this is true to varying degrees for many technologies, the impact of intelligent transportation technologies on air quality and energy use is unclear. Perhaps the biggest hindrance to the widespread deployment of potentially beneficial technologies is the lack of knowledge regarding their actual environmental impact. Assessments of expected impacts have been made, but little work has been done to quantify the effect of transportation technologies on the environment.

Researchers from ITS-Davis and Claremont Graduate School have undertaken a detailed study of ITS and the air quality and energy impacts of various technologies. The objectives of the study are to develop analytical tools and evaluation methods for determining the likely energy and emissions impacts of a number of ITS technologies and then to apply those methods to rank technologies according to their environmental benefit based on results of simulated scenarios.

The team has undertaken an extensive review of literature related to speed-emission relationships, modal emission model development, quantitative and qualitative studies of ITS impacts, evaluation frameworks, modeling tools, and relevant policy and legislation.

A series of interviews and workshops were conducted to develop a set of scenarios for the modeling effort. To develop the scenarios, the research team used a Delphi method, which relied upon the knowledge and understanding of experts in the ITS field, to create a forecast of ITS deployment for a ten-year period. First, experts were interviewed in Washington, DC, and Los Angeles, CA, to gather expert opinions about the future of ITS technologies and market penetration. Not surprisingly, there were similarities and differences between the DC and California experts. The LA respondents highlighted three main technologies and their respective deployment rate: vehicle information systems (mostly low, i.e., less than 10 percent), electronic toll collection (approximately 30 percent of lanes), and advanced traffic signal coordination (between 50 to 100 percent by 2005).

In contrast, the DC experts commented on the same technologies, but they often had different reactions to deployment rates. There was agreement among the industry, government, and public-private partnership experts that advanced traffic signal coordination would be widely deployed and that en-route vehicle information services would have a low market penetration (i.e., less than 10 percent). The scenarios were designed to take account of legal and regulatory requirements, public sector support and market demand for ITS technologies, technology development, and transportation demand. CMS was described as an expensive and inefficient tool by industry. The public-private partnership experts predicted a 25 to 50 percent market penetration rate, while government experts estimated a 100 percent market penetration rate. Hence, there was a great difference in the perceived values of CMS by industry and government. Finally, industry experts expressed more interest in en-route traffic information; they predicted that there would be a 20 to 25 percent market penetration level for this service by the year 2005. Government experts agreed that these rates were reasonable, but they predicted a much lower usage rate (i.e., less than 10 percent). In contrast to both these groups, the public-private partnership experts predicted a very low market penetration to these technologies over the following two to seven years.

Second, the research team used the results of the expert interviews to develop the initial scenarios for the modeling exercise. Four scenarios were developed: 1) a status quo, 2) an industry-dominated, 3) a government-dominated, and 4) a public-private partnership approach. The scenarios provide a context for establishing deployment rates and user acceptance for various types of technologies that may surface over the next ten years. The DC workshop participants reviewed the initial scenarios in September 1997. Based on their input, the scenarios were revised and presented to the California experts in October 1997. Finally, all experts were sent the updated scenarios for review and comment. In November 1997, the final scenarios were compiled (i.e., market penetration estimates and contexts for deployment) for the INTEGRATION modeling effort. The final market penetration estimates by scenario world and technology follow for the Smart Corridor in Southern California for the year 2005:

<u>Scenarios</u>	<u>ETC</u>	<u>ATSC</u>	<u>Vehicle Information</u>	<u>Vehicle Navigation</u>
Status Quo	0	100%	25%, CMS: 100%	5%
Industry	20-25%	100%	30%, CMS: 50%	10%
Government	60%	100%	25%, CMS: 100%	2%
Public-Private Partnership	66%	100%	95%, CMS: 100%	15%

The INTEGRATION simulation model is being applied to assess the impact of advanced traffic signal coordination, electronic toll collection, en-route driver information, and vehicle navigation/route guidance systems on the Santa Monica SMART corridor network within the framework of various scenarios. Unfortunately it has been necessary to undertake this modeling effort in parallel with the development of the modeling tools. However, the capabilities of such tools are expanding and future work in this area will benefit from the results of this study. Results from this research will help planners forecast the environmental impacts of ITS technologies and direct ITS investments toward those technologies and products that are most benign.

***MOU 360 - Short Term Freeway Traffic Flow Prediction Using Genetically-Optimized Time-Delay-Based Neural Networks***

Baher Abdulhai, PATH

Proper prediction of traffic flow parameters is an essential component of any proactive traffic control system and one of the pillars of advanced management of dynamic traffic networks. In this research, we developed a new short-term traffic flow prediction system based on an advanced Time Delay Neural Network (TDNN) model, the structure of which is optimized using a Genetic Algorithm (GA). The model was developed and validated using both simulated and real traffic flow data obtained from the California Testbed in Orange County, California. The model predicts flow and occupancy values at a given freeway site based on contributions (inputs) from their recent temporal profiles as well the spatial contribution from neighboring sites. Both temporal and spatial effects were found essential for proper prediction.

An in-depth investigation of the variables pertinent to traffic flow prediction was conducted examining the extent of the “look-back” interval, the extent of prediction in the future, the extent of spatial contribution, the resolution of the input data, and their effects on prediction accuracy. Results obtained indicate that the prediction errors vary inversely with the extent of the spatial contribution, and that the inclusion of three loop stations in both directions of the subject station is sufficient for practical purposes. Also, the longer the extent of prediction, the more the predicted values tend toward the mean of the actual, for which case the optimal look-back interval also shortens. Interestingly, it

was found that coarser data resolution is better for *longer* extents of prediction. The implication is that the level of data aggregation/resolution should be comparable to the prediction horizon for best accuracy. The model performed acceptably using both simulated and real data. The model also showed potential to be superior to such other well-known neural network models as the Multi layer Feed-forward (MLF) when applied to the same problem.

## **5. Traveler Information Systems**

### ***MOU 339 - Travel Itinerary***

Ryuichi Kitamura, University of California, Davis

The Itinerary Planner was developed as a computer software package to assist travelers by proposing to them efficient itineraries, which maximize their utility. Its development was motivated by two factors. Firstly, since our movement (or travel) is restricted by the amount of available time and our travel speed, it is important that our travel be organized such that the time resource can be best utilized for us to engage in activities in an efficient manner. This becomes especially important when a traveler visits a number of places in a tour. Secondly, it is believed that the development of an efficient information system will aid the traveler in using public transit in a complex tour in which multiple locations are visited. The Travel Planner must be able to handle multi-locations and multi-modes.

The first version of the Planner Prototype came when MOU 228 was completed in December 1997. In this version, the Travel Planner designed a travel itinerary given the users' inputs on locations to visit, time of day constraints, duration constraints, and sequence of visit constraints. Unlike other existing trip planners, the Travel Planner was able to take more than one evaluation criteria into account. These evaluation criteria include minimizing travel time, travel cost, waiting time, number of transfers, etc. The Planner was also able to produce a multi-modal itinerary.

The first version had a number of notable weaknesses. Firstly, the activity locations that the user can choose from are geographically fixed and limited. Secondly, although the overall itinerary is selected with the consideration of more than one criteria, the algorithm that derives the shortest path between any two activity locations only considers travel time. And lastly, the user-interface needs to be improved as well.

These weaknesses led to continued development in MOU 339. In this version which was completed July 1998, the user is free to choose any locations within the study area either by entering addresses or clicking on the map. In addition, the algorithm that derives the shortest path between any two activity locations considers more than one evaluation criteria at a time. The user-interface was also enhanced; users can eliminate modes that they either do not have access to or dislike.

The novel features of the Planner lie in several aspects. Firstly, it is a multi-modal. Four types of modes are available: public transit (such as bus, subway), private automobile, walk and taxi. Secondly, the Planner takes trip planning as a multiple-criteria problem. Unlike existing trip planners which produce itineraries with single criterion (e.g., shortest travel time or lowest travel cost), the Planner produces itineraries that are best in the balance of multiple criteria including travel time, travel cost, parking cost, number of transfers and waiting time. Lastly, the Planner updates its parameters that represent the user's preferences towards trip attributes (e.g., travel time and travel cost) interactively. The Planner thus accounts for differences in preferences across individuals and learns to develop itineraries that are best suited to each individual user while taking into account their preferences.

***MOU 348 - Event-Based ATIS: Practical Implementation and Evaluation of Optimized Strategies***

R. Jayakrishnan, University of California, Irvine

This research project is developing a comprehensive ATIS evaluation framework. In the research, Changeable Message Sign (CMS) routing is the main concern and the routing scheme for event traffic has been implemented in the real world in the city of Anaheim. For on-line real time implementation of optimal routing strategies, faster algorithms to find optimal routing scheme is required. The main benefit from static assignments is that they are faster by orders of magnitude over the dynamic assignment algorithms which exists now. The disadvantage of the static assignment is that they do not capture network congestion dynamics very well due to the very simple link travel time functions used. This research attempt to coordinate static and dynamic assignments in such a way that the computational benefits are gained from the static assignment while the inaccuracies from the results are minimized.

In this research an ATIS evaluation framework is constructed based on dynamic simulation tool, DYNASMART. Using current evaluation framework with fixed compliance rate to CMS messages, off-line simulation for the Anaheim Arrowhead Pond Arena event was conducted as a preliminary test. The test showed that dynamic optimal routing is necessary and CMS messages should be well designed to achieve certain level of compliance resulting in optimal condition.

As a real world implementation, a new CMS message tested in off-line simulation was actually operated during event traffic hours. According to traffic data, it was observed that the new CMS message induced changes in traffic pattern. Rough estimation of compliance rate was 13%, which is higher than expectation. This field test showed that CMS routing can be used a useful tool for event traffic management.

## 6. Public Transportation Systems

### *MOU 280 - Efficient Transit Service Through the Application of ITS*

Maged Dessouky & Randolph Hall, University of Southern California

Intelligent Transportation Systems (ITS) have been investigated as a means to improve the quality of service for automobiles, trucks, buses and other modes. ITS also has the potential to reduce the cost of providing transportation services. In the transit industry, Global Positioning Systems (GPS), Mobile Data Terminals, and Electronic Fare Collection may enable providers to improve the efficiency and productivity of drivers and fleets. This would occur through the execution of real-time control strategies, performance monitoring systems and data collection to support service realignment.

With the use of real-time information and bus control, connectivity between origins and destinations may be improved while reducing passenger waiting times. This may enable the transit operator to maintain service levels with a reduced fleet size. This research evaluates the use of ITS technologies on real-time control of buses. A simulation model of a wide-area transit network is developed to evaluate various real-time control strategies with ITS versus those without ITS. Each bus in the transit network is controlled by some holding strategy when it arrives to a stop or checkpoint. The holding strategy depends on the nature of the stop (e.g., transit centers such as timed transfer stations or uncoordinated stops). To allow for different types of stops in the network, a different holding strategy is defined for each stop in the transit network.

Control strategies evaluated in the absence of bus tracking are (1) no hold (2) all hold and (3) hold for a fixed period of time. However, all three strategies suffer from the lack of accurate up to date information on different bus lines. The static and prefixed schedules do not allow for dynamic decision making by the dispatchers. As a result, the efficiency of the system may be lower using control strategies that do not make use of ITS. The advent of ITS technology for tracking the buses has changed the scenario. In light of the up to date information, more dynamic decision making is feasible.

Control strategies with ITS require forecasting bus and passenger arrival times. We have developed forecasting models of bus arrival and departure times under various scenarios. A sample control strategy using ITS is to hold a bus at a transit center if a connecting bus is forecasted to arrive within 5 minutes. We have also developed an ITS based control strategy that locally minimizes the total passenger waiting.

The control strategies are evaluated based on several performance metrics, including average passenger trip time, and average total passenger waiting time. We experimentally tested the different control strategies on several generic bus networks. Preliminary results show that the overall gain or loss of the system performance is determined by a tradeoff between the two delay components: time saving for transfer passengers because of holding and delay for on board or originating passengers at subsequent stop. The objective function based ITS control strategy tradeoffs these two parts of delay and attempts to achieve a global optimization.

Sensitivity analysis shows that there is no significant difference among the strategies when there is a small headway. The benefit is the most significant when the headway is large. Another interesting observation is that for all strategies except the all hold strategy, system performance gets worse when headway increases. It can be intuitively explained that for bus lines with high headway, a delay related to missing a connection is expected to be longer.

It is apparent that when the number of bus lines increases, the network gets more complicated. When the number of connecting bus lines increases, an all hold strategy becomes the worst performing strategy since it does not make sense to hold all the connecting bus lines for just one late bus. For a small number of connecting buses, a no hold strategy is the worst performing strategy since in this case it is beneficial to wait for all the buses to arrive. Again, the ITS based strategy attempts to balance the tradeoff between these two measures in determining the dispatching time.

In addition to the analysis of the control strategies on generic bus networks, we are currently in the process of evaluating the strategies on a portion of the Orange County bus network.

***MOU 274 - Bus Operations in Santa Clara County, Potential Uses of AVL, and Framework for Evaluating Control Strategies***

Ted Chira-Chavala, University of California, Berkeley

Performance, service quality, and operational characteristics of a transit system are typically influenced by a myriad of factors, some of which are localized. This research has two primary objectives:

1. To develop empirical information about the bus system in Santa Clara County for use as the input in determining how to best use automatic vehicle location (AVL) equipment to improve schedule adherence of buses and transit passenger information,
2. To develop an economic-based evaluation framework for assessing the benefits and cost-effectiveness of alternative improvement strategies.

Major contributing factors for late buses in Santa Clara County were traffic congestion (particularly near and within the downtown area), delays due to numerous traffic signals, unexpected passenger demand during peak hours, handicapped passengers, and driver behaviors. There were slack times up to about four minutes built into the timetables of most buses. Once buses were late by more than this margin, it was usually difficult to become on schedule again.

Buses with service headways of 10 minutes tended to exhibit amplification of lateness downstream, which often culminated in bunching. For service headways of 20-30

minutes, the lateness tended to be maintained throughout the route or amplified slightly downstream.

For buses with service headways of 10 minutes, two-thirds of passengers ignored the printed timetables and arrived at bus stops at random. As service headways became longer, the percent of people looking up bus timetables beforehand increased.

A survey of the county's bus riders revealed that all riders were highly enthusiastic about real-time displays of bus arrival times at bus stops, in addition to conventional bus timetables and route maps posted at bus stops and inside the bus. Regular riders valued the same information via telephone or personal computers less. Female riders valued in-vehicles announcements (upcoming bus stop, transfer stop, and departure time of connecting routes).

An evaluation framework for assessing the benefits and cost-effectiveness of alternative improvement strategies (with and without utilizing AVL) was developed. This framework is sufficiently generalized that it can be used by any transit agency anywhere.

### ***MOU 340 - San Gabriel Valley Smart Shuttle Technology Field Operational Test Evaluation***

Genevieve Giuliano & James Moore, University of Southern California

The San Gabriel Valley Smart Shuttle Technology (SGVSST) Field Operational Test began in January 1998 and is scheduled to run through June 1999. SGVSST is an outgrowth of Project ATHENA, a Field Operational Test initiated by the California Department of Transportation (Caltrans) and the City of Ontario. The purpose of SGVSST is to develop and test a technology system for "smart" demand-responsive public transit service. SGVSST builds on the ATHENA project by utilizing the previously developed system design and adapting it to the present FOT.

The SGVSST includes three cities and four transit operators as follows:

- City of Arcadia, general public dial-a-ride, operated under contract by San Gabriel Transit which already has GPS equipped vehicles and an automated dispatching system
- City of Monrovia, general public dial-a-ride, operated under contract by Dootson Enterprises
- City of Duarte, local fixed route service operated by the City
- Foothill Transit, the regional fixed route bus operator for the area. The routes involved are operated under contract by Laidlaw Transit.

The service concepts to be tested are as follows:



- Computer aided automated or semi-automated system for demand responsive service in Monrovia to replace a completely manual system
- Computer aided dispatch for route deviation on Foothill route 721 which connects the communities of Monrovia and Arcadia with the El Monte Metrolink station
- Use of coordinated dispatch to facilitate transfers between Monrovia, Arcadia and Foothill services (Duarte has no dispatcher)
- Provide all four transit agencies and the cities with monitoring information on vehicle position and status
- Facilitate real-time schedule adherence on Foothill route 187 by utilizing AVL in conjunction with variable service response strategies
- Provide enhanced report generation for Monrovia, Duarte and Foothill Transit.

The SGVSST is currently behind schedule, with partial deployment now scheduled for November and full deployment scheduled for January 1999. System requirements for each transit operator have been established, and equipment procurement has begun. Delays in procurement have been encountered, primarily due to contracting issues among the equipment providers, the technical contractor, and the project sponsors.

The major accomplishments of the evaluation team are described below.

Detailed evaluation plan: Development of the detailed evaluation plan was contingent upon the final specification of the FOT, including the technical and service objectives to be accomplished at each of the four project sites. The evaluation plan describes the process for evaluating the FOT in terms of technical feasibility and system performance, system integration, user acceptance, cost-effectiveness, and institutional issues.

First round of participant interviews: The first round of interviews identified roles and responsibilities of participants, elicited information on participants' understanding and commitment to the FOT, and gathered basic information on the history and operation of each transit service.

Documentation of all advisory group meetings: As part of the institutional analysis, the evaluation team attends all advisory group meetings to document the progress of the FOT, observe interactions among participants, and gauge the extent to which participants are actively involved in the FOT.

Baseline description of the four transit operations: Descriptions of the four transit operations are being prepared. Service characteristics vary greatly, and the performance objectives of the FOT are different at each site. The baseline descriptions give the "before" conditions that will serve as the basis of comparison for the evaluation. The level of detail of the baseline information varies. The most comprehensive data are being collected for Monrovia DAR, which will convert from a completely manual dispatching operation to an automated system. The impacts of the SGVSST should be most pronounced at Monrovia, and the evaluation will therefore concentrate on this system.

Description of the four project sites: The SGVSST is located in four different cities. A description of each city, providing basic population, demographic and geographic information has been prepared.

Project chronology: A chronology of the project is being prepared. The chronology will serve as a reference for the institutional analysis and overall assessment of the project.

### ***MOU 272 - Rideshare and Personalized Public Transit: Potential and Realization***

Jacob Tsao, PATH

This project studies the potential of carpooling among unrelated partners (i.e., inter-household carpooling) for demand reduction during peak commute hours. Basic questions about this potential include the following: 1) Can the current population density, origin-destination distribution, tolerable pick-up and drop-off delays, departure time distribution, and the tolerance for deviation from preferred departure time support a sizable carpooling population that can make a significant contribution to traffic demand reduction? 2) Can the proportion of long trips that are likely candidates for carpooling (e.g., those long trips with similar O-D) be so small that no significant traffic demand reduction could be expected from carpooling?

Although there has been much literature on carpooling and much investment in promoting carpooling, there is very little, if any, research into what the realistic potential of carpooling is for congestion relief. Nearly all the literature about the potential was motivated by the need to counter the national energy shortage in 1973-1974. As a result, the focus of those studies was the maximal potential as a measure of the nation's ability to counter national emergencies like the oil embargo and, therefore, they concluded carpooling has a very high potential.

The potential depends on many factors, some of which are more amenable to quantification than others. Our approach to assessing the potential is to separate such quantifiable factors from the rest, and then, based on these quantifiable factors, identify likely upper bounds for the potential. Coupling such upper bounds with models capturing other behavioral factors in commute-mode decision-making can produce more realistic estimates of the potential. This project focuses on a simplified urban sprawl in which the densities of workers and jobs are uniform over an infinitely large flat geographical area. For the numerical study, the job and worker data from the city of Los Angeles were used to approximate the worker/job density. An entropy optimization model that is equivalent to the well-known gravity model with a large zone size is used for trip distribution. This research assumed only commuters who live in a common zone and work in a common zone would consider carpooling.

Under the assumptions made in the project, carpooling among unrelated partners has little potential for demand reduction. Some researchers observed that recently carpooling has

become a family phenomenon involving mostly family or intra-household members. The findings of this paper could help explain this phenomenon.

***MOU 349 - Smart Carlink Behavioral Study***

Daniel Sperling & Susan Shaheen, University of California, Davis

The vast majority of trips in U.S. metropolitan regions are drive-alone car trips. This form of transportation is expensive and uses large amounts of land. A more efficient, but often less convenient, system would allow drivers to share cars. Car-sharing organizations are becoming common throughout Europe, the United Kingdom, and Canada. Shared-use vehicles offer a modal alternative that can make metropolitan regions more livable for the 75 percent of the U.S. population that now live in them.

The smart CarLink project addresses a shared-use application: smart station car rentals at rail transit. The project is exploring the use of smart communication and reservation technologies to reduce the inconvenience of car sharing, and identifying market segments where smart car sharing (what is called “smart CarLink”) would be attractive. The union of “smart” or intelligent communication and reservation technologies with shared-use cars will provide convenient and flexible accessibility, offering both short-term, automatic services and a diverse fleet of low-emission vehicles to meet the mobility needs of system users.

The three main evaluation components of the Phase I study include: 1) a review of relevant technical and institutional literature, 2) a longitudinal market survey of 200 households in the Bay Area, and 3) focus groups with some of the survey participants.

The objective of the longitudinal survey study is to understand user acceptance of this new form of transportation. Several types of informational material explaining the smart CarLink system will be examined, including: 1) a brochure/questionnaire; 2) a video/questionnaire; and 3) an interactive drive clinic with the Honda compressed natural gas vehicles, smart cards, and a smart key manager kiosk/questionnaire and a three-day travel diary.

This process allows participants time to reflect on their observations from the drive clinic and to answer questions about the CarLink concept within the context of their own actual travel. In this study, it is critical to develop an understanding of how CarLink could affect the travel of households.

In this study, focus groups are designed to provide a setting in which several people who have been through the drive clinic come together at a later date to explore larger visions of the CarLink system in the Bay Area. These images are built by the group through their discussion of their individual experiences through the market survey, namely the drive clinic, and subsequent reflection on these concepts. Through the process of building such images, participants reveal what they consider to be the essential features of these

systems. These features include the important design elements of the system (e.g., what types of cars are available, where they are available, how they are accessed, etc.).

## **7. Systems Integration**

### ***MOU 338 - California Systems Architecture Study***

Tom Horan, Claremont Graduate University

The National ITS Architecture, first published in 1996, is a conceptual and technical framework for developing integrated transportation systems. Yet, essentially all of the decisions about how to develop and implement ITS are left to sub-national levels of government – particularly individual states and local agencies – as well as private companies in the ITS marketplace. As a leader in the development and testing of ITS products and projects, California is well-positioned to take a leadership role in defining how the National Architecture can best guide the implementation of ITS across the state. This study looks at the challenges to developing a California Architecture and, more generally, to effective ITS deployment statewide. The analysis is conducted from three vantage points, corresponding to the three layers of the National Architecture: (1) Standards, (2) System Management, and (3) Policy.

Two objectives for the Architecture are suggested. The first objective is to implement efficient networks, and the second is to facilitate near-term ITS deployment. The first is predicated on the idea that the role of ITS is to help manage existing transportation systems more efficiently. The second objective argues that the Architecture must emphasize near-term deployment of ITS products and projects. The two objectives are not mutually exclusive. Together, the message is to implement efficient networks as ITS technologies are deployed – “Architecture for Action.”

The strategy for achieving these objectives also takes two forms. First, the overriding strategic recommendation is that implementing efficient networks and facilitating near-term deployment must occur from the bottom up. From a standards perspective, this strategy means that standardization should begin at the interface level. From a system management perspective, the implication is that systems must be integrated at local levels first, and built up from there to the regional and state levels. From a policy perspective, a bottom-up strategy means that deployment and the development of the Architecture must begin with local and regional policymakers and implementors. Secondly, there is a need for a more service-oriented public sector, whose role is to provide ITS information, education and training. From the standards, system-management, and policy perspectives, this strategy would have the public sector take a strong role in facilitating rather than directing ITS deployments across the state.

A series of recommendations were developed in coordination with the objectives outlined above. These recommendations represent the research team’s attempts to construct a

longer-term, system-wide strategy for facilitating near-term deployment. Flowing out of this strategy, the specific recommendations for standards, system management and policy are listed below.

#### Standards Recommendations

- Develop a State Interoperability Plan
- Maintain Leadership Position in National ITS Architecture
- Deploy Standards Incrementally & Capitalize on Standards Testing

#### System Management Recommendations

- Develop Model Interagency Agreements and Policies
- Implement a ‘Client/Server’ Model, With ITS as Mechanism

#### Policy Recommendations

- Emphasize Regional and Local Level Coordination
- Adopt a Public Sector Service-Orientation
- Use A Stratified, Market-Driven Approach to Forming Public-Private Partnerships

### ***MOU 273 - The ISTE/ITS Connection in California: The State of the Relationship and Opportunities for Productive and Beneficial Linkages***

Mark Miller, PATH

At the time of this project, ISTE/ had been law for six years and was undergoing initial reauthorization review. The objective of this research was to (1) investigate the then current state of California’s implementation of ISTE/ with respect to ITS, (2) assess the extent to which ITS had been integrated within the State’s transportation planning process, and (3) recommend opportunities for linkages between ISTE/ and ITS that had not yet been recognized.

Initially a literature search was conducted which studied ISTE/’s key features, specific ITS-related issues, the institutional environment, and the specifics of ISTE/’s implementation in California. Next, a survey was developed and implemented through interviews of transportation professionals with first hand knowledge and experience implementing ISTE/. The interviewees represented the public and private sectors, from Northern and Southern California, representing local and regional interests as well as statewide interests, and from the operations and planning perspectives.

The survey provided information in the areas of (1) knowledge and experience with ISTE/, (2) knowledge and familiarity with ITS, (3) ISTE/’s support for ITS implementation, (4) achieving ISTE/ objectives via ITS, (5) impacts of inter-jurisdictional relationships on ITS implementation, and (6) reauthorization of ISTE/ and associated opportunities for ITS implementation.

The survey results indicate that the regional planning process provides tools, e.g. Major Investment Study (MIS), that support ITS implementation. Local agencies view such tools as potentially very useful for transportation planning alternative assessment. Currently there are no Federal guidelines within ISTEA on how to implement a MIS. Some general high-level guidelines would be helpful for the local and regional transportation planners to use in their studies of transportation alternatives.

Local and regional transportation officials also look for ways to improve their ITS knowledge. Participants in ITS project implementation have different educational backgrounds and professional experiences among the professional staffs at transportation-related organizations. Education can play a role to help level the playing field.

Outreach to the general public and to elected officials is still at a fairly rudimentary level. Consequently, local jurisdictions are not inclined to become as actively involved as they could be in ITS planning. Outreach approaches specific to the transportation needs of local and regional communities could achieve better results than a more generic approach. The local and regional agencies tend to focus on issues affecting their own region more than on statewide issues. Continuing efforts at benefit documentation will provide information to make outreach more effective.

Intermodalism is one of the major elements of ISTEA yet it is not a well-defined concept. Work is needed to identify and to conduct research in this area to link it more effectively with the ITS arena, and move toward the implementation phase.

The weakest area in terms of knowledge and familiarity with ISTEA is its effect on land use and economic factors. This area generally falls outside the knowledge and experience base of the respondents. The linkage between land use and transportation is considered important but is controversial. The whole area of ITS and land use/economic factors is a fairly untapped and potentially rich resource for research and application of ITS.

The connection between ITS and air quality improvement has not yet been fully realized. Air quality improvement tends to be viewed as an indirect benefit of ITS applications. There is concern over linkage between ITS and air quality because most deployments of ITS are more locally oriented and air quality issues need more of a regional approach in the search of solutions. When ITS is perceived and implemented regionally and consistently across local jurisdictions, then air quality improvements may be more effectively evaluated and demonstrated.

While applications of advanced technologies in the public transportation arena generally play an active role in ITS, they have not played such a fundamental role in California's implementation of ITS projects. An application of ITS to the transit field offers an opportunity to explore the potential for addressing congestion, safety, and air quality problems and documenting the benefits for transit attributable to ITS.

There is a desire and need for consistency and continuity in federal ITS policies and programs. Local and regional agencies are concerned with consistency in the focus and overall implementation of federal ITS policies and plans. ITS is a relatively new experience for local and regional agencies and it requires both time and commitment to become fully oriented. Thus, federal ITS policies and programs are crucial to the success of ITS implementation at the local and regional level.

Local and regional transportation agencies see value in and a need to develop deployment strategies and plans for ITS. With a concerted effort at ITS deployment in the State, a lot may be learned from actual situations. Requests for ITS deployment may be met at the federal and State levels with assistance and guidance in carefully chosen deployable projects. Moreover, examples of ITS deployment will assist local agencies in understanding ITS. State leadership is to be encouraged, especially in standards development and in providing assistance to the local and regional areas. The State should encourage rural regions in their pursuit of ITS by offering better education, technical and coordination assistance. Continued State leadership, as well as cooperation among state, regional, and local stakeholders, will contribute toward the realization of ITS benefits.

### ***MOU 226 - Intermodal Transportation Management Centers***

Randolph Hall, University of Southern California

Intermodal transportation entails the coordinated movement of different types of transportation (rail, truck, automobile, etc.) to serve the needs of travelers and shippers. Most transportation organizations today have developed a "command and control" structure for coordinating their operations.

Command and control is typically executed through a center that serves as the focal point for regulating the movement of vehicles, assigning employees to tasks, interfacing with customers, and collecting data on the state of the system. The center usually provides links for communicating data and voice, computers for processing data, and displays that provide center operators with decision support aids and "situational awareness." The center is configured in a manner that supports the distinct responsibilities of each operator (usually defined by a geographic area or function), and also provides for communication between operators where coordination is needed. This is the predominant model for a "modal" management system -- a system for managing the operations of a single mode.

Caltrans' Advanced Transportation Systems Program Plan envisions Transportation Management Centers as the nerve centers for integrating new technologies, but states "Additional effort is needed to determine the best way to integrate a greater scope of advanced intermodal functions into TMC operations. This has even greater priority as TMC activities extend to coordination of more functions, modes and agencies, through a mix of computer automation and operator involvement." (Caltrans, 1997).

The purpose of this study was to provide a vision for California's intermodal systems of the future. An intermodal management system could, conceivably, establish a center (or centers) that is responsible for the joint operation of multiple modes of transportation. This is not the preferred vision of the research team. Instead, the researchers envision these systems will retain their current organizational and modal identities in the future. However, systems will be developed to provide interconnections when benefits are significant, examples of which follow:

- Minimize delays at city boundaries, where traffic control systems must be interfaced
- Maximize capacity within a corridor of roadways, especially in the event of incidents
- Reduce the time required to clear incidents and restore capacity, while ensuring safety
- Make quality information available to travelers and fleets to optimize their travel and goods movement decisions

It is also envisioned that the operational functions of transportation management centers will become interconnected with the planning and regulatory functions, so that operational data can be applied to the design of transportation infrastructure and deployment of resources. This would include the existing Intermodal Transportation Management System (ITMS).

## **8. Benefit/Cost Analysis and Evaluations**

### ***MOU 355 - ITS Evaluation Website***

Joy Dahlgren, PATH

LEAP - Learning from Evaluation and Analysis of Performance - is a web site ([www.path.berkeley.edu/~leap](http://www.path.berkeley.edu/~leap)) designed to support decisions regarding ITS implementation and research by making information about the performance of intelligent transportation systems more accessible. It analyzes and summarizes what has been learned from field operational tests, other research, and implementation. The information is organized to suit a range of users. For the policy maker, there are summary-level descriptions of the technology, operation, and status of the primary ITS services. For the local public works engineer or planner, there is more detailed information on specific project evaluations and research summaries. For those seeking even greater detail, references and links to additional on- and off-line resources are provided.

The particular information that is provided about each ITS user service varies, depending on what is available and, more importantly, the state of the practice. Performance measures are more readily available for mature systems, such as electronic toll collection, than for technologies that are still being tested, such as automatic incident detection using video cameras. Information about *measured* benefits and implementation costs is emphasized, and because each ITS application is unique, additional information on the context of each application is also provided when available. For example, in discussing



the performance of electronic toll collection systems, data describing the mix of modes and the traffic volumes at the toll plaza are presented. Barriers to implementation of a given service are noted whenever identified. The quality of evaluations is examined and sources of uncertainty in the data or methodologies are noted. For less mature user services or those that have not yet been implemented, research results are presented. Gaps in the research are discussed.

The information comes from published sources: project evaluation reports, research reports, journals, and conference proceedings. The gathering of information is a continuous process. The site is updated as significant publications become available. In this respect the web site provides a great advantage over published hard copy. It can be kept continually current, whereas hard copy can not be updated every time there is a small revision. Eleven students have contributed to the project in its three-year life. This past year has been particularly productive, and the site now includes information on almost all ITS user services. We plan to actively publicize the web site this fall by establishing links to the major search engines and transportation-related web sites, sending press releases to ITS and transportation publications, and distributing brochures at conferences.

Future plans include enhancing the site by seeking out unpublished material and adding analytical tools to the web site. Addition of a decision analysis module is planned for this year. There is hope to incorporate or provide a link to the benefit/cost guide being developed by PATH (MOU 357).

### ***MOU 357 - Benefits and Costs of ITS***

David Gillen, Jianling Li, & David Levinson, PATH

Research under MOU 205 has focused on developing comprehensive performance measures for the transportation system, identifying data sources for the performance measures, building a website for the ITS cost benefit database, and developing an evaluation framework for assessing and evaluating the costs and benefits of the Intelligent Transportation Systems (ITS) applications.

Under MOU357, the emphasis has been on developing some decision analysis tools for ITS. The original focus was on Benefit-Cost Analysis, but this has been expanded to include cost effectiveness and impact analysis. Two fundamental questions were being asked; is ITS sufficiently different from conventional transportation investment projects that it requires a new decision analysis methodology and, secondly what decision analysis framework should be used in which circumstance, and how is it implemented? Our answer to the first question is, no, a new framework is not required, but what does distinguish ITS projects is the need for modeling to forecast the benefits (and costs in some instances) due to the lack of historical information. In effect, ITS evaluation is modeling intensive rather than purely information intensive. The answer to the second question is that Benefit-Cost Analysis and Cost Effectiveness Analysis are the two decision frameworks most appropriate to ITS evaluation. The key reason is that ITS is fundamentally designed to increase the productivity of existing capacity, not to add

capacity. Hence the impact of the new capacity would have been capitalized with the building of the initial capacity.

A draft report has been submitted presenting the alternative evaluation methodologies for ITS projects. In June 1998, a draft document that contained a simplified and summarized discussion of the evaluation methodologies and an application of the methodologies to Electronic Toll Collection was submitted for review to Caltrans. The intent in any subsequent revisions was to develop a manual that was user friendly for transportation professionals who had no formal training in decision analysis.

Currently the project is proceeding along a number of paths. First, the researchers are undertaking a computerization of the evaluation framework based on the work completed for the ETC assessment. The model is spreadsheet based with an emphasis on ease of use. It will be complementary to other work being undertaken in Caltrans' Transportation Planning Program. Secondly, evaluations of ITS applications of selected projects are proceeding. These include; a) freeway service patrol, b) ramp metering and c) to the extent the data are available, signal synchronization. A major objective in developing a methodological framework for analysis is to provide the transportation community with a generic analytical tool for assessing and valuing the costs and benefits of the ITS implementations as well as for providing a framework for integrating the costs and benefits of the ITS alternatives for future developments. To facilitate the objective, it is necessary to show the application of the methodology in specific cases. Furthermore, the evaluations will identify the breadth of information required in order to have a more generic evaluation tool.

***MOU 278 - Is There A Case For Public Investment In Telecommuting? The Cost/Benefit Analysis***

Patricia Mohktarian, University of California, Davis

The objectives of this project are to assess the costs and benefits of home-based telecommuting, to develop a suitable framework for the future economic analysis of Telecommuting, and to offer policy guidance on the conditions under which benefits may be optimized

A conceptual framework by which cost-benefit analyses of telecommuting should be conducted was developed. The framework included identifying the scale, perspective, and scope of the study, and establishing the base case conditions. The importance of selecting an appropriate discounting method was noted, as well as the importance of sensitivity analysis around key unknown parameters, such as assumed growth in the number of telecommuters and future discount rates. This is particularly important when critical factors are assumed and not based on empirical work. This project also critiqued four specific macro-scale economic evaluations of telecommuting. While these studies commonly used spreadsheet models with macro-scale estimates to estimate the potential benefits of telecommuting, they typically failed to account for most costs as well as to fully monetize most results.

The project assessed four small-scale economic evaluations of telecommuting, representing the state of practice with regard to methodology and assumptions. The researchers addressed the limitations and major findings of these works. This review identified common inputs and discussed the critical assumptions that routinely affect the results. The major findings were presented and compared to each other and to claims found in promotional literature. Among the primary findings is the conclusion that few pilot evaluations contained cost-benefit results. Importantly, however, these reports furnish empirical values that can be used in developing cost-benefit analysis estimates.

This project resulted in a Master's thesis that evaluated the costs and benefits of home-based telecommuting. Combining empirical data from the literature with a Monte Carlo simulation technique, a distribution of cost-benefit ratios is produced from several perspectives: the employer's, the telecommuter's, and the public sector's. This study allows the quantification of many of the uncertainties associated with telecommuting, such as air quality benefits or productivity benefits, by simulating a distribution of possible benefit-cost ratios for each perspective.

The results indicate that for the telecommuter, benefits can generally be high, depending on whether or not the employer bears the majority of the equipment cost burden. If the telecommuter is required to purchase new equipment (i.e. a computer and software) and if the foregone travel distance is small, it is possible for the telecommuter to yield benefit-cost ratios less than one -- the "break-even" point.

For the employer, the cost-effectiveness of telecommuting is dependent largely on productivity benefits. Still, employers need to experience only a small gain in total productivity to balance the costs. Even when parking and office space benefits are included, productivity lies at the center of the telecommuting cost-benefit analysis from the employer's perspective, and in almost all cases, the employer relies on some assumed productivity as the primary benefit.

Lastly, it was concluded that public sector air quality and infrastructure construction benefits remain somewhat questionable and difficult to justify based on current knowledge. The only plausible scenario where these benefits become significant is when telecommuting is concentrated 1) over a small, localized area (such as along a single transportation corridor) or 2) within a single non-attainment air quality basin where the collective air quality benefits can be used toward meeting attainment goals. Still, given these conditions, the measurable public sector benefits are negligible because benefits are countered by reduced fuel tax revenues.

***MOU 279 - Beyond Telecommuting: The Travel/Communications Impacts of Advanced Telecommunications Services***

Patricia Mohktarian, University of California, Davis

The objectives of this project are to examine the behavioral impacts of telecommunications-based information/transaction services, and to review various types of traveler information systems, and examine policy issues relevant to the adoption and travel impacts of these systems

This project resulted in a Master's thesis which examined the interactions among different forms of communication (including travel as one such form), using data from 148 respondents completing an Activity Diary on 636 of their uses of the Davis Community Network. Generation, elimination, modification, and no impact were the four types of potential results of each DCN communication, in any of five potential communication types or modes: in-person, physical object, electronic, in-person with travel, and physical object with travel. The predominant impact of DCN appeared to be neutral (no impact on future communication), and the next strongest impact appeared to be the generation of further electronic communication. Some substitution of travel was also seen, but that effect was relatively small and was outweighed by increases in electronic communication.

The project analyzed data from “before” and “after” Communications/Travel logs completed by 91 respondents in the same DCN study. Temporal relationships among numbers of communication activities in each of six modes (phone, fax, e-mail, physical object, personal meetings, and trips) were examined through structural equations modeling. The predominant effects identified were net generation of communication activities over time, and complementarity rather than substitution across modes.

### ***RTA 65V389 & 65A0006 - TravInfo Evaluation***

Youngbin Yim and Mark Miller, PATH

TravInfo is a Field Operational Test (FOT) of advanced traveler information systems (ATIS) for the San Francisco Bay Area, sponsored by the Federal Highway Administration (FHWA) and Caltrans. The project involves a public/private partnership which seeks to compile, integrate and broadly disseminate timely and accurate multi-modal traveler information through commercial products and services. TravInfo began operations in September 1996 and operated as an FOT through September 1998.

This past year the evaluation has focused on the Traveler Information Center (TIC), the central information acquisition, processing, and dissemination hub for TravInfo. The evaluation team studied the TIC usage, reliability, and impact on traveler behavior.

The researchers examined the TIC data access on the part of both the public and private sectors. With the exception of the month of September 1997 during the Bay Area Rapid Transit (BART) strike, and an initial surge in call volume at the start-up of TravInfo, from September 1996 through December 1997 call volume to the Traveler Advisory Telephone System (TATS) has remained fairly constant at between 50,000 and 60,000 calls per month. The region with the highest call volume was Oakland (monthly average: 46,159) followed by San Francisco (monthly average: 6,236), San Jose (2,799) and Santa

Rosa (570). The advertising campaign from January to March 1997 had only minor effects on overall call volume. It should also be noted that the overall call volume is anomalously skewed upwards because one of the major transit service providers of the San Francisco Bay Area, AC Transit (Oakland area), uses the TATS number as its only number for customers. AC Transit alone contributes on the order of 55% of the overall call volume throughout the reporting period.

The BART strike that occurred in September 1997, had a significant effect on overall call volume during that month. Overall, however, the BART strike did not have any lasting effect on overall TATS call volume. The overall call volume went from 57,730 in August to 196,606 during September and then returned to its normal level of 56,589 in October. The BART strike mostly had an effect on Transit call volume data. Most of the increase in transit calls was attributable to calls for the AC Transit system, which uses the TravInfo hotline as its main telephone line for customers. The strike had only a fairly minor effect on traffic call volume. Typically, traffic call volume is on the order of 1,500 to 2,000 calls per week for the whole TATS system. When the strike was in full swing, traffic call volume doubled to 3,915. By the following week, traffic call volume was back to normal at 1,765. Part of the reason the BART strike had so much effect on transit and little effect on traffic is that during the strike most media outlets (primarily television stations) mentioned the TravInfo telephone number but described it as a transit hotline.

A survey of the TATS users showed that they are satisfied with the service. The effect on their travel behavior, especially on departure time and route modification, is fairly significant. Nearly half of the TATS traffic information callers changed their travel behavior compared to 15% of radio traffic report listeners. In the context of the Bay Area network performance, TATS does not appear to have made a significant impact, mainly because of the relatively small number of calls for traffic information.

TATS system capacity use, assessed by measuring access to the publicly available voice ports, is very low. On average, for the Oakland region which is the busiest regional system, from September 1996 through December 1997, with the exception of the period during and immediately after the BART strike in September 1997, approximately 3% of the TATS system capacity was utilized. System capacity use was significantly lower for the other three regional systems. Port utilization did reach a maximum of approximately 25% and 75% in the Oakland region during the AM and PM peak periods of the first two days of the strike, respectively.

Private sector access of the data, via the Landline Data System, has also been quite limited. From November 1996 to December 1997, 25 of the 40 registered participants (62%) downloaded data at one point or another, mostly in small amounts. Only three ISPs downloaded data on a continuous basis during the period of November 1996 through December 1997, one of which downloaded approximately 90% of all data during the reporting period. Four ISPs downloaded data continuously during the shorter period of July through December 1997.

The evaluation investigated the human element of the TIC by considering the role of the operator in the flow of information through the TIC. The operator's role in the flow of information through the TIC is crucial both in terms of data entry and data interpretation and prioritization. All the data sources, aside from the Freeway Service Patrol (FSP) and in part the loop sensors, are manual thus reinforcing the importance of the operator in the flow of information through the TIC. The two most time-consuming data sources are the CAD and the airborne reports which respectively take up approximately 57% and 26% of all operator time. System and design problems have slowed down the speed of operator response to events to some extent. The greatest potential processing-time choke-point in the flow of information through the TIC is the CAD.

The evaluation examined system failures, including their initial symptoms, causes, severity, and location. During the period of January-June 1997, eighty-nine percent of the problems encountered at the TIC occurred in the main data processing software (TransView). Problems were primarily either major or critical in severity, not minor. Although independent of the functioning of the TIC, it should also be mentioned that there have been repeated problems in data acquisition, namely with the California Highway Patrol Computer Aided Dispatch (CAD) system functioning properly and more serious problems with the quality of the TOS freeway loop data. During the period between July and December 1997, there were thirty-eight new or non-recurring internal problems experienced at the TIC. The problems experienced were quite different than those experienced during the reporting period of January through June 1997. During this reporting period (July - December 1997), only non-recurring problems were documented at the TIC and made available to the evaluation team. Because of the unavailability of documented TIC Problem Reports for recurring problems from July to December 1997, system reliability cannot be analyzed in a complete and consistent fashion throughout the FOT period and, in particular, precludes a valid comparison of the results of this section with the results for the January - June 1997 time period. For the July - December 1997 time period, however, the number of problems located within the acquisition, processing, and dissemination subsystems are 21%, 73.7%, 5.3%, respectively. Of these problems, the number of problems classified as critical, major, and minor are 39.5%, 44.7%, 15.8%, respectively.

#### ***RTA 65V313 Task 4 - Anaheim Field Operational Test Evaluation; Institutional Analysis***

Mike McNally, University of California, Irvine

A systematic evaluation of the performance and effectiveness of a Field Operational Test (FOT) of a Advanced Traffic Control System was conducted from fall 1994 through spring 1998 in the City of Anaheim, California by a consortium consisting of the City, the

California Department of Transportation, and Odetics, Inc. The FOT was cost-share funded by the Federal Highway Administration as part of the Intelligent Vehicle Highway System Field Operational Test Program. The FOT involves an integrated

Advanced Transportation Management System which extends the capabilities of existing arterial traffic management systems in the City. The evaluation entailed a technical performance assessment and a comprehensive institutional analysis. The arterial traffic control systems planned for implementation, 1.5GC and SCOOT, respectively represented a partial automation of existing UTCS (Urban Traffic Control System) control and the separate installation of an adaptive traffic control system as an independent control option. This system, SCOOT, has been installed and evaluated in numerous international locations, thus, the key evaluation issues involve its limited (sub-standard) implementation utilizing existing traffic detection, the development of operational policies for SCOOT operation, and the resultant operational effectiveness for defined scenarios (particularly for special events).

A series of comprehensive interviews of key project participants was conducted to closely examine the phases of project implementation and operations, and the assessment of project maintainability and transferability. Overall, the assessment of the implementation and operational phases can be summarized via three cross-cutting institutional issues: project management, the contractual process, and technical limitations. Most participants agreed that a breakdown in project management in the implementation phase was a critical and potentially fatal stumbling block, almost preventing the implementation of SCOOT and partially compromising the technical evaluation. This management problem was closely tied to contractual problems involving the City and the SCOOT provider, a foreign firm. These management and contractual problems, in part, precipitated technical problems due to compressed implementation and evaluation periods, constraints in project communications when the provider was off-site, and what was deemed as inadequate training which lead to operational limitations.

Despite these institutional constraints, two of the three technologies were implemented (1.5GC never performed as proposed). SCOOT is installed and in limited use in the study area six months after the evaluation, with plans to extend the system despite inconclusive results regarding performance of the limited installation. An improved version of the VTDS is being utilized by the City in construction areas, despite limited technical performance reviews of the prototype system evaluated (see discussion in the next section). The emerging technical performance together with the institutional lessons learned suggest that there is potential for transferability, although unique aspects of the FOT may be constraints. Finally, the City notes potential barriers to maintainability given the added costs of control system hardware and software upgrades, training, and maintenance.

***RTA 65V313 Task 4 - Anaheim Field Operational Test Evaluation; Video Detection***  
Arthur MacCarley, Cal Poly San Luis Obispo

A technical evaluation of a video-based vehicle detection system for activation of traffic signals at intersections was conducted as a subtask of the “City of Anaheim Advanced Traffic Control System Field Operational Test (FOT)”. This system, referred to as the

Vantage VTDS, was developed and is currently marketed by Odetics Inc. as a low-cost replacement for inductive loop detectors. It utilizes video cameras mounted on existing luminaires with a view of the approaches at an intersection. The cost for all equipment for a four-approach intersection is quoted by the manufacturer to be \$15,000, not including installation costs.

During the course of the FOT, the product line was split from the originally proposed general-purpose detection system into separate freeway monitoring and intersection signal actuation products. Only the intersection product was evaluated under this FOT. The sample VTDS unit provided by the manufacturer for evaluation was a November 1996 release of the commercial product.

The VTDS detects the presence of vehicles in “virtual detection windows” which are established in the video image during the setup procedure, duplicating the function and location of inductive loop detectors. Setup and calibration of the system in the field requires only a standard TV monitor and serial PC mouse. The user interface for the VTDS was found to be unsophisticated but effective. Two useful features are the storage of up to four detection window setup configurations, and the option for remote setup and calibration via a serial port connection.

The evaluation focused on the detection performance of the system with respect to the intended application – the detection of vehicles on intersection approaches for signal actuation purposes. Test metrics and Measures of Effectiveness (MOEs) were developed for this purpose. Deployment specifications restricted our field tests to three signalized intersections at which detection cameras were set up and operated by the manufacturer. Video-taped field data was acquired from these intersection camera feeds, accessible at the manufacturer’s facility. A 12-condition video test suite, which represented a typical range of testable traffic and environmental conditions, was assembled from this data, and from video tapes provided by the manufacturer from installations in Texas and Delaware. Documentation was provided by the manufacturer on system operation and setup. Evaluation personnel received training at the manufacturer’s facility on the proper setup and operation of the system, and all tests were performed in compliance with these directions.

65% of all vehicles flowing through detection windows at the intersections were detected correctly, just as they would be detected by a properly working inductive loop detector. 80.9% of all vehicles flowing through detection windows were detected adequately for purposes of proper actuation of the signal phases. An average false detection rate of 8.3% was observed. Relative to all metrics, the general accuracy of the system appeared to be good under ideal lighting and light traffic conditions, but degraded at higher levels of service and conditions of transverse lighting, low light, night, and rain. We noted problems in robustly handling low vehicle-to-pavement contrast, scene artifacts such as headlight reflections and transient shadows, and electronic image artifacts such as vertical smear, which is typical of CCD (charge coupled device) video cameras.



Following their pre-release review of this report, Odetics announced that since the completion of this evaluation, they have observed findings similar to ours in their internal test program, and that both the hardware and software of the VTDS have been subsequently replaced, resulting in significant performance improvements. We have not tested this new system.

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