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PATH ATMIS State of the Research Annual Report Fiscal Year 1998 / 1999

Robert Tam

**California PATH Working Paper
UCB-ITS-PWP-99-15**

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**PATH ATMIS
State of the Research
Annual Report
Fiscal Year 1998 / 1999**

**Robert Tam
University of California,
PATH**

October 4, 1999

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1. Introduction

This report summarizes PATH ATMIS and Systems research for fiscal year 1998/1999. 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 in the end of the report 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**
- **Traveler Information Systems**
- **Public Transportation Systems**
- **Decision Support**

2. Surveillance Systems

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

Michael Cassidy, University of California, Berkeley

The goal of this project is to produce an inexpensive, automated vehicle reidentification algorithm for consecutive detector stations on a freeway, whereby a vehicle measurement made at a downstream detector station is matched with the vehicle's corresponding measurement at an upstream station. The current implementation uses effective vehicle length measured at paired loop detector speed traps. In conventional operation, these detectors only monitor traffic conditions over the loops, leaving most of the freeway unmonitored. By taking the difference in known arrival times for a matched vehicle, it is possible to measure true link travel time and thus, quantify conditions between detector stations. This approach is significant because no one has attempted to use the existing detector infrastructure to match vehicle measurements between detector stations. Thus, with the new algorithm, it is possible to evaluate applications of travel time data without deploying new hardware. The work is also transferable to other detectors capable of extracting a vehicle signature, such as video image processing.

Work during the past year has shifted from proof of feasibility to proof of deployability. The vehicle reidentification algorithms have been converted to real time versions, i.e., they are now compatible with continuous, live data streams. Unfortunately, the existing

communications infrastructure in Caltrans District 4 can not support the 60 Hz data used in this work. We have developed a new communications protocol for the Metricom wireless modems that Caltrans is deploying for conventional detector stations. The new protocol has been deployed for two detector stations along I-80 and the stations are feeding the high resolution data to the U.C. Berkeley campus. We are now making final adjustments to the communications system and anticipate having the real time travel time measurement system on line shortly.

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

Stephen Ritchie, University of California, Irvine

With the existing widespread use of inductive loop detectors (ILDs), Intelligent Transportation Systems (ITS) have a constant source of information on traffic system conditions. However, ILDs typically provide only point measures of traffic characteristics such as volume, occupancy, and depending on the loop configuration, local speed, which are inadequate for many ITS applications. If these detectors could be used in a “smarter” way, more useful information could be obtained for important ITS applications in traveler information and route guidance systems, congestion monitoring and incident detection, and traffic control via freeway ramp meters, surface street signals and changeable message signs. One technique to obtain significantly more information from ILDs is to utilize the vehicle waveforms that are produced when each vehicle passes over a loop. Such waveforms are essentially “signatures” that can be reidentified at downstream stations, and yield more useful information such as real-time section travel times, section speed, and section density, as well as vehicle classification and origin-destination data.

In this project, a prototype field implementation is being accomplished from the results of a previous research project (MOU 224), in which a vehicle reidentification algorithm based on loop signature analysis was developed using freeway traffic data. This algorithm is being extended to non-freeway cases, initially using a section of 2-lane major arterial in cooperation with the City of Irvine, California. The technique is being enhanced to address problems such as “irregularities” in vehicle signatures associated with trucks, tail-gating vehicles and erroneous counting of vehicles, with the objective of obtaining 100% correct counts at each station.

The enhanced algorithm is also being applied to a major instrumented signalized intersection in Irvine to acquire data for real-time congestion monitoring, incident detection and level of service measurement. Instrumentation of the study intersection has been completed and integration support for the field installation of 2070 controllers, cameras, communications link, and TMC hardware/software is underway.

An initial study into deriving real-time intersection level of service (LOS) was also completed. A new delay measure, which will be readily available using the ILD setup and

vehicle reidentification algorithms at the intersection above, was derived using real data from the intersection and compared to conventional delay measures defined by the Highway Capacity Manual. Traffic was light to moderate during the data collection period (LOS A and B). Insufficient data were collected to statistically analyze and relate the two delay measures, but the results were promising, and the approach is planned to be investigated further in a follow-on project with the objective of providing real-time intersection LOS information to traffic management center personnel.

Another application studied the derivation of individual vehicle speeds using waveforms produced by single ILDs. This approach is in contrast to that of using double loops in a speed trap configuration, or conventional single loop methods which depend on the distribution of vehicle lengths and can be quite inaccurate. The vehicle inductive waveforms contain both a leading and trailing edge. These edges are “slew rates” which appear to be dependent on the rate of the metallic mass of the vehicle moving over the loop. In order to predict speed from a single loop, the slew rates were extracted and a linear regression model was developed of speed versus slew rate. The results showed that the developed algorithm performed much better (average errors of about 7%) than conventional single loop estimation methods (average errors of up to about 37%). It was also robust under different traffic conditions and was transferable across surveillance sites without the need for recalibration.

One conclusion of these studies is that use of the extensive existing single loop surveillance infrastructure may be a particularly cost-effective means of obtaining more accurate section and network-wide travel information.

MOU 350 - Video-Based Signature Analysis and Tracking (V²SAT) System

Arthur MacCarley, Cal Poly San Luis Obispo

This project investigates a 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, V2SAT 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, travel time estimation, validation of local modal-based emission models, and possible applications in law enforcement. 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.

We have 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 existence of this external illumination source greatly reduces the difficulty of reliably generating the VSV at each site.

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 at the Loragen facility.

A subcontract was let to Loragen Corp. of San Luis Obispo for the design, fabrication and delivery of all components required for field testing of the complete computer-vision-based system, for testing by the Cal Poly Transportation Electronics Laboratory. Loragen completed the user interface and database generator for the correlation computer and constructed four PC-based detection modules for field testing. A public demonstration of the system in actual service is tentatively planned for September 28, 1999, in San Luis Obispo.

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 vehicle travel time. The key task in the measurement of true travel time is to acquire unique or semi-unique information on vehicles and then reidentify them downstream. For this project, a laser-based detection system has been developed to measure vehicle length and possibly vehicle color for reidentification.

In the past year, the hardware and software of the laser-based prototype detection system have been significantly improved through extensive outdoor testing of the system with a wide temperature range during day and night time on the UC Davis campus. The testing result validates the principle of our detection system for measuring the delineations of moving vehicles on the highway. Extensive safety testing and analysis has been conducted. The detection system meets the national laser safety standard with a large safety margin for field applications.

The optics of the detection system has been upgraded by using a new high power diode laser module which integrates laser diode, high-voltage DC power supply and line generation optics into a single unit. The quality and reliability of the laser line have been improved with the new laser system. A new filter with suitable bandwidth has been selected to overcome the influence of temperature on the characteristics of the laser so that the laser system can work in a temperature range which is wide enough for field application. We also improved the optical system including modification of the cylindrical lens system for obtaining images with better quality.

The sensor electronics have been modified so that they are more compact and less sensitive to noise. A multi-channel sensor circuit was built which can be used to sample four-elements of the photodiode array simultaneously. The successful use of four-channel sensor demonstrated that the multi-element sample method is feasible.

The software is also improved significantly to achieve higher reliability, efficiency, and accuracy in real-time. The signal can be sampled, processed and saved to the disk at the same time. The analog and binary signals, velocity, acceleration, and length of vehicles from all the elements of the photodiode array can be displayed in real-time in an application window.

In addition, the next version of the detection system has been designed. The new mechanical and optical design will make the system more compact and adjustable for final field deployment. With the advanced design and new components, the new electronic circuitry will be much more reliable and lower cost. The research results obtained so far provided a solid foundation for field testing and deployment of the prototype detection system on the highway which will occur in the fall of 1999.

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 research project involves extensive use of CHP and Caltrans District 7 data sources. The research team was only permitted to work at the District 7 TMC during off-peak hours. Four field surveys during off-peak period in the months of August and September were conducted. The survey area was restricted to the only beat operational during off-peak period - the Downtown Loop, which is approximately 26 miles in length, covers 4 peak-hour beats and is served by 4 FSP trucks. The evaluation team collected data from three sources:

- Real time ambient speed of selected freeway segments from a probe vehicle
- FSP truck patrol speed and operation status from the AVL terminal of the CAD computer at the District 7 Interim TMC
- Loop detector data available from the MODCOMP computer at District 7

This field exercise identified some difficulties regarding off-peak survey, data availability and survey design. The team obtained permission from CHP and District 7 to conduct peak-hour surveys in November 1998. In all, the team conducted nine field surveys during peak period in late November and early December of 1998. The team selected a part of FSP Beat # 604-17 (I-10 between Vermont Ave. and Washington Blvd.), which is about 10 miles in length and is served by 4 FSP trucks. The beat was chosen because it is well instrumented with working loop detectors, had sufficient number of FSP trucks and is representative of a typical Los Angeles freeway. The team used the same data sources as that of the off-peak survey done earlier.

The research team identified the feasibility of retrieving FSP truck speed, location and status data in an electronic format from the Administrator section of the AVL Computer. TMSI, the consultant and vendor for the software at CHP LACC, was contacted to help us download the necessary data in electronic format. These log files provides system-wide data for the Los Angeles FSP system. The team is currently analyzing the data set.

A methodology for integrating data from different sources is underway along with the analysis of the data collected, during both peak and off-peak hours. The analysis primarily focuses establishing/determining relationships between the speed data collected from the three primary sources as well as from the fourth source (AVL log files). This project will conclude in December of 1999.

MOU 378 - Investigation of Vehicles as Probes Using Cellular Phones and the Global Positioning System

Y.B. Yim, PATH

The objective of this project is to investigate the feasibility of cellular technologies and the global positioning system (GPS) for traffic surveillance. The research will evaluate cellular and GPS technologies for measurement of vehicle speed or travel time. The project consists of three interrelated research components: 1) investigation of the global positioning system, 2) development of models for vehicle positioning using cellular technologies, 3) examination of institutional issues associated with field operational tests and model deployment.

1. Investigation of the Global Positioning System

To assess the effectiveness and adequacy of cellular and GPS technologies for incident detection and speed information, the current state of the technologies and commercially available GPS units was investigated. The GPS unit will be used to detect nodes in the roads and send IP events through a wireless modem containing information on the position and time of the vehicles to a centralized database. The nodes will be placed on critical points on highways using the TravInfo link definition. The GPS unit will send continuous amounts of data to a laptop computer where software will take in the information and determine if a node point has been passed. Differential GPS will be used to eliminate the inaccuracy inherent in the signals being sent to the GPS unit due to selective availability.

2. Development of Models for Vehicle Positioning Using Cellular Technologies

At this stage, several simple analytical models of the measurement process have been developed. There were a number of reasons for constructing these models: identify important parameters, gain a deeper conceptual understanding, and provide ballpark estimates of system performance.

As a result of the modeling process, a clearer idea of the parameters that need to be estimated was gained. Examples of such parameters include; the distribution of cellular users on the Bay Area Network (BAN), statistical distribution of traffic on the BAN, the distribution of cellular base stations in the Bay Area, size of links, acceptable window time, maximum sampling frequency, measurement accuracy's, and other parameters associated with the road network and the cellular systems. At this state, first cut estimates for all the important parameters have been established.

3. Examination of Institutional issues

There are two major external driving forces for this work; the E911 mandate for cellular positioning and the need to find additional applications of positioning (to leverage the investment in E911 hardware). The major players in the development of a cellular based

network monitoring system are Caltrans, the cellular carriers, and potential service providers. Secondary players are developers of positioning technology, handset manufacturers, and suppliers of cellular infrastructure. In order to further identify and understand the institutional issues we have been carrying out in-person interviews with representatives of both primary and secondary players. As well, a meeting convened involving representatives from most of the interested parties.

To complete the project we intend to carry out the following activities:

- Verify and document the analytical models
- Complete the parameter estimation.
- Complete a simulation of performance assuming a system working on three links of the Bay Area Network.
- Complete the study of the institutional aspects
- Write up the report describing our methodology and our conclusions.

Performance Evaluation Measurement System (PeMS)

Pravin Varaiya, UC Berkeley

Phase I of the Performance Evaluation Measurement System (PeMS) project produced a prototype performance measurement system called Transacct. Transacct processes all of the loop data from District 12 in real time in order to

1. Estimate reliable real-time speeds based on an adaptive on-line estimation of loop- and time-specific average effective vehicle length;
2. Calculate congestion measures based on the Caltrans HICOMP formulas;
3. Calculate a freeway "output" measure---the VMT---and a freeway "input" measure---the vehicle-hours traveled or VHT, so that the output/input ratio, $Q = VMT/VHT$, can be a meaningful productivity measure of freeway performance;
4. Make available on-line historical data going back to January 1, 1998 for use by Caltrans managers, engineers, and the transportation research community;
5. Calculate a loop-detector reliability measure---the percentage of all samples that the loop detector actually reports;
6. Estimate and display over the World Wide Web the shortest route (with or without HOV) between any two points on District 12's freeway network in response to a user requests.

Transacct is at present located on the Berkeley campus. Data from District 12 are received over a Pacific Bell telephone line. The hardware consists of a dual-processor SUN workstation with a large RAM and disk storage. Transacct can be moved to any Caltrans location. Transacct is a web-based system. Statistics about the freeway data are viewed through a web browser. Data can be retrieved through the browser as well. However, Caltrans engineers and researchers who wish to work with a large amount of data should access the database directly.

MOU 376 - An Investigation in the Use of Inductive Loop Signatures for Vehicle Classification

Carlos Sun, PATH

The purpose of this project was to develop an advanced traffic surveillance technique in order to obtain vehicle classification data. Inductive vehicle signature analysis coupled with pattern recognition techniques were used to develop classification algorithms.

The resulting vehicle classification data can have widely applicability in almost all areas of transportation. These areas include transportation modeling, pollution analysis, traffic safety, roadway maintenance, toll collection, bus and emergency vehicle preemption/extension, vehicle reidentification, and intermodal transport.

Two main families of algorithms were developed for vehicle classification. The first is a series of unsupervised algorithms which are implemented as Self-Organizing Feature Maps also known as Kohonen neural networks. These algorithms revealed natural clusters resulting from training with signature data sets.

The second family of algorithms are based on theoretic decision approach. Discriminant functions based on multiple feature vectors were combined in a hierarchical fashion resulting in heuristic trees. Multi-objective optimization was utilized for training and determining optimum discriminant bounds. Golden section search was used for finding the objective function minima.

Testing of the algorithms were performed with data sets composed of inductive signatures and corresponding video capture of the vehicles. Encouraging results from both algorithms demonstrated the potential of inductive vehicle classification systems. Overall classification rates of between 80% to 90% were representative of the performance of algorithms using different data sets.

MOU 377 - Dynamic Origin/Destination Estimation Using True Section Densities

Carlos Sun, PATH

Previous formulations of dynamic origin/destination demand estimation strategies have used flow as an input variable. This results in restrictive assumptions of uniformity of flow (over a link) and non-monotonic link cost functions. Instead, this research presents formulations based on section densities.

The estimation of accurate dynamic origin/destination demands is critical in many Advanced Transportation Management and Information Systems (ATMIS). Applications such as routing and diversion, traffic assignment, and scheduling all dependent on reliable origin/destination demand data.

Dynamic origin/destination demand estimation strategies using both dynamic traffic simulation and dynamic traffic assignment were utilized to load the traffic network and to export the O/D-link incidence matrix to the origin/destination demand estimation module. A comparison was made between these two methods.

Sensitivity analysis was performed on the various origin/destination demand estimation frameworks. The effects of perturbing link saturation volume, seed O/D matrix, network congestion levels, and the number of origin/destination pairs were analyzed. Encouraging results of less than 10% error per origin/destination pair were obtained uniformly even with the use of seed matrices that had as much as 170% error. The research demonstrated that dynamic origin/destination demand estimation frameworks that incorporate section densities, DTA/traffic simulation, and time series methods are feasible.

3. Traffic Management Systems

MOU 356 - Developing and Using Surveillance Data for Research

Joy Dahlgren, PATH

A two-year effort to establish a video surveillance facility on the roof of the Pacific Park Plaza building in Emeryville adjacent to I-80 culminated this July in the signing of a contract with Wiltec, a traffic engineering and data research firm, to set up an array of 14 cameras and 12 video recorders on the site. Wiltec will also collect the data from the cameras. Two of the cameras will transmit live traffic data by modem to the UC Berkeley campus.

The video data will be used for:

- Machine vision research
- Ground truth for testing methods of estimating travel times
- Testing other surveillance devices, such as the radar surveillance system
- Testing the accuracy of methods for utilizing incomplete loop detector data studying traffic dynamics
- Evaluating the accuracy of traffic simulation models
- Studying the effect of increased road capacity (or decreased travel time) on traffic volumes

In order to study the effect of increased road capacity in another way, a license plate survey on the nearby Cypress section of I-880 was begun. Surveys have been mailed to people now using that section of I-880 asking them how its reconstruction has affected their travel time and trip making.

MOU 354 - Incident Management: Process Analysis and Improvement

Randolph Hall, University of Southern California

The objective of this project 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 (reported herein) 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.

The first phase was completed during 1998/99 and the second phase has been initiated. As a general conclusion, we observed that 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.

In total, the incident management process should be optimized, with respect to the following objectives:

- Minimizing the time from when an incident occurs until appropriate crews arrive on the scene, minimizing the time to clear the incident, and minimizing the follow-up investigation time.
- During the incident, minimizing the disruption to traffic by keeping lanes open, reducing the capacity reduction per lane due to driver distraction and hazardous conditions, and minimizing follow-on collisions.
- Ensuring safety throughout the incident, for the victims, incident response crews, drivers and passengers.

RTA 65V313 Task 4 - Anaheim Field Operational Test Evaluation

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. The primary FOT objective was the implementation and performance evaluation of adaptive traffic signal control technologies including an existing second generation approach, SCOOT, and a 1.5 generation control (1.5GC) approach, and implementation of a video traffic detection

system (VTDS). Project evaluation was divided into three tasks: (A) performance assessment of the traffic control technologies, (B) assessment of institutional issues, and (C) evaluation of the VTDS.

SCOOT amply demonstrated that it can operate in a network with significantly non-ideal detectorization, and control the traffic in a manner that does not cause substantial and unacceptable increases in intersection delays and route travel time increases. In all cases, it is both qualitatively and quantitatively clear that the data provided by the SCOOT messages covaries moderately to strongly with the data extracted from video tapes. In all cases, the null hypothesis of no relationship between the information in the SCOOT messages and the flows captured on videotapes is strongly rejected. However, the estimated correlation coefficients observed in Anaheim are lower than values obtained in other locations where SCOOT has been deployed. SCOOT did not show the kind of benefits shown by other proper implementations of SCOOT around the world, which is perhaps to be expected, considering that the performance comparisons were made against traffic under a baseline system which is considered state-of-the-art in US practice.

The abilities of SCOOT were not fully reflected in Anaheim due also to the minimal time spent in fine-tuning the SCOOT parameters. The reason for the non-ideal fine-tuning were the project time deadlines and the City TMC staff not being fully trained in doing the adjustments within the short period before the field study was conducted.

Two broad conclusions can be drawn relative to institutional issues. First, the technologies implemented enjoyed some limited success. Second, given these results, institutional and technical factors were identified which were critical in defining this performance. In this sense, the project was successful, although without more extensive observations under normal operating conditions, it would be premature to advise extended implementation in the City or elsewhere. Institutional issues associated with project management and contractual matters were judged as unexpected and critical influences on the project. While they were ultimately resolved, their presence nearly terminated the project prior to final implementation.

Among the VTDS test results: 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. 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.

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.

RTA 65V313 Task Order 8 - Transit Probe Project Evaluation

Randolph Hall, University of Southern California

The OCTA (Orange County Transit Authority) Transit Probe Project was a field operational test of an automatic-vehicle-location (AVL) system operating in Orange County, California. A unique feature of the project was that system software was designed to estimate roadway congestion levels based on bus travel times over route segments. The system was intended to communicate congestion information to the California Department of Transportation (Caltrans), the City of Anaheim and the City of Santa Ana, who would utilize the information in their traffic management operations. In addition, the system was designed to determine when buses are late or early in real-time, and to store data on the on-time performance of buses.

The evaluation project was directed at measuring four Transit Probe objectives:

- Measurement of the reliability and completeness of data generated by the Transit Probe System.
- Assessment of the effectiveness of interfaces between the Transit Probe System and users.
- Determination of the usefulness of transit probe data for congestion management.
- Evaluation of the institutional performance of the Transit Probe Project.

Our own analysis revealed that when automobiles experience long delays, buses traveling the same route in close proximity are also likely to experience delay. The reverse, however, is not always true. This is because buses frequently wait for extended periods when they run ahead of schedule. Any useful bus probe algorithm would need to distinguish actual congestion versus a stopping delay.

Though Transit Probe was designed to measure congestion on roadway segments, a more useful approach would be to measure congestion approaching major intersections. These are the places where delay is likely to occur. And measuring over an entire segment makes it difficult to identify the exact location of the problem. Moreover, because delay randomly fluctuates in accordance to a vehicle's arrival time relative to the signal cycle, the most sensible approach is to set off a "congestion alarm" when a vehicle is delayed by more than one cycle at an intersection. A congestion alarm would indicate oversaturation, and delay well beyond normal. Congestion alarms like this are feasible with GPS based systems, but were not used in the project.

Bus tracking systems provide many potential benefits, helping: (1) drivers stay on schedule, (2) dispatchers respond to problems, (3) schedulers determine how much time to allocate between schedule check points, and (4) general public know when buses will arrive. However, these benefits cannot be captured without carefully planning operational procedures, data maintenance, and system interfaces and ensuring the

equipment itself it reliable. Design needs to involve many parties within the transportation agency, and include task assignments, data transfer methods, and strategies for using information.

A Stochastic Modeling Approach to Dynamic Prediction of Section-wide Inter-lane and Intra-lane Traffic Variables using Point Detector Data

Jiuh-Biing Sheu, ATMS Testbed

Real-time section-wide lane traffic variables such as density and lane-changing are vital to traffic control and management in urban areas. They can be used as decision variables to determine traffic control and management strategies in real time as well as characterize road traffic congestion for further use in advanced traveler information systems. Therefore, developing techniques which provide real-time information regarding section-wide inter-lane and intra-lane traffic variables is an increasingly important task in the area of advanced transportation management and information systems. This project developed a stochastic system modeling approach to extracting real-time information of section-wide inter-lane as well as intra-lane traffic (e.g., lane-changing fractions, lane densities, etc.) utilizing lane traffic counts detected from point detectors.

The proposed methodology consists of three principle elements: 1) specification of system states, 2) system modeling, and 3) recursive estimation. Preliminary test results indicated that the proposed methodology is promising for estimating real-time section-wide inter-lane as well as intra-lane traffic variables based merely on point detector data. The inter-lane and intra-lane traffic information generated by the proposed method can be further used in developing related technologies such as road traffic congestion detection, automatic incident detection, prediction of driver route choices, variable message signs and in-car navigation devices.

A New Methodology for Incident Detection and Characterization on Surface Streets

Jiuh-Biing Sheu and Stephen G. Ritchie, ATMS Testbed

In this project, a new methodology was developed for real-time detection and characterization of incidents on surface streets. The proposed automatic incident detection approach is capable of detecting incidents promptly as well as characterizing incidents in terms of time-varying lane-changing fractions and queue lengths in blocked lanes, lanes blocked due to incidents, and incident duration. The architecture of the proposed incident detection approach consists of three sequential procedures: 1) *Symptom Identification* for identification of incident symptoms, 2) *Signal Processing* for real-time prediction of incident-related lane traffic characteristics, and 3) *Pattern Recognition* for incident recognition. Lane traffic counts and occupancy are the only two major types of input data, which can be readily collected from point detectors. The primary techniques utilized in this approach include: 1) a discrete-time, nonlinear, stochastic system with boundary constraints to predict real-time lane-changing fractions and queue lengths, and 2) a pattern-recognition-based algorithm employing modified sequential probability ratio tests (MSPRT) to detect

incidents. Off-line tests based on simulated as well as video-based real data were conducted to assess the performance of the proposed algorithm. The test results have indicated the feasibility of achieving real-time incident detection using the proposed methodology.

A Parametric Framework for ATIS with Endogenously Determined Driver Compliance

Jun-Seok Oh and R. Jayakrishnan, ATMS Testbed

This project developed a framework to parametrically evaluate networks under user equilibrium route guidance (UERG) state and system optimal route guidance (SORG) state assuming the unguided traffic to be in stochastic user equilibrium (SUE). Unlike other studies that assumed fixed number of complied drivers, this study explicitly considers compliance rate as an endogenous variable in a general parametric nonlinear programming framework. Under endogenously determined compliance rates, SORG may result in higher total system cost than UERG due to lower compliance rate even though SORG is aiming to minimize total system cost. In contrast, even though UERG is generally preferable because of higher acceptance, UERG may result in increase of total system cost under certain conditions. A simple network was constructed to illustrate the application of the framework. The results show that route guidance performance is highly dependent on the level of unguided driver's familiarity. A significant part of the framework is the scheme to find "sustainable" compliance rates under assumed compliance function.

Integration of DYNASMART Routing Capabilities to Paramics

R. Jayakrishnan, ATMS Testbed

DYNASMART (DYnamic Network Assignment Simulation Model for Advanced Road Telematics), a mesoscopic traffic simulation program, was the original simulator in the ATMS Testbed. The microscopic simulator newly implemented in the Testbed is Paramics. Even though Paramics has many more flexible, advanced and useful features than any other existing microscopic simulations programs, it has limitations for use in the simulation and evaluation of ATIS, due to its inability to find and store individual vehicle's routes and simulate the driver response towards information supply and their route choice, as in DYNASMART. The difficulty arises from the detailed network descriptions used in Paramics. This project integrates Paramics and the routing schemes in DYNASMART, so that the integrated simulator can evaluate information/ routing schemes with route choice behavior models. This integration is based on communication of vehicle positions from Paramics, to a simplified DYNASMART-type network where the path processing is accomplished. The vehicle route decisions are then transmitted to Paramics whose internal routing schemes are disabled.

MOU 346 - CARTESIUS: A Distributed Approach to Network-Wide Traffic Control Management

Michael McNally, UC Irvine

This project developed a distributed architecture for area-wide incident response and traffic control management, composed of two interacting, real-time decision-support systems that are able to perform cooperative reasoning and resolve conflicts. The two units exchange partial and potentially incomplete results during the execution of their problem-solving tasks and exploit inter-agent constraints to resolve inconsistencies that are due to the limitations of their information, in order to integrate local solutions into global, network-wide control plans. Reflecting the complexity of the interaction between the various agencies engaged in the management and control of urban networks, this approach takes into account the desire of each individual agency to preserve its autonomy and maintain the control of the facilities under its jurisdiction, but at the same time tries to exploit their willingness to cooperate and unify their problem-solving capabilities towards a conflict-free, integrated response to operational problems.

Stochastic Adaptive Control Model for Traffic Signal Systems

X.-H. Yu and Will Recker, ATMS Testbed

This project developed an adaptive control model of a network of signalized intersections based on a discrete-time, stationary, Markov decision process. The model incorporates probabilistic forecasts of individual vehicle actuations at downstream inductance loop detectors that are derived from a macroscopic link transfer function. The model was tested both on a typical isolated traffic intersection and a simple network comprised of five four-legged signalized intersections, and compared to full-actuated control. Analyses of simulation results using this approach show significant improvement over traditional full-actuated control, especially for the case of high volume traffic demand.

Phase I Construction of the I-405 Detector Testbed

Will Recker, ATMS Testbed

The purpose of the project is to construct the first phase of a Detector Sub-Testbed within the ATMS Testbed at sites along the I-405. The first phase of the project involves a total of three sites – two mainline sites and one ramp location:

Location 1: Northbound I-405 at Laguna Canyon Road (Mainline, milepost: 2.3)

Location 2: Northbound I-405 at Sand Canyon Road off-ramp

Location 3: Northbound I-405 at Sand Canyon Road (Mainline, milepost: 2.99)

Location A: Alton Parkway and Sand Canyon Road (Fiber Connection)

Each mainline site consists of loops placed in the roadway and video cameras mounted overhead on bridge structures. The objective of this implementation is to provide researchers a "real-world" laboratory for collecting more accurate traffic characteristics

and traffic data necessary for Intelligent Transportation Systems (ITS) applications. This chosen segment of I-405 contains overcrossings at both upstream and downstream locations which allows mounting cameras and other devices as needed for monitoring traffic on a per-lane basis. This will also enable mounting of overhead detectors above each traffic lane in the future. Conventional loop detectors will also be installed in the mainline and on the downstream off-ramp (two per lane). In addition, each site will contain traffic control cabinets to house the necessary pieces to make the system functional and gather data. As part of this installation, communications between these three locations will be provided via a combination of wireless and fiber optic cable communication. Communications to the ATMS Testbed Laboratories will be provided in a subsequent phase.

4. Traveler Information Systems

RTA 65V389 & 65A0006 - TravInfo Evaluation

Youngbin Yim and Mark Miller, PATH

TravInfo was a Field Operational Test (FOT) in the San Francisco Bay Area in the area of Advanced Traveler Information Systems sponsored by the Federal Highway Administration. It was organized as a public/private partnership. The California PATH Program at the University of California, Berkeley has been the designated independent evaluator of TravInfo during the Field Operational Test. There were three primary elements of the evaluation: 1) an institutional element, 2) a technology element, and 3) a traveler response element. The institutional issues element described the process by which the FOT was conducted from the point of funding until the completion of the FOT. The technology element focused on the operational effectiveness of TravInfo's Traveler Information Center and a study of Information Service Providers reaction to and use of TravInfo information. Traveler response investigated public access to and use of the different types of information provided by TravInfo, changes in individual travel behavior based on traveler information, and the market demand and effectiveness of different information-based products.

TravInfo's objective was to collect, integrate and broadly disseminate timely multi-modal traveler information through a range of products and services to meet consumer needs. TravInfo has an open-access database and architecture that allows private sector participants to retrieve the data free of charge and re-package it for its ultimate dissemination to travelers through commercial products and services. An essential element of TravInfo has been to centralize and fuse data sources and to provide standardized access to them. In this way public agencies only have to provide data to TravInfo and private sector participants do not have to go to multiple sources to obtain data. The Traveler Information Center (TIC) is the centralized data fusion hub. The primary means of public access to TravInfo information has been via the Traveler

Advisory Telephone System (TATS), in which the telephone's numeric keypad serves as the interface for callers to obtain TravInfo information from a menu-driven system.

In operation since September 1996, the TravInfo TIC collects, processes, and disseminates traveler information directly to the public through the TATS and provides data access to private-sector information service providers (ISPs) through a Landline Data Server (LDS). There is a single regional telephone number available to callers from all Bay Area regional area codes. Presently, three ISPs disseminate traveler information through traffic web sites using the TravInfo database exclusively.

The institutional issues element was conducted by means of interviews of TravInfo's major participants. The technology element was conducted by means of on-site field observations and measurements at the TIC as well as interviews of TIC staff. The traveler response element was performed by means of surveys of the Bay Area's traveling public as well as TATS users. There are numerous accomplishments and challenges for TravInfo relative to each of the three primary study elements. The major lessons learned are briefly described as follows:

Building and Maintaining a Successful Public-Private Partnership

- It was necessary to lower expectations of the parties while working toward a common goal.
- The TravInfo organization was effective, but a consensus-based partnership was slow at making critical decisions.
- A deployment plan early in the process might help to define realistic project directions.
- Experts' advice was beneficial to the project team for the development of the TravInfo system.
- The project goals were ambitious and unrealistic to achieve within the FOT time frame.

Dealing with Technological Uncertainties

- A flexible system could help deal with rapidly changing technologies.
- Streamlining the process of data collection would be effective.
- A systematic approach to project implementation was necessary.
- Having risk assessment and contingency planning policies are vital to moderating the potentially negative consequences of unforeseen events.
- Operator quality control measures need to be given priority during the early stages of a project and be maintained throughout its lifetime.
- The designer of a computer-user interface should know who the users are and incorporate their needs and assigned tasks into the design.

Dealing with Financial Uncertainties

- Financial support of TravInfo from the public sector was necessary.
- Cost sharing with the private sector was not realized in the short-run.

Dealing with Market Uncertainties

- TravInfo could benefit from consumer research on public needs and desires.

- Marketing was critically important to TravInfo deployment.

Managing Schedule Delays and Planning/Implementation Issues

- Alternative courses of action would help deal with planning and implementation issues.
- Early consideration of potential risks associated with contractors could be beneficial.

Generating New Ideas, Approaches, and Partners

- Collaboration among public agencies can generate new ideas and approaches.
- New ideas and approaches can be developed by sharing experience with others.

Conducting an Evaluation of a Field Operational Test

- The evaluation plan is a “living” document and will undergo changes over time.
- Further research of the long term impacts on travel behavior is needed.
- Regular meetings with the Evaluation Oversight Team were valuable.

The following recommendations are suggested for use in both TravInfo’s post-FOT environment and new Field Operational Tests or similar types of projects.

- Continue to collaborate on the management and operation of TravInfo among three regional agencies.
- Provide strong incentives to public agencies for their participation in deployment of a regional ATIS.
- Continue to seek public funding to support TravInfo operation until the statewide asset management plan is implemented.
- Investigate ATIS products and services market potential by continued consumer behavior research.
- Develop and implement aggressive marketing strategies for public awareness of TravInfo.
- Apply certain strategies to help insure operator quality control.
- Continue the operator response time assessment to help specify the individual impact of operator performance and operator workload.
- Study the feasibility of designing an improved TIC-operator interface would be beneficial.
- Allow sufficient time to conduct necessary administrative tasks in the pre-planning phase of an FOT.

MOU 365 – TravInfo Evaluation, TIC Study: Operator Interface

Mark Miller, PATH

The TravInfo Traveler Information Center (TIC) was under examination from various perspectives including the interface between the TIC and its operators, the physical working environment, and operator response times. The unique situation here is that the TIC is under a private-public operation and management framework.

The TIC-operator interface was evaluated to identify the degree to which this aspect of the operators' workplace supports the operators in performing their tasks. Although the TIC software, overall, allows operators to perform their tasks relatively efficiently, the interface could have been designed to better support operator tasks. Shortcomings included: 1) the organization and layout of some windows do not always consider operator tasks, 2) the menus on the two most important and commonly used windows are poorly ordered, filled with rarely used items.

With respect to the physical working environment, operators found it quite acceptable and a consensus suggested only minor changes to potentially increase their productivity and performance.

Operator response times were evaluated to understand the importance of the operator role in TIC operation with respect to the time taken to obtain, process, and disseminate incident-related information from the California Highway Patrol to the TIC. Results indicate that 1) the quality of operator job performance and 2) the level of operator workload are the two most influential factors of response times.

MOU 343 – Assistive Devices and Services for the Disabled

Reginald Golledge, University of California, Santa Barbara

This study examined the effect of using Remote Infrared Signage Systems (in particular the Talking Signs® product) has on performance of blind or vision impaired people when undertaking a variety of bus user tasks. These tasks included finding a suburban bus stop, identifying a specific bus and boarding it, disembarking at the downtown terminal and finding the entrance, traversing the terminal and learning the location of facilities located therein, and, simulating the exiting of a bus, navigating through the terminal, exiting via a different door and searching for the boarding area of an express bus about 120 ft. away on the frontal street(the bus transfer task).

Twenty-seven participants were divided into two groups. One group used TS® first on specific trials for each task, while the other group did not use TS® on the first trial of those tasks. Our hypotheses predicted significant response time (RT) reduction when using TS® plus higher success rates and fewer errors. It was also hypothesized that perceived stress, anxiety and difficulty of tasks would be reduced when using TS®, while perceived independence would be increased.

T-tests on the response time differences between use of TS® and non- TS® trials emphatically supported our hypotheses. With TS®, all tasks were completed quickly, independently, and successfully. Without the use of TS® participants sometimes failed to complete tasks in the allotted time, gave up, or in some cases had completion times 4 or 5 times longer than the TS® aided times. In the real world, this would have meant that some participants would not have been able to identify a stop or the relevant bus, would not have been able to make a successful transfer, and would not have been able to

effectively use terminal facilities. These are significant problems inhibiting the use of public transit by most of the 8-9 million severely vision impaired people in the USA.

In addition, use of TS® was perceived to reduce stress, anxiety, and difficulty of the various tasks associated with use of public transit. And, in post-task evaluations, participants on average strongly agreed that, if the TS® were made permanent on all buses and at the terminal, they would use public transit much more than they do now. They also supplied recommendations as to where TS® could be located throughout the city to make it truly accessible for all their regular activities. Although no direct benefit-cost estimates could be made, our estimate is that, for about \$150,000, the Santa Barbara MTD buses and terminal could be equipped with TS®. A relatively small amount to pay for the increased independence and quality of life of this disabled group, although the amount could be doubled when we add TS® at selected downtown and suburban stops. Subjectively, therefore, we suggest a high benefit to cost ratio would result from installation of TS® on urban transit lines. There is no reason to expect that user attitudes would change in larger, more complex environments and current work in the City of San Francisco by Smith-Kettlewell Rehabilitation Engineering Research Institute seems to be confirming this.

MOU 348 – Event-based ATIS: Practical Implementation and Evaluation of Optimized Strategies

R. Jayakrishnan, UC Irvine

The purpose of this project is to find optimized ATIS routing schemes, with special focus on CMS routing schemes, to construct a comprehensive ATIS evaluation framework, and to conduct field studies on applying the routing schemes to a real world traffic network under special events, in the city of Anaheim.

For ATIS application, path-based optimal solutions are necessary. Unlike other transportation network optimization algorithms, the gradient projection algorithms refined during this research can provide optimal path flow solutions that can be used for route guidance. This study showed efficiency and usability of the algorithm for static analysis of ATIS routing. The study developed an algorithm to find optimal CMS messages, taking interaction between information providers and drivers into account. The study also developed methods to find dynamic optimal routing schemes for both instantaneous information and predictive information through a dynamic traffic simulation.

In addition to simulation-based evaluation of ATIS schemes, a parametric analytical evaluation framework was also developed, incorporating endogenously determined driver compliance. Using a simple network, and assumed behavioral models, the study illustrated the application of the framework and showed that route guidance performance is highly dependent on the level of unguided driver's familiarity. A significant part of the framework is the scheme to find "sustainable" compliance rates under assumed

compliance function. For CMS, driver compliance rates are dependent on reliability of the information. The hypothetical study analyzed this by updating driver compliance rates day-to-day based on drivers' previous experiences. We tested three different CMS types: an optimized static CMS, an instantaneous optimal CMS, and a predictive optimal CMS. In this experiment, the predictive CMS showed better performance (compliance rate 65%; average travel time 6.4 minutes) than the static CMS (42%, 7.3 minutes) and instantaneous CMS (55.1%, 7.3 minutes).

The field study of ATIS routing was performed in the City of Anaheim in Orange County near the special event traffic generators (Edison Field Angels Baseball Stadium and the Arrowhead Pond Arena). The first field test was based on the CMS routing schemes suggested by the above framework involving DYNASMART simulations for traffic arriving at the Pond arena. With the assumption of 40% compliance, the simulation estimated 2% of travel time saving network-wide, though for specific market-fractions, the benefits are much higher. The field study used two CMS's on freeway 57 for guiding event traffic to Arrowhead Pond Arena. The new routing scheme was applied in order to reduce congestion on the main entrance road. The field test observed 13% of the drivers diverted. The data was taken 30 minutes before the event was scheduled to begin. Although strict overall performance measures including exact queue waiting times could not be obtained with current monitoring systems, better traffic movement was observed with reduction of congestion on the main entrance road, and increased speeds on the 57 freeway.

The second field study involved the traffic arrivals at the Edison Field. After consultations and a joint meeting involving the City of Anaheim, Caltrans, and CHP, five CMS's on the I-5, SR-57 and SR-22 freeways were used for guiding event traffic to the Edison Field, according to the ATIS routing suggested by the above framework. A survey was conducted to study driver response to the CMS message at the stadium. Since the previous field study focused on traffic benefits, the second study focused on the driver's responses to CMS, as the study site offered more diverse CMS routing information. 50% of drivers recognized the CMS messages, and 46% of drivers switched to the suggested routes. Drivers' recognition of CMS and compliance get higher as event start time gets closer. Unfortunately in both field tests, complete network-wide benefit measures could not be obtained, as the archived data available from the detectors were not comprehensive. However anecdotal evidence from observers suggest better traffic performance, and thus future efforts on full-scale, real-world implementation of the ATIS routing frameworks can now be contemplated.

5. Public Transportation Systems

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 Field Operational Test is intended to deploy technology integrating demand responsive and fixed route activities across four transit operators in the San Gabriel Valley. In July 1998, a series of interviews with some of the transit system operators were conducted to obtain available performance data. The focus was on the FOT's impacts on the City of Monrovia and its transit contractor, Dootson Enterprises. It was understood the operations at Duarte and Arcadia to be largely unaffected by the San Gabriel Valley Smart Shuttle FOT; whereas the Monrovia dispatching operations will be completely restructured as a result of the Trapeze software. Preliminary reports were prepared based on the data obtained which documented ridership patterns. Unfortunately, accurate cost-related data was not available. During the last two months of calendar year 1998, a second round of interviews with representatives from the cities and their transit operators was scheduled.

In February, the evaluation team decided to shift some of its focus to Foothill Transit. Employee turnover delayed full implementation of the system at Monrovia; and the evaluation team wanted to obtain some more baseline data on routes 187 and 184 prior to installation of the AVL system on the Foothill buses. The team recorded scheduled and actual departure times for a majority of runs on Route 187. However, the team has decided not to pursue further information on Route 184. There appears to be little deviation from scheduled times, primarily because of the relatively short distance covered by the route.

In May and June, a series of mid-evaluation interviews were conducted. This was a critical time given continuing problems with the deployment of the Trapeze software product. Also, the status of certain contracts changed with the end of the fiscal year and it was necessary to speak with participants whose roles would be limited or ending as of June 30. Also in June, the evaluation team began a detailed review of the various contracts initiated as part of the FOT. This is part of the analysis of overall project costs.

MOU 349 & 380 – Carlink: A Smart Carsharing System

Daniel Sperling & Susan Shaheen, University of California, Davis

The Institute of Transportation Studies at UC Davis, and its partners Caltrans, the Bay Area Rapid Transit (BART) District, American Honda Motor Company, UC's Lawrence Livermore National Laboratory (LLNL), Teletrac, and INVERS are studying the use of intelligent communication and reservation technologies to reduce the inconvenience of carsharing and to identify market segments where smart carsharing (what the project team calls "CarLink") would be attractive.

Researchers at the Institute of Transportation Studies at UC Davis implemented a three-part longitudinal survey. The study explored how individuals acquire knowledge about a transportation innovation, specifically smart carsharing. The survey was designed to examine how exposure to the smart carsharing concept affected understanding of the

innovation and willingness to adopt such a transportation mode into their lives. The research team started with an initial sample size of 430 different individuals (representing 255 households) from the San Francisco bay area.

The participants were divided into experimental and control groups. Both groups completed an initial questionnaire, which supplied researchers with the following: demographics, current travel patterns, views about transportation, and any prior knowledge of carsharing. Both groups also received a brochure to explain the CarLink concept. After the respondents returned their first set of questionnaires, the experimental group received a video further explaining the CarLink concept. The final exposure for the experimental group was a drive clinic. One hundred seventy-one households (232 individuals) participated in the clinic. At the clinic, participants were able to ask questions and try the CarLink system, including smart cards, an electronic key manager kiosk, and a fleet of specially equipped compressed natural gas vehicles. Researchers noted questions that the respondents asked and administered an exit interview when individuals completed the clinic. ITS-Davis researchers also conducted a series of focus groups with both experimental and control group participants to more fully explore the smart carsharing concept.

The remainder of the fiscal year was spent entering and analyzing survey data. To summarize the main findings, the experimental group gained a greater understanding of the concept and became more willing to adopt with each successive exposure. The control group, who received no further information after the brochure, rapidly lost interest in the concept, implying that brochures were insufficient to maintain long-term interest or to adequately explain the innovation.

Launched on January 20, 1999, the CarLink demonstration project involves over 60 participants sharing 12 CNG Hondas based at the Dublin Pleasanton BART station and at LLNL. Three types of participants use the cars at different times, paying different prices:

Homeside Users drive a CarLink vehicle between home and the BART station daily, keeping the car overnight and on weekends for personal use. A \$200 monthly fee includes a tank of CNG fuel, insurance, and maintenance costs. Participants can also pay for additional fuel with a refueling card at approximately \$.80 per gallon.

Workside Commuters take BART to the Dublin-Pleasanton station and drive a CarLink vehicle to and from LLNL. A \$60 monthly fee, which can be shared with a co-worker by carpooling, again includes fuel, insurance, and maintenance costs.

Day Users pick up a CarLink vehicle at either BART or LLNL and use it for business trips or personal errands during the day at a fee of \$1.50 per hour and \$.10 per mile. Users are not charged for business trips because LLNL has donated the fuel to this demonstration. Approximately 30 day-use members are signed up to participate at LLNL.

Researchers found that willingness to use CarLink was influenced by the amount and type of informational stimuli, as predicted by social marketing and learning theories. For example, many individuals who only read the brochure lost interest over time, while a large majority of those who read the brochure, watched the video, and participated in the clinic, stated that they would use CarLink.

Logistic regression models developed for this study indicate that individuals are more likely to choose CarLink when they are:

- Exposed to Carlink informational media
- Concerned with the environment, and
- Dissatisfied with their current modes.

Reasons that individuals select current modes (i.e., autos and transit) are:

- Vehicle enjoyment,
- Modal satisfaction,
- Cost, and
- Convenience.

In the final phase of the CarLink longitudinal survey, 77.9% of experimental (n=161) and 32.6% of control respondents (n=31) said they would use the CarLink system. In contrast, only 53.6% of experimental (n=111) and 17.8% of control participants (n=17) indicated that they would be interested in participating in the CarLink field test. Interestingly, no one from the control group was able to join the field test. Twenty-three percent of participants, who wanted to be contacted about field test participation, became members. Ten percent of the total survey population actually joined the field test, and 15% of experimental participants joined. It is likely that these percentages (i.e., 10 to 15%) provide a more accurate picture of the initial target adopter rates than response to the question “would you use Carlink” (i.e., 33 to 78%), given program eligibility and cost requirements.

MOU 345 - Efficient Transit Service Through the Application of ITS

Maged Dessouky, USC

Recently, bus transit service providers have begun to adopt Intelligent Transportation System (ITS) technologies such as Global Positioning Systems (GPS), Mobile Data Terminals, and Electronic Fare boxes. GPS systems are particularly useful for vehicle tracking and mobile data terminals may be used for passenger counting. These systems taken together have the potential to reduce the cost of providing transportation services through the execution of real-time control strategies, performance monitoring systems and data collection to support service realignment.

The objective of this project is to investigate the application of ITS technologies to improve the overall efficiency and productivity of transit operations. The perspective is to minimize the cost of achieving a desired level of service or, alternatively, maximizing

the service quality within a given budget. Metrics that are investigated include fleet size and service frequency, passenger waiting and travel times, driver hours-of-service, and fare-box collection. The investigation covers field evaluation of the impact of ITS on driver and fleet productivity and simulation of transit networks with ITS capabilities.

As part of this project, bus control strategies using ITS were evaluated against those without ITS. Two levels of ITS are considered: (1) system with centralized tracking and (2) system with information on connecting passengers, as well as centralized tracking. By making use of real-time information such as vehicle location, it is expected that control strategies using ITS have the potential to improve connectivity between origins and destinations while reducing passenger waiting times. Results of the simulation analysis show that the ITS based strategies have the potential to improve connectivity between origins and destinations while reducing passenger waiting times.

MOU 375 – Assessing Opportunities for ITS in California’s Passenger Intermodal Operations and Services

Mark Miller, PATH

An overview of the current state of passenger intermodalism was performed. This included a discussion of the motivating factors for an intermodal system, barriers to its implementation, support of intermodalism via policy measures, development of intermodal terminals and intermodal performance evaluations, transit and its linkages with intermodalism and intelligent transportation systems, implementing an intelligent intermodal system, and lessons learned.

There are a number of barriers that have prevented the significant advancement of intermodal passenger transportation. Such barriers include: institutional, system integration, interoperability requirements, funding constraints, poor condition of physical infrastructure, low market demand for intermodal services, user concerns, lack of data, lack of performance criteria, uncertainty of actual benefits. However, the passage of legislation at the federal level has provided the policy support for a national intermodal system. In particular, ISTEA and its recent reauthorization, the Transportation Equity Act for the 21st Century, have provisions for encouraging further development of an intermodal system using the application of advanced technologies. Efforts to improve the physical infrastructure of the intermodal transportation system are also evident by the substantial investment in intermodal facilities in many major metropolitan areas ranging from simple projects to major developments.

Since intermodal trips often involve the use of at least one form of transit, addressing transit performance is necessary to improve passenger intermodalism. The inability of transit to adequately serve transportation needs is a major deterrent to intermodalism, but one which ITS can effectively address. ITS technologies can improve transit by addressing major problems, such as inconvenient bus routes, anxiety caused by waiting for the bus, long transfer times, safety concerns, and cost to the customer using

technologies such as automatic passenger counters, geographic information systems, and automated vehicle location.

The realization of an intelligent intermodal system will require continued support from policy makers, changes in institutional attitudes, substantial investment in infrastructure, and technological expertise. While ITS cannot provide solutions for all the barriers to intermodalism, the evolution of ITS has created new opportunities for improving intermodal operations and services. From the review of the literature, it is evident that little has been done in the area of evaluating passenger intermodalism. There is little evidence of evaluations being performed at any intermodal transfer facilities. In addition, there are few documented results on quantifiable benefits of the deployment of ITS for transit applications. A possible explanation for this is the lack of data and quantifiable measures of effectiveness. Absence of data on linked intermodal trips poses a barrier to identifying where transfers occur, where intermodal needs are unmet, and where they might be improved. Many measures of effectiveness are not quantifiable, making it more difficult to perform evaluations that can be compared across modes or facilities. These qualitative measures, such as passenger comfort and convenience, are just as important as quantitative measures nonetheless.

6. Decision Support

MOU 355 - ITS Evaluation Website

Joy Dahlgren, PATH

The LEAP website (www.path.berkeley.edu/~leap/), Learning from Evaluation and Analysis of Performance, is designed for a wide audience:

- people who wonder what Intelligent Transportation Systems (ITS) are
- potential ITS implementers who wonder if ITS might help travelers in their region or might reduce costs for their agency and who want to know what other agencies have done and how well it worked
- policy makers who want to learn about the results of ITS implementation and research
- researchers who want a good initial source of information on ITS with references.

LEAP researchers gather information from a variety of sources and analyze, summarize and present the information in an easy to use format. LEAP describes user services and tells how they work, where they have been implemented and how they performed. It provides references for people who want to learn more. It focuses on evaluations of performance in field tests and deployments. This information is supplemented by research results from prospective modeling of ITS services.

The website began in July 1996, with one user service, incident clearance. Since then it has steadily grown and now includes almost all users services included in the ITS National Architecture, except for advanced vehicle control and safety systems. New services added this year were: en-route driver information, en-route transit information, probe vehicle surveillance, highway-rail intersections, personalized public transit, public transit security, and emissions testing and mitigation were added to the website. Older sections were updated and reorganized for easier access. The brochure describing the site was also updated.

MOU 357 - Benefits and Costs of ITS

David Gillen, Jianling Li, & David Levinson, PATH

The emphasis on this project has been on developing decision analysis tools for ITS. The original focus was on Benefit-Cost Analysis but this was 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 distinguishes ITS projects is the need for modeling to forecast the benefits (and costs in some instances) due to the lack of historical information and the unique features of ITS benefits. 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. Secondly, ITS generates benefits that are not fairly represented by traditional aggregate measures of VMT. In this sense more care must be taken in measuring the benefits of ITS investments. One important difference is the emphasis on economic efficiency rather than purely productive efficiency.

In the course of this research a technical manual presenting the alternative evaluation methodologies for ITS projects was developed. This provides a detailed description and comparison of benefit-cost analysis, cost effectiveness and impact analysis as applied to ITS projects. In addition to this general treatment, a detailed examination and evaluation of electronic toll collection (ETC), ramp metering and ATIS were conducted. A computerized spreadsheet benefit-cost model for ETC and ramp metering were also produced. These two evaluation models are applied to cases in California.

The ETC research used the Carquinez Bridge ETC project as an example of an ITS application. The contribution of this research was identifying and measuring the categories of costs and benefits for an ETC application and assessed the degree to which ETC should be implemented at a given site, meaning the proportion of lanes that should be electronic and the factors that influence this decision.

The ATIS research examined the issue of driver behavior, as they become more informed with the advent and deployment of in-vehicle navigation systems. Information technology will provide the driver the minimum travel time between his or her current location and final destination, updated to consider real-time recurring and non-recurring congestion. This research considers the effects of those systems, which not only reduce the driver's travel time and vehicle operating costs, but also have positive or negative external travel time effects for other commuters and environmental effects for society at large. Furthermore, over the long term, such systems may reduce the need to construct additional highway infrastructure, or may induce additional demand.

The ramp metering study undertakes an evaluation of the benefits and costs of ramp metering. The primary purpose was to provide empirical information on the value of the introduction and use of this form of ITS technology. Three cases are examined in the analysis. The impact of ramp metering on traffic behavior is simulated based on a cell transmission model and an assumed travel demand on the freeway as well as the ramp. Temporal travel demand change is determined based on the average travel pattern obtained from the I-880 freeway database. Isolated, single traffic responsive ramp metering is assumed. We identify and quantify the benefits and costs based on established assumptions, and finally analyzed economic value of ramp metering. Benefits of ramp metering are derived based on travel time value and fuel consumption and by savings in travel delay. In this study, it turns out that there is a net increase in vehicle emissions as a result of with ramp metering. The costs of ramp metering are site dependent and a function of planned metering technology. Since this study is not for any specific site, costs are estimated for three cases obtained from conversation with traffic engineers at Caltrans District 4 or literature.

MOU 361 – HOT Lanes and Demand for Travel Time Savings

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The HOT and HOV lane concepts were compared and a model was developed to compare the performance of a HOT lane, an HOV lane, and a mixed flow lane in terms of total person delay. The model was applied for a variety of circumstances in which a new lane might be added to a freeway. The circumstances included initial maximum delays of 15, 30, and 45 minutes and initial percentages of HOVs of 5%, 10% and 20%. Nine cases were modeled. In all but one case a HOT lane resulted in less total person delay than an HOV lane. In the other case the delay was the same. These findings suggest that in locations where tolling would be feasible and where HOV lane utilization is low, HOT lanes might be a preferable alternative to an HOV lane. A mixed flow lane performed as well as or better than a HOT lane in terms of total person delay except when the initial maximum delay was 45 minutes. However, an HOT lane provides people an opportunity to buy a delay free trip. In this analysis it was assumed that the toll could be set to achieve the maximum utilization of the HOT lane consistent maintaining free flow speeds on the lane.

Data from the variable priced express lanes on SR 91 in Orange County were used to analyze the demand for travel time savings. Regression analysis, using a number of different formulations, was used to estimate how the number of vehicles using the toll lane varied with the cost per minute saved (the toll divided by the difference between travel time on the main lanes and toll lane). The best fit was obtained by regressing the logarithm of the number of vehicles using the toll lane on the logarithms of the cost per minute saved and the total number of vehicles on the freeway at two locations. However, the findings were inconclusive. Eastbound, afternoon travel showed a low negative elasticity of demand for travel time savings. Westbound, morning travel showed a positive elasticity. This unreasonable result was apparently caused by a strong positive correlation between total freeway volumes and tolls, which caused the effect of the volumes to obscure the effect of the toll. The high level of aggregation of the data may also have contributed. More analysis using less aggregated data and a longer time series is needed.

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