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CALIFORNIA PATH PROGRAM
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PATH ITS Research Digests

Ted Chira-Chivala

**California PATH Working Paper
UCB-ITS-PWP-2001-20**

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

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

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PATH ITS Research Digests

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Technology Transfer

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Table of Contents

1. Benefits	1
2. Detection	29
3. ITS	69
4. Signal	109
5. System Performance	133
6. Traveler Information	157
7. Video	189

Benefits

Title: Assessing the Benefits and Costs of Intelligent Transportation Systems:
Ramp Meters

Author: Seungmin Kang, UC Berkeley-PATH

UCB-ITS-PRR-99-19 (1999)

Problem

Ramp meters are commonly used to relieve congestion on freeways. What is the value of these systems? Ramp metering can alleviate recurrent, regular traffic congestion, such as that caused by the daily commute. The goal is usually to maintain uninterrupted freeway flow at a certain acceptable level, but it transfers delay to the entrance ramp, where excess demand is forced to wait. This report summarizes ramp metering technologies, reviews the algorithms commonly used with them, and uses a traffic simulation model to identify the benefits and costs of using these systems.

Method

We used a combination of experience from 10 different sites using ramp metering and a traffic simulation model to identify and test costs and benefits.

Because our assumptions produced positive results, we changed some of them to reduce benefits, but even so we found ramp metering to be worth implementing. The changed assumptions included reduced ramp demand, reduced freeway demand, and reduced capacity.

Findings

Benefits from using ramp metering systems include increased speed of traffic, travel time reductions, accident reductions (as high as 50%), and an increase in traffic flow, which by reducing stop-and-go conditions on freeways also reduces fuel consumption and some emissions—even when the increase in fuel consumption caused by vehicles waiting on the ramp is accounted for. However, ramp metering also causes a general increase in emissions.

Costs include: installation and maintenance, the major expense in this area being for communications between the ramp and the control center; ramp delay and spill back, including increased traffic on alternative routes; and an increase in fuel consumption and emissions.

In every case, the benefit-cost ratio exceeds 1, so ramp meters are a worthwhile investment.

Title: Automated Travel Time Measurement Using Vehicle Lengths From Loop Detector Speed Traps

Author: Benjamin Coifman, Civil Engineering, Ohio State University

UCB-ITS-PRR-2000-12 (2000)

Problem

Travel time data is a useful tool for traffic engineers, offering the possibility of better incident detection, ramp meter control, and traveler information. It will become even more useful as input for emerging technologies such as dynamic traffic assignment; more importantly, it can be used now to quantify the benefit of such new technologies before making significant infrastructure investments.

This report presents a method of measuring travel time using existing loop detector infrastructure, inexpensive computers, and real traffic data.

Method and Findings

This method uses an algorithm to match vehicles detected at one loop detector station with the same vehicle at the next station; the difference in time between stations is the actual travel time of that vehicle.

Because the loop detectors measure effective vehicle length, it is possible to distinguish individual vehicles as they pass over it. However, such a length measurement may be accurate to only two feet, depending on the speed of traffic, making it difficult to match pairs from one detector to another. It is simple to eliminate unlikely matches from this scenario; however, the data produces a series of “possible matches” that must then be distinguished in order to make sense of the information.

To eliminate false matches, the algorithm matches platoons where vehicles pass both detectors in the same relative order. The platoon should produce a contiguous sequence of possible matches; if these are long enough, the problem posed by false matches can be eliminated.

Three closely related algorithms use different strategies to eliminate spurious sequences due to false matches. The algorithms were used to measure travel times on a large data set and the average measurement error for the different algorithms ranged between 0.7 percent and 4.5 percent, corresponding to an average segment velocity error between 0.4 mph and 1.5 mph.

Call Number: UCB-ITS-PWP-2001-2

Title: Caltrans TOPS Evaluation: Assessing the Net Benefits of ITS Applications

Authors: David Gillen

Date January 2001

Method

The purpose of the research was to provide the Caltrans Traffic Operations Group and New Technology Group with a measure of the expected net benefits with the application of ITS projects to parts of the California highway system. The value of the research is that it would provide measures of the changes in benefits from ITS projects as the size of the projects change and as projects are introduced in combination with one another.

The outcome of a set of experiments undertaken to assess the net benefits of ITS applications in a stylized urban and near-urban highway network is presented. The work was completed using the IDAS Build I package. Despite the limitations of this first generation package, the research was able to assess a number of different ITS technologies including ramp meters, incident management, integrated technologies and synergies from multiple ITS applications.

Findings

While not able to conduct the experiments originally envisioned and not having been able to utilize Paramics as the preferred simulation tool, the experiments conducted using IDAS were successful. They provided some insight into the application of ITS projects to a highway system. The research examined change in net benefits resulting from expansion of the number of ramp meters as well as a shift in technology from moving from pretimed ramp meters to centrally controlled ramp meters. The research also examined incident management and the change in net benefits as the response time to the incident was reduced. Finally, the research also examined the synergies that might arise as combinations of ITS applications are applied to the highway system.

The research concluded that there are diminishing returns to adding a given technology. With ramp meters, there was a huge transfer in benefits from arterial road users to freeway users since traffic was held on the ramp to increase speeds on the freeway by a small amount. However, when the model was shifted from 5 pre-timed to 5 centrally controlled ramp meters, an increase is seen in the benefit/cost ratio. The conclusion is that the shift from a pre-timed "old technology" ramp meter to a "central control" new technology results in considerable benefits. Furthermore, the benefits from new technology (i.e., ITS) exceed those of expanding the old technology (e.g., increasing the number of pre-timed ramp meters). The increase in benefits is sufficiently large that the "gainers" could compensate the "losers" and still be better off themselves.

Title: The Costs and Benefits of Telecommuting: A Review and Evaluation of Micro-Scale Studies and Promotional Literature

Authors: Kevan R. Shafizadeh, Patricia L. Mokhtarian, Debbie A. Niemeier, Ilan

Date August 2000

Description of the Research

The purpose of this study is to assess the methodologies, assumptions, and results of economic evaluations of telecommuting presented in reports on "small-scale" pilot demonstration programs. Micro-scale studies focus on the costs and benefits at the individual and organizational level whereas macro-scale studies typically focus on estimating the aggregate costs and benefits for regional or national populations of telecommuters.

This report examines four micro-scale studies in order to provide information on the individual costs and benefits of telecommuting using empirical data (most often from employee surveys) that cannot be obtained from macro-scale studies, which are largely hypothetical in nature.

The studies reviewed were:

- \$ *Evaluation Report: Telecommuting Pilot Project for the South California Association of Governments* (Southern California Association of Governments, 1988)
- \$ *County of San Diego Dept. of Public Works, Telecommuting Prototype Program, Telecommuting Pilot Study Final Report* (County of San Diego Department of Public Works, 1990)
- \$ *State of California Telecommuting Pilot Project Final Report* (JALA Associates, 1990), and
- \$ *City of Los Angeles Telecommuting Project* (JALA International, 1993)

Many other studies were also considered, but only the aforementioned four studies had collected and reported detailed monetized cost-benefit results.

Conclusions of the Research

In the studies considered, not all costs were accounted for. Those that were accounted for remain specific to the "bottom line" of the employer and fail to consider the telecommuter. In general, the primary goal of the studies considered was that of evaluating the feasibility and cost-effectiveness of telecommuting from the employer's perspective. Key costs and benefits of telecommuting were often acknowledged, but not fully quantified.

It is important to realize that the studies reviewed show only a part of the picture and should be used in concert with macro-scale studies. To fully understand the direct and indirect economic ramifications of telecommuting programs, care should be taken to include perspectives of the telecommuter, the employer, and the public sector, with the retrospective costs and benefits correctly assigned to each party. As noted in the Southern California Association of Governments study, "when pooled into a large sample, this information can give valuable insight into the transportation, energy, and telecommunications impacts of widespread telecommuting."

Finally, it is observed that there is still a need for empirical telecommuting cost/benefit data collection focusing both on direct and indirect costs and benefits for the telecommuter and the employer.

Locator Number:
UCB-ITS-PRR-2000-13

Title: Definition and Measurement of Transportation System Performance
Authors: Joy Dahlgren (California PATH, Institute of Transportation Studies, Berkeley)

UCB-ITS-PRR-98-24 (1998)

Problem

Performance measures are needed to help make decisions regarding the overall level of resources to devote to a transportation system, where to allocate these resources, and how best to use them.

Decisions regarding the level of resources and where to allocate these resources require regular monitoring of the system to reveal opportunities for improvement. The decision of how best to use transportation resources must be more carefully examined in order to evaluate multiple means of addressing transportation needs and their respective costs and benefits to the public.

Method

The overall goal of a transportation system is to maximize the benefit of the system over its costs. Performance measures should therefore relate benefits to costs.

Specific attention is given to intelligent transportation systems which have both the capability to deliver benefits to a transportation system, and the capability to generate useful data on vehicle-miles and travel time within a transportation network.

Findings

The primary costs of transportation: time, money, property damage and injury, environmental degradation, and discomfort, such as the stress or delay caused by difficult driving conditions. Transportation system performance is measured in terms of the amount of transportation provided, which indicates the amount of access provided (person-trips, person-miles, and \$-miles of freight), travel time (both the average and the variation), and the amount of property damage and injury, and public monetary costs. These are the primary determinants of overall benefits and costs. These determinants are measurable and they can be influenced by the actions of transportation agencies.

In order to provide useful data for routine transportation system performance assessment, the following is recommended:

- Limit the number of routine measures, to concentrate resources on the most useful measures.
- Continue research to improve methods for measuring volumes and travel times.
- Develop a prototype travel time and volume measurement system, including data collection, processing, and storage, and characterization of performance.
- Develop schedules for measuring performance that are appropriate for different traffic situations.

Title: Definition and Measurement of Transportation System Performance
Authors: Stephen G. Ritchie and Carlos Sun (University of California, Irvine)

UCB-ITS-PRR-98-33 (1998)

Problem

The research sought to improve traffic incident detection and congestion monitoring for more accurate and reliable measurement of traffic system performance.

Method

This project presents a new set of advanced traffic surveillance techniques based on inductive loop detector (ILD) technology currently in widespread use. The emphasis is on applying new algorithms to inductive loop detector data to obtain vehicle “signatures.” By correlating the vehicle signature data from two sets of loop detectors, one “upstream” and one “downstream,” data can be obtained on the traffic characteristics of a section of the transportation network.

The research included development of a process for extracting vehicle feature vehicle pattern matching information from the inductive loop detector data so that information on traffic density and travel time data could be obtained. A video system was used to validate the inductive loop detector data and vehicle pattern matching accuracy.

Findings

The section-related data generated by the system developed for this research project provides a quantitative measure of traffic density, which can be used as a direct measure of traffic demand. Traffic density also gives a good idea of the “closeness” of vehicles, which can reveal the psychological comfort of drivers. For example, the stress level associated with free-flowing traffic is much less than that of “stop-and-go” traffic.

Call Number: UCB-ITS-PRR-2000-11

Title: Deploying Electronic Tolls
Authors: David Levinson and Elva Chang
Date May 2000
UCB-ITS-PRR-2000-11

Problem Addressed by Research

Electronic toll collection (ETC) is a completely new way to collect tolls, with the potential to reduce congestion, delay, and gasoline consumption, staffing costs of the toll agency, and air pollution. Implementing agencies need to know how quickly lanes should be converted to ETC, and what discount to offer subscribers. Too many lanes converted too quickly will increase delay for those who are not yet subscribers, and too high a discount can cut into the toll agency's revenue.

Method

We used a dynamic payment choice model to understand how users choose whether to buy an ETC transponder or not. In the model, travel time, ideal lane configuration, optimal discount, and payment choice are all interrelated. We apply the model to California's Carquinez Bridge.

Findings:

Societal benefits and costs of ETC vary with demand and the number of ETC lanes, and the question for agencies is: what provides the most benefit at the least cost?

Overall welfare is improved the greater the ETC market share, and the sooner that share is achieved. Toll agencies can affect the evolution of ETC by imposing congestion on manual toll lanes by decreasing their number, and by increasing the size of the discount offered to ETC subscribers.

There is a "buy-in" hurdle that keeps people from subscribing to ETC, which involves buying a transponder and establishing an account. At this time we are unable to say precisely what is the source of that reluctance, and whether it will rise or fall over time. While our data for the Carquinez Bridge suggests it might not fall, the agency did very little marketing while it learned to make the technology work smoothly, and a more concerted effort in this area could shift preferences towards ETC. Also, non-user confidence increases with the number of users, as drivers see others benefiting from it.

Compatible systems using the same transponder (various bridges and toll roads, and even parking lots and service stations, as has been implemented in some areas) increase the utility and value of the transponders as well as the likelihood that drivers will become subscribers.

Title: Evaluation Methods for Measuring the Value of ITS Services and Benefits from Implementation: Part X Freeway Service Patrols
Authors: David Levinson, Pavithra Kandadai Parthasarathi
Date January 2001

Problem Statement

Incident management programs are one of the key elements of Intelligent Transportation Systems (ITS). The goal of such programs is to clear the incidents from the roadways and return traffic flow to normal as soon as possible. Incident management programs have been introduced in many places to facilitate incident detection and reduce incident duration. They make use of ITS services and coordinate among the various operating agencies to meet the goals of quick detection and clearance of incidents.

Highway assistance services, also called the freeway service patrols (FSPs), are one of the main approaches used by incident management programs. These patrols use vehicles to patrol the heavily traveled segments and congested sections of the freeways that are prone to incidents. The main goals of the FSPs are to help identify incident locations, reduce the incident duration time, get the freeway capacity back to the fullest and to reduce the risks of secondary accidents without any assistance from other agencies. In cases of major incidents, the patrols help assess the equipment and resources needed to clear the incidents, coordinate with other agencies involved, and provide the needed traffic control and buffer between the workers and traffic. They also help detect and verify incidents like major accidents and pass on the required information to the transportation management centers (TMCs). This helps reduce delay, congestion, wasted fuel, emissions and potential for secondary accidents.

Previous analyses of the freeway service patrols include studies conducted by California PATH (Partners for Advanced Transit and Highways) program at the Institute of Transportation Studies (ITS) University of California Berkeley and Texas Transportation Institute concluded that FSPs are cost-effective, successful in their objectives of reducing incident duration and facilitating quick detection, and highly popular among motorists.

This research sought to determine the value that people place on the benefits offered by FSPs in comparison to private assistance services such as the Automobile Association of America (AAA), and how much they would be willing to pay to avoid being stranded when their vehicle breaks down on the freeway. The studies conducted so far have focused on the effectiveness of the freeway service patrol whereas this report analyzes the factors that influence people in choosing to rely on the freeway service patrol.

Findings

This research shows that the probability that an individual would choose the highway assistance services depends on the key attributes like the annual fee of the program, the fee at the time of assistance, the time of waiting for assistance and cost of breakdown. The findings also show that the presence of the highway assistance services in a state does have a small influence on the auto club (AAA) membership.

The researchers also concluded that the data sets for Stated Preference and Revealed Preference analyses were too small. Larger data sets were anticipated to provide better results and clearly indicate the factors influencing people's choices. A pilot survey conducted on a larger scale would likely provide a better evaluation of the factors influencing people's choices related to FSP use.

In addition, the research concluded that the sample set was probably socio-demographically too homogeneous. A larger heterogeneous sample set would provide better indications of the way the socio-demographic variables impact the choices of motorists.

Locator Number:
UCB-ITS-PWP-2001-3

Title: New Aggregation Strategies to Improve Velocity Estimation From Single Loop Detectors

Author: Benjamin Coifman and Zu-Hsu Lee

UCB-ITS-PWP-2000-12 (2000)

Problem

Single loop detectors are commonly used to measure speed and flow on highways, but they have serious shortcomings in this area, as do conventional methods for estimating velocity from their information. For example, velocity and length cannot be measured independently at a single loop. Typically, operators set length to a constant value so they can estimate velocity. However, long vehicles can be up to four times as long as other vehicles, so they skew the data, and thus cause inaccurate results. Researchers have attempted to fix this by estimating mean velocity using aggregate flow and occupancy rates. We have come up with a new way to aggregate data, rather than manipulate aggregate data, to reduce estimation errors.

Method and Findings

We studied data from dual loop detectors, which can measure true vehicle velocity and length. By experimenting with the data, we found that median length estimates were much closer to accurate than mean length estimates. We also found the same to be true for the resulting velocity estimates: median estimates were much less subject to error.

Working with fixed time samples rather than the fixed number-of-vehicle samples we used in the preceding example, and insuring that the sample periods were long enough to be useful, we found similar results: there were significant errors in the mean velocity estimate and few in the median estimate.

We found that five minutes provided sufficient sample size. However, this may be too long in some cases, so we also set the time period shorter and sampled across five lanes at once, obtaining similar results.

Title: Evaluation of ITS Technology for Bus Transit Systems

Authors: Randolph Hall, Maged Dessouky, Lei Zhang, Ajay Singh, Vishal

Date November 1999

Description of the Research

Recently, bus transit service providers have begun to adopt Intelligent Transportation Systems (ITS) technologies such as Global Positioning Systems (GPS) and Mobile Data Terminals. 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. This research evaluates bus control strategies using ITS against those without ITS. Two levels of ITS are considered: 1) a system with centralized tracking, and 2) a system with information on connecting passengers, as well as centralized tracking. For those strategies using ITS, we develop methods to forecast bus arrival times to a stop and the number of passengers on board the bus.

Conclusions of the Research

Several different ITS strategies were evaluated. In terms of minimizing the average passenger trip time, the ITS strategies outperformed the non-ITS based strategies for the random generated problem sets, though not for one real-life dataset.

Overall, the researchers found it disappointing that ITS did not provide larger time savings in the analysis conducted for this research. A fundamental reason for this is that in many situations, it is optimal to either have a bus leave immediately whether or not connecting buses have arrived, or to wait as long as possible until all connecting buses have arrived. These extreme cases require no communication and no ITS.

ITS was found to be more beneficial for cases in which a connecting bus incurs a small delay and it is more advantageous to wait for its arrival than to depart without the connecting passengers.

The savings per passenger appear to be no more than 1 minute, which translates into annual time savings on the order of 500 to 2000 hours per bus. Savings of this magnitude may be sufficient to justify installation of an ITS system with payback within a few years. More generally, the savings are highly site-specific and should be evaluated on a case-by-case basis. Cost-benefit analysis was not performed as part of this research.

Locator Number:
UCB-ITS-PRR-99-38

Title: Evaluation of ITS Technology for Bus Transit Systems

Authors: Randolph Hall, Maged Dessouky, Lei Zhang, Ajay Singh, Vishal

Date November 1999

Description of the Research

Recently, bus transit service providers have begun to adopt Intelligent Transportation Systems (ITS) technologies such as Global Positioning Systems (GPS) and Mobile Data Terminals. 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. This research evaluates bus control strategies using ITS against those without ITS. Two levels of ITS are considered: 1) a system with centralized tracking, and 2) a system with information on connecting passengers, as well as centralized tracking. For those strategies using ITS, we develop methods to forecast bus arrival times to a stop and the number of passengers on board the bus.

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Locator Number:
UCB-ITS-PRR-99-38

Title: Evaluation of the OCTA Transit Probe System

Authors: Randolph W. Hall, Nilesh Vyas, Chintan Shyani, Vikas Sabnami, Simit

Date: November 1999

Description of the Research

The OCTA (Orange County Transit Authority) Transit Probe Project is a field operation test of an automatic vehicle-location (AVL) system operating in Orange County, California. The system software was designed to estimate roadway congestion levels based on bus travel times over route segments and communicate this information to Caltrans, the City of Anaheim, and the City of Santa Ana.

This report presents the final evaluation of the project, concentrating on the year-long field operational test period. The report provides a detailed description of the system and its design. It also provides analyses of data reliability and accuracy, and analysis of the usefulness of Transit Probe data for predicting automobile travel times. Institutional issues are evaluated, based on interviews with involved personnel, direct observation, and review of project documents. Surveys of bus riders and kiosk users are also documented.

Conclusions of the Research

Bus tracking systems provide many potential benefits related to scheduling, problem response, and bus arrival information for users. However, these benefits cannot be captured without carefully planning operational procedures, data maintenance, system interfaces, and ensuring that the equipment is reliable. These important issues did not receive adequate consideration in the system design phase of the project. Although the evaluation produced important insights as to how bus tracking should be implemented and the likely problems to expect, the OCTA Probe failed to live up to its promise because the system was not used by drivers, dispatchers, planners, schedulers, or the general public.

Transit Probe did not meet reliability standards for an actual deployment. The majority of schedule data points are either missing, undetected, or duplicated, thus confounding data analysis.

Transit Probe never created its intended interfaces to Caltrans, the City of Anaheim, or City of Santa Ana due to a reduction in scope of the deployment and a reduced budget.

Only one public interface kiosk was installed, and though it was well-received in a test evaluation, it wasn't functional until the end of the project and therefore didn't have any positive impact.

Customers perceived that bus schedule adherence had improved during the Transit Probe project, though whether this represents a real improvement or merely public perception is not altogether clear. From bus driver interviews, it seems that the installation of a clock in driver view may have encouraged better schedule adherence. However, drivers generally ignored Transit Probe indicator lights, and therefore the improvement could not have resulted from Transit Probe's schedule adherence capabilities.

The congestion measurement component of Transit Probe was never fully established due to many factors, including: 1) inadequate congestion information dissemination, 2) improperly established baseline bus route segment speeds, 3) inaccurate speed estimation algorithm in Transit Probe, 4) lack of relationship between slow bus speeds and general traffic speed.

In terms of the institutional performance of OCTA Transit Probe, OCTA involved partner agencies commendably while moving the project forward and meeting deadlines during the design phase. However, once the project progressed to the test phase, the organization became rather conventional with a contractor and contract manager and outside participation virtually disappeared.

Locator Number:
UCB-ITS-PRR-99-39

Title: Freeway Performance Measurement System: Final Report

**Authors: Pravin Varaiya
University of California, Berkeley**

Date: January 2001

Description of the Research

This report summarizes the design, operation, and implementation of PeMS (Performance Measurement System). Topics covered include the communication and software architecture of PeMS, its applications, observations of PeMS in operation, and an appendix consisting of an empirical study of congestion, capacity, and ramp metering using PeMS.

Conclusions of the Research

PeMS is a low-cost freeway performance measurement system for all of California. PeMS processes 2 GB/day of 30-second loop detector data in real time to produce useful information to travel network managers, traffic engineers, planners, researchers, and travelers.

PeMS utilizes an open communication and software architecture, meaning that the code used to develop the software is publicly accessible and that modifications or add-ons can easily be made to PeMS. A new district can be added to the PeMS system with six person-weeks of effort and no disruption of the district's TMC (Traffic Management Center); data from new traffic loops can be easily added as it is available. PeMS applications are accessed via a Web browser, an interface with which the majority of users will already be familiar.

PeMS is inexpensive, utilizing off-the-shelf products for communication and computation. PeMS uses data retrieved from the existing Caltrans ATM wide area network to which all districts are already connected.

PeMS benefits users in several ways:

- \$ Caltrans managers can instantly obtain a uniform and comprehensive assessment of the performance of the freeway network.
- \$ Caltrans traffic engineers can base their operational decisions on knowledge of the current state of the freeway network.
- \$ Caltrans planners can examine solutions to congestion. Traffic control equipment, such as ramp-metering and changeable message signs, can be optimally placed and evaluated.
- \$ Travelers can use PeMS via products developed by VARs (Value Added Resellers) to choose optimal travel routes.
- \$ PeMS can serve to guide and assess intelligent transportation system (ITS).

**Locator Number:
UCB-ITS-PWP-2001-1**

Title: Freeway Service Patrol Evaluation

**Authors: Alexander Skabardonis, Hisham Noeimi, Karl Petty, Dan Tydzewski,
Pravin P. Varaiya, Haitham Al-Deek**

UCB-ITS-PRR-95-5 (1995)

Problem

The Freeway Service Patrol consists of teams of tow trucks that patrol highways and provide assistance to motorists. It is used in several places throughout the state for quick removal of incidents and to reduce congestion delay and other adverse effects from incidents on freeways. How well does the patrol work?

Method

We collected incident information for a section of freeway in the San Francisco Bay Area (in Hayward) using probe vehicles, loop detectors, the CHP dispatch system, FSP records, and tow truck company logs. In all, 276 hours of field data went into a unique, comprehensive database that represents a complete representation of freeway operating conditions. We were able to study and compare conditions both before and after the institution of the Freeway Service Patrol on this section of freeway.

Findings and Recommendations

This study found that the Freeway Service Patrol increased the number of assisted incidents, and reduced response time and duration. The FSP is also cost effective in terms of incident delay and fuel consumption savings.

The response time for breakdowns where FSP assisted was cut by 57%; for all incidents, the response time went down by 35%. Accident and breakdown clearance remained about the same, as did incident duration. The reduction in assisted incidents is probably largely accounted for by a quicker response time because the tow trucks were already in the field.

Other benefits from the service which we did not quantify include time and cost savings to assisted motorists, improved incident detection, and a reduction in the amount of work the CHP has to do, allowing them more time for enforcement.

The effectiveness of FSP would be higher in places with similar incident patterns and a higher traffic volume, especially where there are mixed lands and narrow or no shoulders.

Title: An Investigation in the Use of Inductive Loop Signatures for Vehicle Classification
Author: Carlos Sun

UCB-ITS-PRR-2000-4 (2000)

Problem

If we could accurately sort vehicles using our highways according to predefined classes, we could improve vehicle re-identification algorithms and traffic simulation models, gaining useful information to benefit highway maintenance, vehicle emissions management, highway design, traffic safety, and automatic toll collection systems. If we could do this using the current inductive loop technology already in place, we could gain all these benefits immediately, and with simpler equipment than is used by other commercially available systems.

Method and Results

Using different pattern recognition techniques, we tested vehicle classification algorithms on the SR-24 freeway. We used existing loop detectors that can output a vehicle inductive signature. We divided vehicles into seven classes (car, SUV/pickup, van, limousine, bus, two-axle trucks, and larger trucks) to test two classification methods. The first method, a heuristic discriminant algorithm, used multi-objective optimization for training the heuristic algorithm. We developed three different heuristic algorithms which yielded 81 to 91% accuracy. The second method used self-organizing feature maps (SOFM), which are artificial neural networks, and got similar rates of 80% accuracy.

Title: **Measuring the Aggregate Productivity Benefits from ITS Applications: The California Experience**

Authors: **David Gillen, Matt Haynes**

Date **September 2000**

Description of the Research

There are three comprehensive policies contained in California's Transportation Plan (CTP). These policies are to promote economic vitality through mobility and access; to provide safe, convenient and reliable transportation; and to provide environmental protection. Transportation applications such as Intelligent Transportation Systems (ITS) offer much in the way of addressing the policies given in the CTP.

Because investments in ITS technologies will clearly have widely differing impacts, there is an inherent uncertainty in predicting the impacts of a particular ITS strategy in a given location. If better understanding can be gained of the extent to which ITS strategies provide benefits to the economic output of a county or region, then decisions to invest in ITS in the future will be better informed. This study uses measures of productivity to assess the impacts that ITS applications have had in California counties.

Conclusion of the Research

Two related models were used to evaluate the economic benefits of ITS.

The first model was a production function model that represented the way a county assembled and delivered a range of goods and services to the marketplace. Included in the production function were private capital, labor resources, highway capital, and measures of the development and integration of ITS projects into the highway system. Two ITS technologies were considered: ramp meters and changeable message signs. The empirical results show that highway capital provides counties with a competitive advantage creating output gains and a net positive benefit.

The second modeling effort was to develop measures of Total Factor Productivity (TFP). This productivity measure takes account of the aggregate growth in outputs as well as inputs. The research estimates show that ITS adds benefits that should be counted in any project evaluation. The benefits are in the form of improvements in productivity. This leads to cost reduction in the delivery of gross county product.

Further research should focus on answering the following questions: What industries are most affected by ITS applications? Does it matter how many ITS applications are present, in other words, are there diminishing returns to similar ITS projects? Finally, does it matter how ITS projects are combined?

Locator Number:
UCB-ITS-PWP-2000-17

Title: A New Methodology for Evaluating Incident Detection Algorithms

Authors: Karl Petty, Peter J. Bickel, Jaimyoung Kwon, Michael Ostland, John Rice

Date August 2000
UCB-ITS-PWP-2000-11

Problem Addressed by Research

Automatic incident detection algorithms (AIDs) can operate on data from inductance loop detectors using methods including filtering, pattern recognition, catastrophe theory, neural networks, and genetic algorithms. Determining which AID is best for a given situation is difficult, in part because parameters must be set by the practitioner, and performance is very sensitive to these settings. Standard evaluation of AIDs has focused on the difference between detection rates (DR) and false alarm rates (FAR), but this method is fraught with difficulties. For one, judging what constitutes an incident is a subjective action, and makes fair comparisons between different algorithms nearly impossible. Also, DR-FAR curves treat all incidents with equal importance, whether they are low-impact breakdowns on the shoulder or major accidents causing hours of delay.

Method:

Our approach to evaluating AIDs attempts to solve these problems by using costs rather than DR-FAR curves. That is, we estimate costs of delay as well as the costs of implementing the AID (dispatching tow trucks, etc). The estimates are based on assumptions using training data, and can be consistent for all algorithms under evaluation. Severity of incidents and time to response are automatically factored into the analysis, as they are reflected in the cost.

Practitioners are best qualified for making assumptions linking congestion and costs, and our method allows for flexible formulations of cost. For example, the cost function could reflect increasing benefit for responding promptly to injury accidents.

An AID can be "tuned" to be very sensitive, which reduces delay because incidents are quickly detected. However, greater sensitivity also means increased implementation costs, as more interventions are called for. The goal is to strike a balance between costs of delay and costs of implementation.

Our equation converts delay and implementation actions to costs and finds the lowest possible cost of an AID using a given set of data.

Findings and Recommendations:

Our method systematically tunes the parameters of an AID and makes it possible to fairly compare different types of AIDs, avoiding several problem inherent in DR-FAR curves. For example, the severity of an incident in terms of congestion and the time it takes to detect it are automatically factored into the analysis. Our flexible framework allows practitioners to tailor the cost functions to the particular problem, and to set AID parameters systematically by finding the lowest cost for a given set of data.

Title: Productivity Benefits and Cost Efficiencies from ITS Applications to Public Transit: The Evaluation of AVL

Authors: David Gillen Elva Cange Doug Johnson

Date September 2000

Description of the Research

Automatic Vehicle Location technology is a component of Intelligent Transportation Systems (ITS) that enables transit agencies to monitor fleet vehicle performance and location. AVL has the potential to improve the on-time rate of public transit and timed transfers, accessibility and accuracy of passenger information, availability of data for transit management and planning, and efficiency and productivity of transit services.

AVL has the potential to increase efficient fleet utilization and reduce expenditure for fuel, labor, and capital. AVL can also facilitate and integrate on-board electronic fare collection among different transit systems within a region. With an AVL system in place, passengers could use a single fare medium for multiple transit systems, resulting in more efficient fare collection and more efficient transfer among transit agencies that share routes or transfer credit.

This research uses information from operations and financial information from the Federal Transit Commission's database and information on AVL applications to explore whether and how AVL applications lead to changes in productivity and resource use.

Conclusion of the Research

The overall assessment of AVL is that it provides sizable benefits for both consumers and transit agencies. The research focused on the cost efficiency improvements from AVL, but some demand side benefits were explored as well.

Higher numbers of passenger trips were reported when AVL was implemented by the transit agency. The most significant improvements were in productivity and cost efficiency. Whether output was measured as passenger oriented or service oriented, productivity was greater with the use of AVL. The sources of the productivity gains came from better use of capital, decreased need for buses, more efficient use of fuel and energy, and reduction in vehicle maintenance and vehicle operations

**Locator Number:
UCB-ITS-PWP-2000-16**

Title: Simulation of ITS on the Irvine FOT Area Using ‘Paramics 1.5’ Scalable Microscopic Traffic Simulator: Phase I; Model Calibration and Validation
Authors Baher Abdullah, Jiuh-Biing Sheu, Will Recker

UCB-ITS-PRR-99-12 (1999)

Problem

Intelligent Transportation Systems (ITS) appear to provide a set of intuitively promising tools to improve the increasingly complex and rapidly deteriorating transportation systems of today. Comprehensive research tools for quantifying the expected benefits from ITS are, however, still absent.

In order to quantify potential benefits of a given Intelligent Transportation System, traffic simulators are needed that can be used to assess the benefits of ITS in the planning stages, as well as in the implementation stages as a way to generate and evaluate traffic scenarios, optimize control, and predict transportation network behavior.

Method

This report sought to present a list of traffic simulator attributes, or a “wish list” that a useful traffic simulator should possess in order to adequately model Intelligent Transportation Systems.

The research also calibrated, validated, and evaluated one promising traffic simulator called Paramics1.5 developed by Quadstone UK. The evaluation was performed on a model of the transportation network in Irvine, California, composed of a highly congested, non-grid arterial network in a rapidly growing employment center.

Findings

A list of requirements for a traffic flow simulator to successfully model ITS was developed.

Paramics1.5 proved to be an excellent “shell” or “framework” for a comprehensive traffic simulator. However, it also proved to have some limitations.

The most promising aspect of the Paramic1.5 program is its Application Programming Interface, or API, which is currently available and being further enhanced by Quadstone UK and is regarded as the most important capability of the software. A comprehensive API for Paramics1.5 would allow researchers to modify the program and customize it to allow researchers to overcome many of the limitations the program currently has.

Title: Definition and Measurement of Transportation System Performance
Authors: Joy Dahlgren (California PATH, Institute of Transportation Studies, Berkeley)

UCB-ITS-PRR-98-24 (1998)

Problem

Performance measures are needed to help make decisions regarding the overall level of resources to devote to a transportation system, where to allocate these resources, and how best to use them.

Decisions regarding the level of resources and where to allocate these resources require regular monitoring of the system to reveal opportunities for improvement. The decision of how best to use transportation resources must be more carefully examined in order to evaluate multiple means of addressing transportation needs and their respective costs and benefits to the public.

Method

The overall goal of a transportation system is to maximize the benefit of the system over its costs. Performance measures should therefore relate benefits to costs.

Specific attention is given to intelligent transportation systems which have both the capability to deliver benefits to a transportation system, and the capability to generate useful data on vehicle-miles and travel time within a transportation network.

Findings

The primary costs of transportation: time, money, property damage and injury, environmental degradation, and discomfort, such as the stress or delay caused by difficult driving conditions. Transportation system performance is measured in terms of the amount of transportation provided, which indicates the amount of access provided (person-trips, person-miles, and \$-miles of freight), travel time (both the average and the variation), and the amount of property damage and injury, and public monetary costs. These are the primary determinants of overall benefits and costs. These determinants are measurable and they can be influenced by the actions of transportation agencies.

In order to provide useful data for routine transportation system performance assessment, the following is recommended:

- Limit the number of routine measures, to concentrate resources on the most useful measures.
- Continue research to improve methods for measuring volumes and travel times.
- Develop a prototype travel time and volume measurement system, including data collection, processing, and storage, and characterization of performance.
- Develop schedules for measuring performance that are appropriate for different traffic situations.

Title: TravInfo Evaluation Traveler Response Element: TravInfo 817-1717 Caller Study Phase 1 Results

Author: Youngbin Yim, Randolph Hall, Ronald Koo, Mark A. Miller

UCB-ITS-PWP-98-25 (1998)

Problem and Method

TravInfo is a federally funded Field Operational Test (FOT) of an open-access traveler information system for the San Francisco Bay Area. In operation since September 1996, TravInfo Traveler Advisory Telephone System (TATS) disseminates real-time traffic information and multi-modal travel options to Bay Area travelers through a landline telephone system.

The purpose of this research was to measure the effectiveness of TATS in helping callers make informed travel decisions. The initial survey was conducted seven months after TravInfo began operation. The effectiveness of TATS was measured by the satisfaction of callers with the service, the impact on their travel behavior, and the benefits perceived by them. TATS callers made use of either traffic information or transit information services.

Findings

Key findings of the research are:

An overwhelming majority of the callers were satisfied with the information they obtained from TATS and they mostly (60.4 percent) found the TATS information more useful, reliable, and accurate than radio. Nearly half (46.7 percent) of callers who learned about traffic problems from TATS changed their travel behavior.

TATS has attracted a segment of the driving population which rarely relies on radio or television reports in making travel decisions. Nearly half of the traffic information callers (48.3 percent) seldom or never listen to radio reports. The majority of the traffic information callers (86.2 percent) were repeat users; 51.3 percent of transit information callers were repeat users.

Most participants (98.3 percent of the traffic information survey group and 88 percent of the transit information survey group) said they would use TATS in the future.

Approximately one third (30.5 percent) of the traffic information survey group requested information via cellular phone *en route*. TATS was found to be better utilized than the traffic information systems offered by cellular providers (GTE Mobilnet, Cellular One).

Title: TravInfo Field Operational Test Evaluation: Target Study Final Results
Authors: Ronald Koo Youngbin Yim
Date: March 2000

Problem

TravInfo is a regional traveler information system in the San Francisco Bay Area. The goal of TravInfo was to broadly disseminate accurate, comprehensive, timely, and reliable information on traffic conditions and multi-modal travel options to the public in the Bay Area through a public-private partnership.

The TravInfo Field Operational Test (FOT) was comprised of four elements: institutional evaluation, technology assessment, traveler response, and transportation network performance. The traveler response evaluation had four coordinated studies:

1. Broad Area,
2. Target,
3. TravInfo Traveler Advisory Telephone Information System (TATS), and
4. Information Service Provider (ISP) Customer Studies.

This paper presents the final results of the Target Study, a case study of commuter response to traffic information on incidents along US-101 south of San Francisco. This corridor was selected because it offers several alternate roadways and mass-transit options for commuters who utilize it.

The Target Study objectives are to understand the extent to which incident information influences travel decisions, to measure the effects of incident information on overall travel patterns, and to assess the benefits of incident reports to travelers.

Findings

Within three to four days following a major traffic incident along the highway segment, a sample of commuters who used the highway during the time of the resulting congestion was interviewed. At the time of publication, four such incidents had been covered.

Results included the following:

Generally, commuters have the opportunity to obtain traffic information both before departure and en route. However, those who obtain information don't necessarily use it, and those who endure bad traffic one day may not be affected enough by it to obtain more information the next day.

Of those respondents who actually encountered traffic on US-101, 64.8% said that they were no more likely to obtain traffic information prior to departure, and 54% said that they were no more likely to obtain traffic information after departure.

Of those who obtained traffic information, 36.8% thought the information helped them save time and 9% thought the information made them waste time. Over half (52.3%) were unsure.

Of those who said the information they received made them waste time, half (50.0%) said they were nonetheless more likely to obtain traffic information during their commute in the future. Of those who said the information saved time, 66% said they were nonetheless more likely to obtain traffic information during their commute in the future. Of those who were unsure of whether the information saved them time, 63% said they were no more likely to obtain traffic information en route in the future.

Of travelers who obtained traffic information, only 17% changed their departure time, 9% changed their mode of travel, and 24% took an alternate route.

Locator Number:
UCB-ITS-PWP-2000-3

Call Number: UCB-ITS-PWP-2000-2

Title: TravInfo Field Operational Test Institutional Evaluation Final Results

Authors: Youngbin Yim Elizabeth Deakin

Date February 2000

Problem

TravInfo is a regional traveler information system in the San Francisco Bay Area. The goal of TravInfo was to broadly disseminate accurate, comprehensive, timely, and reliable information on traffic conditions and multi-modal travel options to the public in the Bay Area through a public-private partnership.

The institutional evaluation of TravInfo was one of four test elements which comprised the TravInfo Field Operational Test (FOT). The other elements were technology assessment, traveler response, and transportation network performance. The transportation network performance test was not performed because of the lack of traffic data to realistically measure the changes in traffic flow during the field test.

The institutional evaluation measured the performance of TranInfo's public-private partnership at the organizational level. It examined how well TravInfo's institutional organization worked to achieve its objectives, what benefits the project partners were able to gain from the field test, and what institutional challenges they had to overcome.

Findings

TravInfo's organizational structure was unique, with a high degree of openness in the public-private partnership. TravInfo meetings were conducted as open forums to encourage the entrepreneurial participation of the advanced traveler information industry as well as the active participation of local public agencies. The ultimate responsibility for TravInfo lay with the public sector in the form of the Management Board, the members of which came from regional transportation agencies.

The TravInfo organization was effective in appropriately utilizing public and private sector talent. By placing the Metropolitan Transportation Commission, which is the transportation planning organization for the nine-county Bay Area, in a leadership role, the project recognized the importance of consensus building.

The project helped foster constructive relationships among the projects principal public participants. The project also fostered alliances among many of the private participants.

The project also encountered many challenges. Two major setbacks were insufficient coverage of the Bay Area transportation network by the data supplied to the TravInfo Traveler Information Center (TIC) and an inefficient system design that required the TIC to be considerably more dependent on manual operations than expected.

Call Number: UCB-ITS-PWP-2001-5

**Title: TravInfo Evaluation: Traveler Response Element Willingness to Pay for
Traveler Information: Analysis of Wave 2 Broad Area Survey**

Authors: Louis Wolinetz, Asad J. Khattak, Y.B. Youngbin Yim
Date: January 2001

Problem

TravInfo is a federally funded Field Operational Test (FOT) to deploy real-time traveler information in the San Francisco Bay Area.

Real-time traveler information is presently available free of charge in many US urban areas. Commercial radio/television stations, highway advisory radio, changeable message signs, in-vehicle devices, and the Internet all provide individuals with travel information. Substantial government resources are invested in the collection, processing, and dissemination of this information. The rationale is that information can help travelers make better decisions that ultimately reduce traffic congestion and pollution. However, the personal benefits of certain types of high quality travel information may motivate individuals to pay for that information.

The Broad Area study is part of the TravInfo FOT evaluation. For the Broad Area study, two household surveys were conducted, one in November 1995, eight months prior to the start of the TravInfo FOT, and the other one in November 1998, three months after the FOT was completed. This research examines the willingness of users to pay for the traveler information offered by TravInfo. The data utilized are from the second survey (1000 San Francisco Bay Area Residents), conducted in 1998.

The data were collected through a computer-assisted telephone interview in which respondents were chosen through random digit dialing. The study analyzes respondents' willingness to pay for a hypothetical ATIS (Advanced Traveler Information System) that provides: 1) Automatic notification of unexpected congestion on respondents' usual route, 2) Estimated time of delay from this congestion, 3) Automatic alternate route planning around this congestion, and 4) Estimated travel time on respondents' usual route and any planned alternate routes.

Findings

Of the original 1000 respondents, 342 did not receive transit or traffic reports from any source and so were not asked for their willingness to pay for ATIS. Of the remaining 658 respondents, 73% would be willing to pay for ATIS, 22% would not, and 5.2% weren't sure or didn't know.

Many respondents were not entirely averse to paying for quality travel information. Almost all "information seeking" respondents (97%) acknowledged a willingness to pay at least some fee for ATIS. The majority (77%) preferred to pay on a per-call basis as opposed to a monthly fee. 53% were willing to pay up to one dollar per call; 38% were willing to pay \$7 per month.

Respondents indicated that the most desirable information options were constant updates, alternate route information, in-car computer information, and delay and route time information.

It is still not clear whether ATIS user fees could cover the costs of such a system. It is also unclear whether public provision through taxpayer dollars is the best way to produce ATIS, given that the goals of decreasing congestion and improving mobility are in the public interest for economic and air quality reasons. Given that survey respondents indicate some willingness to pay a fee, partial funding of ATIS could be possible for appropriately customized high-quality content. More research is needed, particularly in the form of ATIS demonstration projects that do charge a fee so that real data can be generated rather than that generated by preference surveys.

Call Number: UCB-ITS-PWP-2001-7

Title: TravInfo Evaluation: Traveler Response Element; TravInfo 817-1717 Caller Study; Phase 2 Results

Authors: Ronald Koo, Y. B. Youngbin Kim

Date: February 2001

Problem

TravInfo is a Field Operational Test (FOT) sponsored by the Federal Highway Administration (FHWA) of the US Department of Transportation and the California Department of Transportation (Caltrans). Its objective is to provide benefits to San Francisco Bay Area travelers and to stimulate the deployment of privately offered traveler information products and services. In operation since September 1996, TravInfo disseminates free, current traffic information and multi-modal travel options to Bay Area travelers through a landline telephone system called TravInfo Traveler Advisory Telephone System (TATS) and through the Internet via Information Service Providers. As part of the TravInfo FOT evaluation project, two surveys of the TravInfo TATS callers were conducted, the first survey in April 1997 and the second survey in April 1999. This paper reports the findings of the second survey.

The purpose of the first TravInfo TATS caller survey was to establish a baseline profile of the callers with respect to their call and travel behavior. The purpose of the second survey was to assess the changes in callers' behavior and to measure the effectiveness of TATS in helping callers make informed travel decisions. The first survey was conducted seven months after TravInfo began in operation and the second survey was conducted seven months after the field test was concluded. The effectiveness of the TravInfo telephone system was measured by the satisfaction of callers with the TravInfo TATS service, the impact on their travel behavior, and the benefits perceived by them.

Findings

The results of the second survey are quite similar to those of the first survey. This may be due to the fact that during the two years between surveys, not much behavioral change could take place. However, one noticeable change was found: in the second survey; greater number of calls were made from a vehicle via cellular phones en route (46.8% in the second survey versus 31.5% in the first survey) among callers seeking traffic information. The other noticeable change was mode shift: it appeared that more people switched their mode from personal vehicle to public transit in the second survey. However, the sample size is too small to make any definitive conclusion.

Other important findings include:

In the first and second surveys, an overwhelming majority of the callers in the first and second surveys were satisfied with the information they obtained from TravInfo 817-1717. In both surveys, callers found that TravInfo TATS traffic information was more useful, reliable and accurate than radio or television reports. Both surveys showed that about half of the TATS traffic information callers changed their travel behavior as a result of TravInfo TATS information regarding a traffic problem. However, the effects of the TravInfo TATS service on mode shifts was minor even though three times as many people switched to public transit from personal vehicle when they learned of traffic congestion. The second survey also indicated that TravInfo TATS has been effective in providing quality information and in attaining a high level of customer satisfaction although its customer base has not increased significantly. As with the first survey, the second survey showed that TATS has attracted a segment of the driving population that rarely relies on traffic reports in making travel decisions and seldom or never listen to radio traffic reports. Most participants in the transit survey group said they would use TATS in the future because of its easy access to information via a single telephone number while the traffic survey group said they would use it again and recommend it to others because of its most current traffic information pertaining to their own trip. Transit information callers are interested in the availability of the service and service schedules while traffic information callers are interested in getting traffic conditions to avoid congestion. Therefore, very few calls were rerouted from traffic calls to transit calls or visa versa. However, it was apparent that the transit survey group favored TravInfo TATS having a single phone number for getting all travel related information.

Detection

Title: Advanced Image Sensing Methods for Traffic Surveillance and Detection
Author: Art MacCarley (California Polytechnic State University, San Luis Obispo)

UCB-ITS-PRR-99-11 (1999)

Problem and Method

This study sought to assess advanced imaging technologies for application to roadway surveillance and detection. A major motivation for this study was the possibility of improved effectiveness under foggy or dusty conditions by using wavelengths longer than those of the visible spectrum.

Current electronic imaging methods used to detect vehicles on roadways utilize conventional video equipment which must have adequate lighting, whether natural or artificial, and fairly clear atmospheric conditions. During times of low light or during smoky, dusty, or foggy atmospheric conditions, these systems may be inadequate. Yet, it is in these conditions of low visibility that the greatest need for traffic detection may exist in order to advise motorists of impending dangerous traffic situations.

This project studied several alternatives to visible spectrum imaging technology which have superior ability to operate in conditions of low light or less than ideal atmospheric conditions. The most promising technologies are *infrared (IR) sensitive cameras* and *passive millimeter-wave radiometric imaging*.

In order to use these new technologies, computer vision applications were developed and used to compare videotaped or digitally-stored imagery from field work using these systems. The concept of using more than one of these technologies simultaneously was also evaluated.

Findings

The non-visible spectrum imaging technologies evaluated in this study both provide advantages for detection in low light and low visibility situations. However, the cost of these systems is currently very high, making their implementation unlikely for most situations. However, certain situations were identified for which non-visible spectrum imaging technologies may be good candidates:

- § Roadways characterized by frequent, dense fog, smoke, or dust in combination with recurrent hazardous traffic patterns, where surveillance could reduce traffic incidents.
- § Situations in which the temperature information provided by non-visible spectrum imaging is useful, such as for detection of overheated truck brakes.
- § Machine vision applications in which the shadow and glare reflection features of IR imaging are required for proper detection or measurement.

**Title: Anaheim Advanced Traffic Control System Field Operation Test Task A:
Evaluation of SCOOT Performance**

**Authors: James E. Moore, II, R. Jayakrishnan, M.G. McNally,
C. Arthur MacCarley**

UCB-ITS-PRR-99-26 (1999)

Problem

The city of Anaheim, California, implemented SCOOT (Split, Cycle, and Offset Optimizer Technique) as part of a larger Field Operational Test which included several other related technologies. This part of the FOT was meant to evaluate SCOOT, which controls systems of signals rather than just isolated intersections, in terms of the following issues: its limited implementation as an option for Anaheim traffic controllers, the development of operational policies, and the evaluation of its operational effectiveness.

Evaluation Task A1 assessed the value of existing loop detectors for SCOOT (the detectors were already in place, but closer to intersections than SCOOT is designed to use them), and assess the quality of SCOOT's internal representation of traffic flow. We did this by comparing SCOOT's performance to videotapes of actual conditions at intersections.

Evaluation Task A2 assessed the performance of traffic under SCOOT in terms of delay. We posted observation teams at intersections to measure delay and used floating cars to measure running, stopped, and total travel time, both before and after the implementation of SCOOT, during PM peak and evening off-peak hours, and for special event and nonevent traffic.

Findings and Recommendations

SCOOT successfully models traffic conditions, but there is room for improvement. In general, SCOOT performed better off peak, for special events at smaller-volume intersections, and very well at specific intersections with heavy traffic during special events.

When SCOOT performed worse than the baseline system, it did so rarely more than ten percent, and when it performed better, the difference was normally less than five percent. (It must be kept in mind that the existing traffic control system in Anaheim is considered state-of-the-art, and that SCOOT was using information from loop detectors in nonstandard locations.)

Delays between the two systems were generally comparable, and SCOOT caused no unacceptable delays or catastrophic problems.

**Title: Anaheim Advanced Traffic Control System Field Operational Test
Task B: Assessment of Institutional Issues**
**Authors: M.G. McNally, James E. Moore II, C. Arthur MacCarley,
R. Jayakrishnan**

UCB-ITS-PRR-99-27 (1999)

Problem

The city of Anaheim, California, was committed to implementing three new traffic control technologies: SCOOT (Split, Cycle, and Offset Optimizer Technique), a signal control system developed and used in Britain; a 1.5 Generation Control system whose purpose was to update baseline timing plans for SCOOT from the first generation system already in use, and a video traffic detection system to supplement loop detectors. The project required coordination between a number of agencies and partners, including the city of Anaheim, its systems contractor JHK/Transcore, SCOOT vendor Siemens, video system provider Odetics, Eagle Signal, Caltrans and the FHWA, who funded the Field Operational Test, and PATH.

The purpose of this report is to answer the question: through what structures and methods can the technologies be applied without being confounded or restricted by institutional issues?

Method

Information was gathered through direct observation of project participants, primarily at formal meetings, and detailed interviews of all key project participants. Interview questions covered project goals and objectives, implementation, funding, and working relationships. They addressed administrative, financial, leadership, personnel, legal, liability, and technical issues.

Findings

Numerous institutional problems were identified by participants, some of them interwoven with technical problems. Prime among them was a lack of leadership during a crucial period in the process of implementation, when the Principal Traffic Engineer left and was not replaced for 8 months. Although his duties were reassigned, the lack of someone in a leadership and advocacy role led to several delays, including a long delay before a contract was signed with SCOOT provider Siemens. This caused other delays, and could have ended the project altogether had Caltrans not allowed several extensions.

Other main findings include:

- A strong, proactive project manager is needed.
- Delays caused unanticipated costs that put the project over budget and did not leave enough time for proper training.
- Staff failed to plan adequately for training and maintenance needs, and they overestimated the operators' ability to switch to a new system.
- Unanticipated communication problems included differences between British and American standards, differences between software systems, integrating older systems with SCOOT, and a time difference that created difficulties communicating with the SCOOT vendor.
- Staff was not motivated to fully learn the new system because it wasn't clear to them whether the new system would actually be used after the FOT.
- Everyone interviewed had a different idea of what the FOT's goals were.

Title: Anaheim Advanced Traffic Control System Field Operational Test
Task C: Video Traffic Detection System
Author: C. Arthur MacCarley

UCB-ITS-PRR-98-32 (1998)

Problem

As one part of the City of Anaheim's Advanced Traffic Control Field Test (in partner with Caltrans, FHWA, and JHK Consulting), we conducted an evaluation of a video detection system marketed by Odetics, Inc. as a low-cost alternative to loop detectors. Using video cameras, the system detects vehicles at intersection approaches in "virtual detection windows" for signal phase actuation. It can be set up and calibrated in the field using only a TV monitor and a PC mouse; up to four detection window setups can be stored; and it can also be set up and calibrated remotely. The user interface is simple but effective.

Method

Nine vehicle detection event classes and six phase actuation event classes were defined for this test, with different lighting, weather, and traffic conditions. Videotapes acquired in the field were slowed down, analyzed, and compared to the system's detection results.

Findings

In general, we found that detection was good under ideal lighting and light traffic conditions, but degraded at higher traffic levels and low light, night, and rainy conditions.

65% of vehicles were detected properly, which is similar to the performance of loop detectors. 80.9% were detected adequately for the purpose of signal phase actuation, and there was an average 8.3% false and latch detection rate (latch detection happens when the system detects a vehicle but fails to notice when it has moved on).

The manufacturer, Odetics, says it has since replaced both hardware and software to address these problems, but we have not tested the new system.

Title: Automated Travel Time Measurement Using Vehicle Lengths From Loop Detector Speed Traps

Author: Benjamin Coifman, Civil Engineering, Ohio State University

UCB-ITS-PRR-2000-12 (2000)

Problem

Travel time data is a useful tool for traffic engineers, offering the possibility of better incident detection, ramp meter control, and traveler information. It will become even more useful as input for emerging technologies such as dynamic traffic assignment; more importantly, it can be used now to quantify the benefit of such new technologies before making significant infrastructure investments.

This report presents a method of measuring travel time using existing loop detector infrastructure, inexpensive computers, and real traffic data.

Method and Findings

This method uses an algorithm to match vehicles detected at one loop detector station with the same vehicle at the next station; the difference in time between stations is the actual travel time of that vehicle.

Because the loop detectors measure effective vehicle length, it is possible to distinguish individual vehicles as they pass over it. However, such a length measurement may be accurate to only two feet, depending on the speed of traffic, making it difficult to match pairs from one detector to another. It is simple to eliminate unlikely matches from this scenario; however, the data produces a series of “possible matches” that must then be distinguished in order to make sense of the information.

To eliminate false matches, the algorithm matches platoons where vehicles pass both detectors in the same relative order. The platoon should produce a contiguous sequence of possible matches; if these are long enough, the problem posed by false matches can be eliminated.

Three closely related algorithms use different strategies to eliminate spurious sequences due to false matches. The algorithms were used to measure travel times on a large data set and the average measurement error for the different algorithms ranged between 0.7 percent and 4.5 percent, corresponding to an average segment velocity error between 0.4 mph and 1.5 mph.

Title: Data Utilization at California Transportation Management Centers
Authors Shirley Chan, Elbert Chang, Wei-Hua Lin, Alexander Skarbardonis

UCB-ITS-PRR-98-34 (1998)

Problem

This study examined the operations and functions performed at the Caltrans Transportation management Centers (TMC) with emphasis on the data sources, data processing and performance measures. Currently, much of the investment at the TMCs is in real-time traffic data collection primarily from inductive loop detectors. Much of this data is archived without further analysis due to the staff and budget limitations.

Method

The objective of this study is to evaluate how traffic data from several sources (loop detectors, closed circuit television, cellular phone calls for incidents, airborne reports, freeway service patrol logs, etc.) is currently acquired, processed, used, and stored by the Caltrans TMCs and to assess the potential to improve efficiency in data utilization. A literature review was performed to obtain information on the role and functions of TMCs in California and throughout the country. Additional information was gathered through interviews with the staff of ITS America, metropolitan planning organizations, as well as field visits to various Caltrans TMCs. The research then explored the role of information from new technologies and data processing algorithms in supporting TMC operations.

Findings

TMCs are an important means for managing the transportation system by collecting information in a centralized location and developing coordinated action plans. However, much of the investment is in real-time data collection and information dissemination. Little investment has been made for off-line applications (for example, to predict traffic growth). According to TMC staff members, much of the data is stored in the computer system or archived unanalyzed.

Most TMCs do not have the manpower available to ensure that loop detectors operate properly. Thus the data is often not reliable.

Data from video systems and emerging sources (such as electronic toll collection) need to be integrated into the database to assist in the data checking and verification.

New software and hardware will permit TMCs to have access to all types of traffic data from a single workstation. The new software being developed can potentially reduce the amount of human intervention needed for data analysis and collection and reporting of significant events that require TMC action.

Title: Development and Testing of Field-Deployable Real-Time Laser-Based Non-Intrusive Detection System for Measurement of True Travel Time on the Highway

Author: Harry H. Cheng, et al, Integration Engineering Laboratory, Department of Mechanical and Aeronautical Engineering, UC Davis

TR-IEL-2000-101 (2000)

Problem

Reliable, real-time traffic speed information is invaluable for traffic planners. Current methods for measuring travel time do so by measuring speed at one or more points along a link and then extrapolating speed across the entire length of the link. Loops, radar, and video image processing all use extrapolation to deduct travel time. However, when traffic flow slows because of an accident, speed variations along any given link can be quite large. This is when accurate information for making routing decisions is most critical, and the uncertainties caused by extrapolation are magnified.

Vehicle-as-Probe (VAP) methods determine travel time by identifying vehicles at the start of the link and then re-identifying them at the end of the same link, giving true travel time as the time difference between the two. The cost of VAPs is quite high, however, requiring a large number of vehicle tags and tag readers to be effective.

It is possible to identify some distinguishing characteristic on a vehicle at the beginning of a link and then re-identify that same vehicle at the end of a link without the set-up costs of a VAP. If a characteristic can be found that separates cars into 100 possible classifications, a match between upstream and downstream vehicles can be made with high probability. Even more classifications would make the process even more accurate.

Method

This project developed a laser detection system that can directly and accurately determine origin and destination information for vehicles in the traffic stream non-intrusively and without violating privacy. It produces local vehicle speed, vehicle volume, and vehicle classifications, even under high flow conditions. Point-to-point travel time and incident detection can easily be determined.

This system can be mounted above the road, which allows it to be installed and maintained without tearing up the road or disrupting traffic. It operates on a simple “on/off” basis, requiring much less computation for vehicle detection than video methods. It also produces and senses its own signal, so it does not depend on time of day and weather conditions for accuracy (as do video detection systems). There are no moving parts, and power and bandwidth requirements are very low.

The system projects a laser onto the ground, and then collects the reflected light onto a photodiode array. A vehicle is detected when it passes under the beam, based on the absence of the reflected light. With two identical laser/sensor pairs placed close together,

it is possible to measure the speed of both the front and the rear of the vehicle as it triggers each sensor. The length of each vehicle is determined from the speed and the amount of time the vehicle spends under the detector.

Findings

We have built a field prototype detection system and tested it under real traffic conditions. Our test results verify that the principle of this system is technically sound and the software works in most cases. There are a few situations, such as stop-and-go traffic, where the detection of vehicle length does not work well.

We also found that the separating distance of the two laser-sensor detectors was too small in our test, which made the system detect different speeds for the front and the rear of vehicles. Also, the slowness of the analog signal contributed to the error. Both of these problems will be fixed in the next prototype, by putting the pairs farther apart and by using a faster digital signal.

**Title: Evaluation of the Anaheim Advanced Traffic Control System Field
Operational Test: Executive Summary**
Author: M.G. McNally, James E. Moore II, C. Arthur MacCarley, R. Jayakrishnan

UCB-ITS-PRR-99-18 (1999)

Problem

The city of Anaheim, California, experiences heavy traffic on a regular basis. Delays at intersections are a significant problem, and many special events create special traffic problems. The city has an advanced traffic control system, but wanted to test out several new technologies, so this field operational test was set up both to assess the technical performance of these methods and to analyze the institutional issues around their implementation and operation.

The three systems were: SCOOT (Split, Cycle, and Offset Optimizer Technique), a second generation technology for controlling systems of signals as opposed to isolated intersections, already in use in Europe; a 1.5 Generation Control system under development, whose purpose was to update baseline timing plans for the entire system; and a video traffic detection system presented as a low-cost alternative to loop detectors for critical areas.

Method

The evaluation was broken down into three main parts: a performance assessment of the technologies, an assessment of the institutional issues, and a separate evaluation of the video traffic detection system.

For the performance assessment, we looked first at how well SCOOT “sees” traffic and then at how well it performs to control traffic.

Findings

SCOOT is designed to rely on information from loop detectors placed farther away from the intersections than the mid-block locations of the loops already in place in Anaheim. We needed to know whether these loops could provide adequate information to the system, so we compared SCOOT’s estimates of queue length and clearance time to real time video at certain intersections, and identified large inconsistencies. Nevertheless, SCOOT successfully models traffic conditions, in general, but can be improved either by changing the location of loop detectors or by adjusting global control settings to compensate for the actual location of detectors.

To assess SCOOT’s performance, we used teams both at intersections to measure delay and in cars to measure travel time, before and after implementation. We discovered that SCOOT performed better than the existing system during off-peak hours, and very well at certain intersections during special events. However, our findings are inconclusive as to whether SCOOT is better than the system already in place.

To evaluate institutional issues, we used direct observation and interviews, all of which produced subjective information that was structured to provide many different points of view. We looked at implementation, operations, transferability, and maintainability of the system. There was an immediate problem with delaying implementation due to a vacancy in a key position (Principal Traffic Engineer), which led to a lack of experience and authority in the city's relations to the contractor (Siemens). We were not able to adequately evaluate operational issues because of the resulting delays, which led to late delivery, and limited staff training and experience prior to the evaluation. In terms of transferability of technology, we concluded that products that are not widely deployed are essentially still in the research and development process, subject to delays, changes, and cost overruns. This is especially true for the 1.5 GC system. Maintaining the new systems would involve significant costs, and much more training is needed to properly utilize it. Our overall conclusions in regard to institutional issues is that we have no specific recommendation, but costs would be likely to go up if SCOOT were to be expanded beyond its present limited deployment.

The last evaluation task, of the video system which is marketed as a low-cost alternative to loop detectors, found that its user interface is unsophisticated but effective. The system's performance results were good under ideal lighting and light traffic conditions, but not so good in low light, night, rain, or heavy traffic. (The manufacturer, Odetics, says it has since addressed and corrected these issues, but we have not evaluated the new system).

Title: Evaluation of the OCTA Transit Probe System

Authors: Randolph W. Hall, Nilesh Vyas, Chintan Shyani, Vikas Sabnami, Simit
Date: November 1999

Description of the Research

The OCTA (Orange County Transit Authority) Transit Probe Project is a field operation test of an automatic vehicle-location (AVL) system operating in Orange County, California. The system software was designed to estimate roadway congestion levels based on bus travel times over route segments and communicate this information to Caltrans, the City of Anaheim, and the City of Santa Ana.

This report presents the final evaluation of the project, concentrating on the year-long field operational test period. The report provides a detailed description of the system and its design. It also provides analyses of data reliability and accuracy, and analysis of the usefulness of Transit Probe data for predicting automobile travel times. Institutional issues are evaluated, based on interviews with involved personnel, direct observation, and review of project documents. Surveys of bus riders and kiosk users are also documented.

Conclusions of the Research

Bus tracking systems provide many potential benefits related to scheduling, problem response, and bus arrival information for users. However, these benefits cannot be captured without carefully planning operational procedures, data maintenance, system interfaces, and ensuring that the equipment is reliable. These important issues did not receive adequate consideration in the system design phase of the project. Although the evaluation produced important insights as to how bus tracking should be implemented and the likely problems to expect, the OCTA Probe failed to live up to its promise because the system was not used by drivers, dispatchers, planners, schedulers, or the general public.

Transit Probe did not meet reliability standards for an actual deployment. The majority of schedule data points are either missing, undetected, or duplicated, thus confounding data analysis.

Transit Probe never created its intended interfaces to Caltrans, the City of Anaheim, or City of Santa Ana due to a reduction in scope of the deployment and a reduced budget.

Only one public interface kiosk was installed, and though it was well-received in a test evaluation, it wasn't functional until the end of the project and therefore didn't have any positive impact.

Customers perceived that bus schedule adherence had improved during the Transit Probe project, though whether this represents a real improvement or merely public perception is not altogether clear. From bus driver interviews, it seems that the installation of a clock in driver view may have encouraged better schedule adherence. However, drivers generally ignored Transit Probe indicator lights, and therefore the improvement could not have resulted from Transit Probe's schedule adherence capabilities.

The congestion measurement component of Transit Probe was never fully established due to many factors, including: 1) inadequate congestion information dissemination, 2) improperly established baseline bus route segment speeds, 3) inaccurate speed estimation algorithm in Transit Probe, 4) lack of relationship between slow bus speeds and general traffic speed.

In terms of the institutional performance of OCTA Transit Probe, OCTA involved partner agencies commendably while moving the project forward and meeting deadlines during the design phase. However, once the project progressed to the test phase, the organization became rather conventional with a contractor and contract manager and outside participation virtually disappeared.

Locator Number:
UCB-ITS-PRR-99-39

Title: Evaluation Methods for Measuring the Value of ITS Services and Benefits from Implementation: Part X Freeway Service Patrols
Authors: David Levinson, Pavithra Kandadai Parthasarathi
Date January 2001

Problem Statement

Incident management programs are one of the key elements of Intelligent Transportation Systems (ITS). The goal of such programs is to clear the incidents from the roadways and return traffic flow to normal as soon as possible. Incident management programs have been introduced in many places to facilitate incident detection and reduce incident duration. They make use of ITS services and coordinate among the various operating agencies to meet the goals of quick detection and clearance of incidents.

Highway assistance services, also called the freeway service patrols (FSPs), are one of the main approaches used by incident management programs. These patrols use vehicles to patrol the heavily traveled segments and congested sections of the freeways that are prone to incidents. The main goals of the FSPs are to help identify incident locations, reduce the incident duration time, get the freeway capacity back to the fullest and to reduce the risks of secondary accidents without any assistance from other agencies. In cases of major incidents, the patrols help assess the equipment and resources needed to clear the incidents, coordinate with other agencies involved, and provide the needed traffic control and buffer between the workers and traffic. They also help detect and verify incidents like major accidents and pass on the required information to the transportation management centers (TMCs). This helps reduce delay, congestion, wasted fuel, emissions and potential for secondary accidents.

Previous analyses of the freeway service patrols include studies conducted by California PATH (Partners for Advanced Transit and Highways) program at the Institute of Transportation Studies (ITS) University of California Berkeley and Texas Transportation Institute concluded that FSPs are cost-effective, successful in their objectives of reducing incident duration and facilitating quick detection, and highly popular among motorists.

This research sought to determine the value that people place on the benefits offered by FSPs in comparison to private assistance services such as the Automobile Association of America (AAA), and how much they would be willing to pay to avoid being stranded when their vehicle breaks down on the freeway. The studies conducted so far have focused on the effectiveness of the freeway service patrol whereas this report analyzes the factors that influence people in choosing to rely on the freeway service patrol.

Findings

This research shows that the probability that an individual would choose the highway assistance services depends on the key attributes like the annual fee of the program, the fee at the time of assistance, the time of waiting for assistance and cost of breakdown. The findings also show that the presence of the highway assistance services in a state does have a small influence on the auto club (AAA) membership.

The researchers also concluded that the data sets for Stated Preference and Revealed Preference analyses were too small. Larger data sets were anticipated to provide better results and clearly indicate the factors influencing people's choices. A pilot survey conducted on a larger scale would likely provide a better evaluation of the factors influencing people's choices related to FSP use.

In addition, the research concluded that the sample set was probably socio-demographically too homogeneous. A larger heterogeneous sample set would provide better indications of the way the socio-demographic variables impact the choices of motorists.

Locator Number:
UCB-ITS-PWP-2001-3

Title: Freeway Performance Measurement System: Final Report

**Authors: Pravin Varaiya
University of California, Berkeley**

Date: January 2001

Description of the Research

This report summarizes the design, operation, and implementation of PeMS (Performance Measurement System). Topics covered include the communication and software architecture of PeMS, its applications, observations of PeMS in operation, and an appendix consisting of an empirical study of congestion, capacity, and ramp metering using PeMS.

Conclusions of the Research

PeMS is a low-cost freeway performance measurement system for all of California. PeMS processes 2 GB/day of 30-second loop detector data in real time to produce useful information to travel network managers, traffic engineers, planners, researchers, and travelers.

PeMS utilizes an open communication and software architecture, meaning that the code used to develop the software is publicly accessible and that modifications or add-ons can easily be made to PeMS. A new district can be added to the PeMS system with six person-weeks of effort and no disruption of the district's TMC (Traffic Management Center); data from new traffic loops can be easily added as it is available. PeMS applications are accessed via a Web browser, an interface with which the majority of users will already be familiar.

PeMS is inexpensive, utilizing off-the-shelf products for communication and computation. PeMS uses data retrieved from the existing Caltrans ATM wide area network to which all districts are already connected.

PeMS benefits users in several ways:

- \$ Caltrans managers can instantly obtain a uniform and comprehensive assessment of the performance of the freeway network.
- \$ Caltrans traffic engineers can base their operational decisions on knowledge of the current state of the freeway network.
- \$ Caltrans planners can examine solutions to congestion. Traffic control equipment, such as ramp-metering and changeable message signs, can be optimally placed and evaluated.
- \$ Travelers can use PeMS via products developed by VARs (Value Added Resellers) to choose optimal travel routes.
- \$ PeMS can serve to guide and assess intelligent transportation system (ITS).

**Locator Number:
UCB-ITS-PWP-2001-1**

Title: Freeway Service Patrol Evaluation

**Authors: Alexander Skabardonis, Hisham Noeimi, Karl Petty, Dan Tydzewski,
Pravin P. Varaiya, Haitham Al-Deek**

UCB-ITS-PRR-95-5 (1995)**Problem**

The Freeway Service Patrol consists of teams of tow trucks that patrol highways and provide assistance to motorists. It is used in several places throughout the state for quick removal of incidents and to reduce congestion delay and other adverse effects from incidents on freeways. How well does the patrol work?

Method

We collected incident information for a section of freeway in the San Francisco Bay Area (in Hayward) using probe vehicles, loop detectors, the CHP dispatch system, FSP records, and tow truck company logs. In all, 276 hours of field data went into a unique, comprehensive database that represents a complete representation of freeway operating conditions. We were able to study and compare conditions both before and after the institution of the Freeway Service Patrol on this section of freeway.

Findings and Recommendations

This study found that the Freeway Service Patrol increased the number of assisted incidents, and reduced response time and duration. The FSP is also cost effective in terms of incident delay and fuel consumption savings.

The response time for breakdowns where FSP assisted was cut by 57%; for all incidents, the response time went down by 35%. Accident and breakdown clearance remained about the same, as did incident duration. The reduction in assisted incidents is probably largely accounted for by a quicker response time because the tow trucks were already in the field.

Other benefits from the service which we did not quantify include time and cost savings to assisted motorists, improved incident detection, and a reduction in the amount of work the CHP has to do, allowing them more time for enforcement.

The effectiveness of FSP would be higher in places with similar incident patterns and a higher traffic volume, especially where there are mixed lands and narrow or no shoulders.

Title: Freeway Service Patrol Evaluation (Los Angeles)

Authors: Alexander Skabardonis, Karl Petty, Pravin P. Varaiya, Robert Bertini

UCB-ITS-PRR-98-31 (1998)

Problem

The Freeway Service Patrol consists of teams of tow trucks that patrol highways and provide assistance to motorists. It is used in several places throughout the state for quick removal of incidents and to reduce congestion delay and other adverse effects from incidents on freeways. In addition to evaluating the effectiveness of the FSP, our objectives for this study were to develop a comprehensive database on freeway incidents and operational characteristics and to develop an evaluation methodology in the face of a lack of “before” data (the FSP had already been operating for about seven years along this section of freeway).

Method

We collected average travel speed and incident information for a 7.8-mile section of the I-10 freeway between Eastern Avenue and Santa Anita Avenue (“Beat 8”) in Los Angeles by using seven probe vehicles with 5.7 minute headways, 6 hours a day, for 32 weekdays. This was combined with information from loop detectors, tow truck logs, and CHP logs.

We selected a test site that had mixed lanes, narrow shoulders, closely spaced loop detectors, high volumes of traffic, frequent incidents, and no construction planned for the test period.

Findings and Recommendations

This study found that the Freeway Service Patrol is successful and cost effective. The FSP handles a large number of minor incidents that may cause congestion. It detects and verifies major incidents. It reduces delay, fuel consumption, and emissions, and well as the amount of time the CHP spends on minor incidents.

The FSP should be used as a mobile data service for incident detection and freeway conditions.

**Title: The I-880 Field Experiment:
Effectiveness of Incident Detection Using Cellular Phones**
Authors: Alexander Skabardonis, Ted Chira-Chavala, Daniel Rydzewski

UCB-ITS-PRR-98-1 (1998)

Problem

Cellular phones can be an inexpensive alternative to other incident-detection technologies, involving little capital or infrastructure costs. However, calls by motorists can vary greatly in detail and quality of information, and in the timeliness of reports. How well do they perform compared to other methods?

Method

We compared incidents reported by cell phones along a nine-mile section of I-880 in the Bay Area to data obtained from field observation and other detection sources, creating a database of 264 incidents (accidents and lane blockages) and 1429 “other events” (stalls and events other than accidents that did not block lanes). We measured the quality and adequacy of cell phone data in terms of the incident detection rate, false alarm rate, timeliness, and available details such as location, type, and severity of incident, and type and number of vehicles involved.

Findings

Cell phone callers detect 38% of incidents and 1% of other events. 7% of calls about incidents were false alarms, and 32% of calls about other events were false alarms.

Cell phone users report an additional 35% of incidents that are not witnessed by the CHP; the CHP and cell phone users together detect 60% of incidents.

Relative to other sources, cell phones have the highest detection rate and are the fastest detection source. However, they have a high false alarm rate (perhaps due to the fact that drivers can't tell whether a car by the side of the road is stalled or just temporarily stopped), and a low detection rate for other events (perhaps because drivers don't pay attention to events unless they present an immediate hazard). Also, callers provide limited information on the severity of incidents, and the calls need verification, which contributes to the fact that incidents detected by cell phone users take longer to clear than CHP-detected incidents.

Cellular phones are not enough by themselves to detect incidents and other events, but they could be more effective if the CHP changed verification and response practices.

Title: Identifying the Onset of Congestion Rapidly with Existing Traffic Detectors
Author: Benjamin Coifman

UCB-ITS-PWP-99-17 (1999)

Problem

Traffic surveillance systems need to reliably identify the presence of congestion, and to respond rapidly when congestion is detected. Loop detectors are good at the first, but not so good at the second task. This paper presents an algorithm using existing dual loop detectors in a new way to improve their performance on these tasks; it promises to be deployable in the short term.

Method and Findings

Loop detectors calculate flow and occupancy at discrete points on a freeway. We generally assume that this information represents the space between links as well. However, under congested conditions this is not always so; the traffic stream can change significantly from moment to moment in both directions, especially when traffic is heavy.

Conventional loop detectors easily identify the presence of congestion, but response time is usually slow. Our method solves this by looking for free-flow traffic instead of congestion. Recognizing that signals emanate from an incident in two directions—a drop in speed moving backwards at about 8 mph, and a drop in flow moving forward at the prevailing traffic speed—the algorithm looks for a fast-moving drop in flow, thus quickly identifying the onset of delay.

The drop in flow is found by identifying long vehicles at a detector station, then looking for a similar vehicle in the same lane upstream within a certain time window, defined by the amount of time it would take the vehicle to travel that far at free-flow speeds. If the vehicle is identified, then the presence of free-flow traffic reveals itself. Since lane changes are less common under free-flow conditions than congestion, the likelihood of identifying the vehicle is higher. Using long vehicles, which can be four times as long as smaller vehicles and thus easier to identify with some certainty, we can quickly ascertain whether free-flow conditions are met, or not.

This work is compatible with existing detector infrastructure, and simple enough to implement on existing Model 170 controllers, which are based on twenty-year-old computer technology. It is intended to augment, not supplant, conventional surveillance strategies to improve performance.

Title: Individual Vehicle Speed Estimation Using Single Loop Inductive Waveforms
Author: Carlos Sun, Rowan University, Glassboro, New Jersey
Stephen G. Ritchie, University of California, Irvine

UCB-ITS-PWP-99-14 (1999)

Problem and Method

This research sought to develop a new method to estimate vehicle speed using a single loop detector rather than a “speed trap” setup in which two loop detectors are used in sequence.

Prior to this research, methods were developed to estimate vehicle speed using a single loop detector. However these methods are dependent on an assumption of vehicle length distribution, which leads to biased results for individual vehicles outside the assumed vehicle length (such as trucks and motorcycles).

This research developed a speed detection algorithm that analyzes the waveform generated by vehicle passing over a single loop detector and estimates the speed of the passing vehicle independent of the vehicle length, leading to more accurate speed estimation than previous single detector methods.

Findings

The method developed as part of this research was found to perform better than other previously developed single loop detector methods of estimating speed. This is in part due to the fact that unlike the earlier methods, the method developed in this research estimates speed independent of vehicle length assumptions.

The ability to utilize the current loop detector infrastructure to obtain reasonably accurate estimates of vehicle speeds may save considerable cost and traffic delay associate with the construction of new loops. However, double-loop speed measurement methods (“speed traps”) are still necessary if high accuracy in speed computation is required.

Title: Investigation of Vehicles as Probes Using Global Positioning System and Cellular Phone Tracking

Authors: Y. B. Youngbin Kim, Randall Cayford

Date: December 2000

Problem Statement

This study investigates the feasibility of vehicle tracking technologies for vehicles as probes (VAP). Two technologies were evaluated: Global Positioning Systems (GPS) and cellular phone tracking technologies developed by US Wireless.

The study consisted of three phases of project tasks: Phase I—program development and initial field test, Phase II—field operational tests, and Phase III—a large-scale field implementation. The overall goal of the study is to set up a VAP system.

Vehicle probe information can be complementary to those freeways that have single loop detectors because the single loop detectors are not capable of producing the most accurate traffic speed and density measurements. Probe vehicle data can also be used for rural freeways or minor urban freeways where no instrumentation is planned. Local streets and arterials are also good candidates for collecting data from probe vehicles.

Currently, no off-the-shelf software exists for VAP applications. A custom software package was developed as part of this project in order to conduct the technology evaluation.

Findings

Analysis showed that accurate location technologies are capable of producing travel time information for nearly all roads. A technology with 20-meter accuracy can produce data for approximately 99% of the road and freeway segments in the two counties (Alameda and Contra Costa in the San Francisco Bay Area) studied. Currently used GPS systems provide 15-meter or better accuracy. However, current cellular technologies typically provide 100-meter accuracy, with 50-meter accuracy mandated by 2002 (Emergency 911 system requirement).

Aside from location accuracy, results from the field tests show that variability in the positional accuracy and the total length of the tracking sequence are also important factors in the success of a tracking technology for VAP. With a sensing accuracy of 10 meters such as provided by some GPS systems, tracking the vehicle for twice the accuracy dimension (in this case, 20 meters of travel) is often sufficient to establish a travel time for the probe. However, for an accuracy of 100 m, such as provided by many current cellular phone technologies, the vehicle may need to be tracked for a mile or more to establish a travel time.

Other challenges of VAP, particularly for cellular phone-based tracking, include being able to filter out “uncharacteristic behaviors” from tracked vehicles, such as a vehicle stopped out of traffic by the side of the road, or a vehicle being towed, which might yield misleading data. Post-processing of the VAP data may be able to address some of these types of challenges.

Other challenges encountered with the technologies evaluated included being able to distinguish freeway travel from frontage road travel. All technologies also produced outlying data points that made tracking difficult.

Overall, GPS systems provided greater accuracy than cellular phone-based systems. Of the cellular technologies evaluated, at least one implementation shows promise, but needs further study to produce quantifiable travel time data.

Locator Number:

UCB-ITS-PWP-2001-9

Title: An Investigation in the Use of Inductive Loop Signatures for Vehicle Classification
Author: Carlos Sun
Date: March 2000
UCB-ITS-PRR-2000-4

Problem:

If we could accurately sort the vehicles that use our highways into predefined classes, we could improve vehicle reidentification algorithms and traffic simulation models, gaining useful information to benefit highway maintenance, vehicle emissions management, highway design, traffic safety, and automatic toll collection systems. If we could do this using the current inductive loop technology already in place, we could gain all these benefits immediately, and with simpler equipment than is used by other commercially available systems.

Method and Results:

Using different pattern recognition techniques, we tested vehicle classification algorithms on the SR-24 freeway. We used existing loop detectors that can output a vehicle inductive signature. We divided vehicles into seven classes (car, SUV/pickup, van, limousine, bus, two-axle trucks, and larger trucks) to test two classification methods. The first method, a heuristic discriminant algorithm, used multi-objective optimization for training the heuristic algorithm. Some advantages of using heuristic algorithms include smaller data transmission and storage requirements, and a sequential discrimination procedure in which each stage can be individually fine-tuned. We developed three different heuristic algorithms which yielded 81 to 91% accuracy.

The second method used self-organizing feature maps (SOFM), which are artificial neural networks. A large advantage of using SOFM is that it needs only a small training data set to produce similarly high rates—more than 80% accuracy.

We also developed a speed measurement system using single loops, since it's necessary to accurately estimate speed in order to be able to judge a vehicle's size. Our method produced more accurate results than previous single loop estimation methods.

Different technologies work best with classification schemes suited to their particular method of signal detection; for this reason, using a combination of technologies will probably produce even more consistently accurate results.

Title: Mobile Surveillance & Wireless Communication Systems Field Operation Test

- 1) Executive Summary (UCB-ITS-PRR-99-6)**
- 2) FOT Objectives, Organization, System Design, Results, Conclusions, and Recommendations (UCB-ITS-PRR-99-7)**
- 3) Appendices A-J Containing Evaluation Data Gathered During the Anaheim Special Event and I-5 Tests (UCB-ITS-PRR-99-8)**

Author: Lawrence A. Klein

Date: 1999

Problem

Traffic monitoring can be difficult in areas where permanent detectors, electrical power, and communications systems are not available. This research sought to evaluate the performance of wireless traffic detection and communications systems.

Method

The researchers designed and built six surveillance and three ramp meter trailers, a video and data retransmission (or relay) site, and video and data reception facilities at the Caltrans District 12 and Anaheim Traffic Management Center (TMCs) and the University of California at Irvine Institute of Transportation Studies Laboratory. The system was evaluated in two different types of tests. The Anaheim Special Event Test assessed the surveillance trailers in an application that transmitted video imagery in support of arterial traffic control during a special event. The Interstate-5 (I-5) Test examined the use of the mobile surveillance and ramp meter trailers to transmit video imagery and data in support of freeway ramp metering.

Findings

Several difficulties were encountered with the trailers. These include:

- **Frequent discharge of electrical systems.** This was remedied with a complete redesign of the generator, battery, charging, and power architecture systems.
- **Difficult logistics and setup with the use of the trailers.** Several weeks and multiple personnel were required to select sites, perform signal strength testing, secure permits, and determine the best way to position the trailers. Moving a trailer a few kilometers and deploying it took about an hour. On construction sites, contractors need to be made aware of the surveillance trailers' use so that space can be allocated for them and thereby reduce the need for the trailers to be repositioned. Supplemental relay sites would also reduce logistics problems.
- **Strong winds occasionally moved antennae off mark.**

The video system used tended to over-report mainline volume. This is due in part to the maximum height at which the video detectors can be mounted on the portable trailers. In particular, tall vehicles tended to be counted as multiple vehicles; tall vehicles also tended to obscure smaller vehicles and cause them to be underreported. A method of compensating for vehicle overcount by the system studied is needed in order to report more accurate traffic volumes.

The ramp signals responded properly to vehicle demand an average of 85 percent of the time. This is not adequate for ramp-metering operation. Positioning the video camera closer to the ramp may reduce this error. Increasing the camera's field of view and using optical recognition logic may further reduce the error.

Fuel (LPG) consumption of a surveillance trailer was estimated at 0.46 gallons/hour. With an LPG cost of \$1.75/gallon, fuel for continuous surveillance trailer operation is estimated at \$0.80/hr.

Title: New Aggregation Strategies to Improve Velocity Estimation From Single Loop Detectors

Author: Benjamin Coifman and Zu-Hsu Lee

UCB-ITS-PWP-2000-12 (2000)

Problem

Single loop detectors are commonly used to measure speed and flow on highways, but they have serious shortcomings in this area, as do conventional methods for estimating velocity from their information. For example, velocity and length cannot be measured independently at a single loop. Typically, operators set length to a constant value so they can estimate velocity. However, long vehicles can be up to four times as long as other vehicles, so they skew the data, and thus cause inaccurate results. Researchers have attempted to fix this by estimating mean velocity using aggregate flow and occupancy rates. We have come up with a new way to aggregate data, rather than manipulate aggregate data, to reduce estimation errors.

Method and Findings

We studied data from dual loop detectors, which can measure true vehicle velocity and length. By experimenting with the data, we found that median length estimates were much closer to accurate than mean length estimates. We also found the same to be true for the resulting velocity estimates: median estimates were much less subject to error.

Working with fixed time samples rather than the fixed number-of-vehicle samples we used in the preceding example, and insuring that the sample periods were long enough to be useful, we found similar results: there were significant errors in the mean velocity estimate and few in the median estimate.

We found that five minutes provided sufficient sample size. However, this may be too long in some cases, so we also set the time period shorter and sampled across five lanes at once, obtaining similar results.

Title: A New Methodology for Evaluating Incident Detection Algorithms

Authors: Karl Petty, Peter J. Bickel, Jaimyoung Kwon, Michael Ostland, John Rice

Date August 2000
UCB-ITS-PWP-2000-11

Problem Addressed by Research

Automatic incident detection algorithms (AIDs) can operate on data from inductance loop detectors using methods including filtering, pattern recognition, catastrophe theory, neural networks, and genetic algorithms. Determining which AID is best for a given situation is difficult, in part because parameters must be set by the practitioner, and performance is very sensitive to these settings. Standard evaluation of AIDs has focused on the difference between detection rates (DR) and false alarm rates (FAR), but this method is fraught with difficulties. For one, judging what constitutes an incident is a subjective action, and makes fair comparisons between different algorithms nearly impossible. Also, DR-FAR curves treat all incidents with equal importance, whether they are low-impact breakdowns on the shoulder or major accidents causing hours of delay.

Method:

Our approach to evaluating AIDs attempts to solve these problems by using costs rather than DR-FAR curves. That is, we estimate costs of delay as well as the costs of implementing the AID (dispatching tow trucks, etc). The estimates are based on assumptions using training data, and can be consistent for all algorithms under evaluation. Severity of incidents and time to response are automatically factored into the analysis, as they are reflected in the cost.

Practitioners are best qualified for making assumptions linking congestion and costs, and our method allows for flexible formulations of cost. For example, the cost function could reflect increasing benefit for responding promptly to injury accidents.

An AID can be "tuned" to be very sensitive, which reduces delay because incidents are quickly detected. However, greater sensitivity also means increased implementation costs, as more interventions are called for. The goal is to strike a balance between costs of delay and costs of implementation.

Our equation converts delay and implementation actions to costs and finds the lowest possible cost of an AID using a given set of data.

Findings and Recommendations:

Our method systematically tunes the parameters of an AID and makes it possible to fairly compare different types of AIDs, avoiding several problem inherent in DR-FAR curves. For example, the severity of an incident in terms of congestion and the time it takes to detect it are automatically factored into the analysis. Our flexible framework allows practitioners to tailor the cost functions to the particular problem, and to set AID parameters systematically by finding the lowest cost for a given set of data.

Title: Paramics API Development Document for Actuated Signal, Signal Coordination and Ramp Control

**Author: Henry X. Liu
Lianyu Chu
Will Recker**

University of California, Irvine

Date: February 2001

Description of the Research

This report discusses the process and technology behind development and expansion of the Paramics software suite.

Paramics is a suite of software tools used to model the movement and behavior of individual vehicles on urban and highway road networks. The Paramics Project Suite consists of four components: Modeler, Processor, Analyzer, and Programmer. The Programmer enables the user to customize many features of the simulation model. Access to the Programmer is provided through an Application Programming Interface, or API.

Conclusion of the Research

The capability to access and modify the Paramics simulation model through an API is essential for research. Such an API should have a dual role:

- § first, to allow researchers to override the simulator's default models, such as car following, lane changing, and route choices, and
- § second, to allow researchers to interface complementary modules, for example ITS applications such as signal optimization, adaptive ramp metering, incident management, and so on, to the simulator.

This report describes three new APIs for complex simulation and modeling in Paramics. These are:

- § **Full-actuated signal control.** This API enables the modeling of a typical intersection with traffic detectors to simulate left-turn vehicle presence detection and vehicle detection for vehicle "through movement" phase.
- § **Actuated signal coordination.** This API enables the simulation of actuated signal coordination designed to allow "platoons" of traffic to form and progress through several signals with minimum stops and delays.
- § **Actuated ramp metering control.** This API enables the simulation of ramp metering systems utilizing a time-based ramp control algorithm.

The research also outlines possible future development of more APIs to handle several specific simulation issues. The proposed APIs can be built upon the APIs developed in this research. Examples suggested include:

- § Actuated ramp metering control rather than time-based metering
- § Actuated signal control utilizing detection methods other than loop detectors, such as machine vision or other "wide area" traffic detection technologies nearing implementation.

**Locator Number:
UCB-ITS-PWP-01-11**

**Title: A Real-Time Laser-Based Prototype Detection System
for Measuring Delineations of Moving Vehicles**

**Authors: Jonathan E. Larson, Kirk Van Katwyk, Cheng Liu, Harry H. Cheng,
Ben Shaw, Joe Palen**

UCB-ITS-PWP-98-20 (1998)

Problem

The goal of this project is to build a system that can gather reliable travel time data non-intrusively for use in traffic planning and ITS. Laser detection systems offer several advantages over other methods like loop detectors: ease of installation and maintenance (no digging or rerouting of traffic required), simple computational needs, and no dependence on existing lighting conditions.

Method

A laser is projected onto the ground, and an optical sensor collects the reflected light, focusing it onto a photo sensor that converts the signal to a readable sample. It can detect a vehicle as it passes under the laser by the absence of reflected light. With two such systems set a known distance apart, the speed of the passing vehicle can be measured, as well as its length (useful for identifying and re-identifying vehicles).

We built and tested an indoor prototype to prove the concept and develop algorithms, and are developing a full-scale system for outdoor testing. This report describes the design and implementation of the components of the lab prototype, the configuration of the field testing system, and software design and implementation.

Findings

The lab prototype can detect the profile and measure the length of a small test vehicle passing at varying speeds with high repeatability.

Problems we encountered include electrical noise and sunlight interfering with sensors; these can be fixed with continued work.

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

Problem Addressed by Research:

An over-saturated freeway exit ramp that causes congestion in the exit lane also causes slow-down in the adjacent lanes, and can create a serious bottleneck on all lanes of the freeway.

Method:

We observed the La Paz Road off ramp from Interstate 5 in Orange County using videotapes, a probe vehicle, and loop detectors (which worked intermittently).

Findings:

In this particular case, the bottleneck did not seem to be caused by drivers squeezing into the exit lane at the last opportunity; this happened at a very low rate and rarely affected through-moving traffic. Non-exiting drivers simply seemed unwilling to drive fast while next to stop-and-go-traffic in the exit lane, which slowed all the lanes until they reached the off ramp.

When the traffic signal downstream of the off ramp provided right-of-way to exiting vehicles, no queue formed in the off ramp and no bottleneck arose; the traffic on the entire freeway had a very high flow. This particular traffic signal has a queue elimination strategy, triggered by a particular loop detector on the exit ramp. Such a strategy is very valuable, since it can prevent a bottleneck which might affect all lanes of the freeway. Where complete elimination of exit queues may not be feasible, these observations suggest that at least some improvement in freeway conditions can be realized by keeping these queues as small as possible.

Title: Traffic Surveillance and Detection Technology Development: New Traffic Sensor Technology

Authors: Jitendra Malik, Stuart Russell, University of California, Berkeley

UCB-ITS-PRR-97-6 (1997)

Problem

Transportation management agencies are faced with having to manage ever increasing volumes of traffic on roadways. New developments in traffic surveillance and detection technology are aimed at improving the accuracy and reliability of real-time traffic data so that traffic conditions can be observed more accurately.

Method

A video system was used to obtain visual traffic data. A computer hardware and software system was developed to process the video data. The goal of the processing was to identify, group, and track vehicles using various algorithms and data filters.

Findings

The method of vehicle detection used is known as “feature based tracking.” This method uses a computer to process the video data to identify features of the vehicles, such as corners, the arrangement of lights (at night), height, width, and so on.

This method was found to be very accurate in determining traffic speed because even false detections will move with the general traffic speed. A vehicle detection that doesn't move within a percentage of the other detected vehicles is eliminated from the data set, so false detections don't significantly alter the speed data.

Title: Travel Time Estimation on the San Francisco Bay Area Network Using Cellular Phones as Probes

Authors: Jean-Luc Ygnace, Chris Drane, Y.B.Yim, Renaud de Lacvivier

**Date: September 2000
UCB-ITS-PWP-2000-18**

Problem Addressed by Research:

Currently, travel time estimates are largely based on data from road sensors embedded in the pavement. These loop detectors wear out and require a certain amount of maintenance and construction costs. This report explores the possibility of gathering travel time information using cellular telephones, which many drivers in the Bay Area already carry in their vehicles.

Method:

The FCC E-911 mandate requires that cellular phones be locatable to an accuracy of about 125 meters by October, 2001, which means that cellular positioning systems are very likely to be implemented in most areas of the US within a few years. This paper discusses the basic technological issues in cellular positioning, and developments that are already taking place in this field. We present results from several analytical and simulation models, which provide insight into the various parameters that will affect the performance of positioning systems. We also look at the business issues, and discuss how a field trial could be carried out.

Findings and Recommendations:

Cellular positioning technology is a very active area of research, and a number of different solutions are being worked on. The prospects of developing an accurate positioning system within the time frame demanded by the FCC are good.

Accurate travel time estimates will be possible provided around 5% of vehicles on the Bay Area network are equipped with live (i.e. switched-on) cell phones, and evidence suggests that they will be.

Our analysis also suggests that cellular telephone positioning could be a cost-effective method of garnering travel-time estimates. The system load needed to make the measurements is only a small proportion of total capacity, and cellular operators might be interested in implementing travel time estimation as a secondary business operation.

A field test depends on PATH researchers being able to access cell phone positioning technologies, much of which is being undertaken in conditions of industrial secrecy. Data collected using cell phone systems would have to be compared to data obtained from the road network; the stretch of I80 between Albany and Emeryville is well instrumented and can provide fairly accurate travel time information, and can be confirmed using GPS-equipped vehicle probes.

Title: TravInfo Evaluation (Technology Element) Traveler Information Center (TIC) Study: System Reliability and Communications Interface (9/96–12/97)
Author: Mark Miller, Dimitri Loukakos

UCB-ITS-PWP-98-21 (1998)

Problem and Method

TravInfo is a field operational test (FOT) of advanced traveler information systems (ATIS) for the San Francisco Bay Area. The project seeks to compile, integrate, and broadly distribute timely and accurate multi-modal traveler information through commercial products and services. The public sector component centers on the Traveler Information Center (TIC), which collects and integrates both static and dynamic traveler information.

This study focused on the technology component of the TravInfo project. The technology evaluation covered in this paper consists of four elements: systems reliability, communications interface, operator interface, and response time analysis. This study focused particularly on system reliability and the communications interface during the period July through December 1997. Study results from the period September 1996 to June 1997 are reported in UCB-ITS-PWP-98-7.

The communications interface is divided into two distinct groups: Traveler Advisory Telephone System (TATS), utilized primarily by the traveling public to access traffic and transit information, and LDS (Landline Data System), utilized primarily by the private sector to download traffic information to add value to it and re-sell to the public.

Findings

During the period between July and December 1997, 38 new or non-recurring internal problems were experienced at the TIC. These problems were quite different than those experienced during the period September 1996 to June 1997. These problems were classified as critical, major, and minor with a frequency of occurrence of 39.5, 44.7, and 15.8 percent, respectively.

With the exception of the month of September 1997 during which the Bay Area Rapid Transit (BART) system workers were on strike causing an initial surge in call volume, the volume of TATS has remained fairly constant (50,000 to 60,000 calls per month). Call volume was at about 3 percent of the TATS system capacity except during the first two days of the BART strike when it rose to as high as 75 percent during peak hours.

LDS usage was fairly limited and well below capacity during the period of study. Access by the private sector participants is essentially limited to three providers, one of which accounts for approximately 90 percent of the total data accessed. The TravInfo system has not yet stimulated development of publicly available ATIS products. Troubling for TravInfo is the fact that between 55 and 85 percent of the data accessed is speed and congestion data, which relies on loop detector data, 75 percent of which have critical accuracy problems.

Usage of TravInfo has fallen well short of that envisioned in the general goals set out for the TravInfo Field Operational Test. Collection of data has been satisfactory, with the exception of serious problems in loop detector data quality. However, dissemination of the data, as reflected in TATS usage, fell far short of the study's goal.

**Title: TravInfo Evaluation (Technology Element)
Traveler Information Center (TIC) Study (September 1996–June 1997)
Authors: Mark A. Miller, Dimitri Loukakos**

UCB-ITS-PWP-98-7 (1998)

Problems and Findings

TravInfo is a field operational test (FOT) of advanced traveler information systems (ATIS) for the San Francisco Bay Area. The project seeks to compile, integrate, and broadly distribute timely and accurate multi-modal traveler information through commercial products and services. The evaluation of the TravInfo system consists of four major elements: (1) institutional, (2) technology, (3) traveler response, and (4) network performance. This paper focused on the technology component of the TravInfo project.

The technology evaluation covered in this paper consists of four elements: systems reliability, communications interface, operator interface, and response time analysis.

System Reliability

Issues in the primarily software, TransView, were the major factor contributing to a loss in reliability of the TravInfo system. The system reliability problems encountered were found to be of serious or critical nature.

Communications Interface

The communications interface is divided into two distinct groups: Traveler Advisory Telephone System (TATS), utilized primarily by the traveling public, and LDS (Landline Data System), utilized by the private sector for electronic traveler information devices.

The demand for access to the TravInfo communications interface was consistently within capacity for the period of this study. TATS access was fairly constant, with some increase in usage due to media reports about the system. TATS usage is disproportionately high for Oakland residents because AC Transit uses the TATS line as a customer information service. However, total usage, even for the disproportionately heavy Oakland region, was well within capacity.

The LDS system experienced problems due to some system reliability issues – problems with the update of data originating in the software led to LDS users (private sector users of the travel data) having to download data several times.

This report goes on to summarize call volume, LDS logons, user preferences by region, and other uses of the TravInfo system. The report also summarizes how certain data are incorporated into the TravInfo system. Finally, “choke points” in the flow and delivery of information in the TravInfo system are identified.

Conclusion

The researchers conclude that the TravInfo system successfully collects and integrates traveler information with the exception of problems encountered with the accuracy and reliability of loop detector data. However, the system falls far short of reaching the

number of intended TATS users, even with an accompanying media campaign to make potential users aware of the TravInfo system.

Use of the TravInfo system was also far short of expectation for the private sector LDS participants. This is concluded to be a result of unreliable loop detector data, which the private sector uses to assess congestion and suggest alternate travel routes.

Approximately 85% of the LDS data accessed was speed and congestion data provided by loop detectors, 75% of which had critical data accuracy problems.

Title: Vehicle Lateral Warning, Guidance and Control Based on Magnetic Markers: PATH Report of AHSRA Smart Cruise 21 Proving Tests
Authors: Han-Shue Tan, Bénédicte Bougler
Date: January 2001

Problem Statement

PATH tested a vehicle that provides automatic steering control, driver lane guidance control, and lane departure warning at the test track of PWRI in Tsukuba City, Japan for the “Smart Cruise 21” proving tests. The steering warning/guidance/control system developed by PATH includes magnetic sensors to detect the vehicle lateral deviation relative to the magnetic markers installed on the roadway; an antenna to receive the radio-wave control point marker information; an automatic steering actuator; a display screen showing the anticipated position of the vehicle to support the driver in steering the vehicle; and a speaker to provide an audio warning signal to the driver when the car is off-course. This system addresses prevention of overshooting on a curve, support for prevention of lane departure under expressway speed condition, and support for prevention of lane departure under fog and rain condition. Only the issues related to steering control are addressed; throttle and brake are controlled by the driver.

This report focuses on the discussions of the following five proving test items that are related to the magnetic markers sensing system:

1. Capabilities of the PATH steering warning/guidance/control system based on the benchmark test results to support the prevention of overshooting on curve, prevention of lane departure under expressway speed condition, and prevention of lane departure under fog condition.
2. Results from the PATH Demo2000 scenarios to further substantiate the steering effectiveness of the magnetic marker based lateral warning/guidance/control system.
3. Presentation of the proving test results of the PATH steering warning/guidance/control system without the knowledge of the road curvature information.
4. Comparisons of the performance of the PATH steering warning/guidance/control system with respect to 2m, 4m, and 6m magnetic marker spacing.
5. Discussions on the effects of different magnetic markers (nail and plate types) on the PATH and AHSRA magnetic sensing system, as well as on noise characteristics observed on the North Loop of the test track.

Findings

1. The capability of the steering warning/guidance/control system based primarily on the magnetic markers was shown to be effective to support automated steering control, driver steering control based on the display screen information alone, and driver steering control based on lane departure warnings alone.
2. The results from the PATH Demo 2000 scenario proved to be very successful. No failures occurred during four days of demonstration and five days of rehearsal. The Demo 2000 scenario included automated steering around the entire test track at various speeds and road curvatures, obstacle detection, switching between manual and automated steering, and steering guidance in zero visibility conditions.
3. The dynamic performance of the PATH guidance/control/warning system is very similar with or without the knowledge of road curvature.
4. Satisfactory performance for the proving test can be obtained using 2-meter magnetic marker spacing. The performance degradation from 2m spacing to 4m spacing is relatively small except at very low speed or sharp curves. Noticeable performance degradation can be observed from 4m to 6m marker spacing especially at lower vehicle speeds. High speed on a straight curve is the least sensitive to the increase of the marker spacing, except at very large departure angles. Low speed on sharp curves is the most sensitive to an increase in marker spacing.
5. a) A “noisy section” exists on the North Loop of the test track. The earth field “noises” in the “noisy section” are observed to be greater than those from the normal section. b) The results do not show a clear distinction between the nail and plate type magnets. However, this may not be true for the AHSRA sensors when the vehicle height is changing. c) AHSRA sensor measurement is not smooth when the magnet is directly between two sensors—this was the reason PATH used only the PATH magnetic sensors for the proving tests.

Locator Number:
UCB-ITS-PWP-2001-6

Title: Videobased Vehicle Signature Analysis and Tracking Phase 1: Verification of Concept and Preliminary Testing

Author: C. Arthur MacCarley, California Polytechnic State University, San Luis Obispo

UCB-ITS-PWP-98-10 (1998)

Problem

There is currently no way to automatically identify and track vehicles traveling on California freeways. With such a system, the California Department of Transportation could obtain data on vehicle flow patterns on California's freeways and arterial roadways to better manage traffic.

In order to meet this interest, a detection system must provide:

- 1) reliable detection and re-identification of a wide variety of vehicles under all possible traffic flow, environmental, and light conditions;
- 2) operate at very low power consumption to permit autonomous battery-only or photovoltaic (solar-powered) operation; and
- 3) be of low to moderate cost.

This report discusses Phase 1 of the research to address this problem. Phase 1 involves preliminary work to test the accuracy, reliability, and robustness of the basic technologies (a combination of video sensing, software processing of the video signal, and wireless transmission of data to other detection modules for a network of connected detection modules) upon which the detection method is based. Together, the technologies are termed Video-based Vehicle Signature Analysis and Tracking (V²SAT).

Phase 2 involves the development of experimental hardware and software for automated detection.

Phase 3 involves the design, development, and testing of a production prototype module. Based on the prototype, several such modules will be built, deployed, and tested.

Phase 4 involves the development of the wireless network components for telemetry between individual modules and local site transponders and the hardware and software components for telephone/modem communication between overcrossing transponders and a central correlation computer.

The proposed system is comprised of:

1. a detection module located on a physical structure (such as a freeway overpass) directly above each traffic lane; multiple modules make up a "site"
2. a local transponder/repeater, one per site, which receives data from up to ten modules and retransmits data via modem and telephone line to a network hub

3. a network hub, which receives the data stream from all detector modules and correlates the data to track vehicles through the monitored area

Method

The sensor is a simple video camera. The image is processed using filters and an efficient detection algorithm to develop a Vehicle Signature Vector (VSV), which is comprised of various measurements of the vehicle dimensions.

For Phase 1, two time-synchronized video systems were deployed at consecutive overcrossings spaced 0.5 to 0.6 miles apart on US Highway 101 in three different locations in the California Central Coast area. Data was collected on three different dates to cover four different illumination conditions.

Videotaped images from the field were then analyzed manually in the laboratory to test the accuracy and repeatability of the optical signature vector as a means for classifying and re-detecting vehicles. The analysis also sought to assess the general usability of the vector as a means for classifying a range of vehicles by dimensional measurements.

Findings

Under daylight conditions (midday and afternoon), an average of 98 percent of all vehicles were detected at the second site, for a sequence of 200 vehicles. For this data set and conditions, the method incorrectly matched the vehicle with the incorrect vehicle 0.87 percent of the time. Under daylight conditions, when a “reasonable time of arrival” window was used to admit only vehicles that could have traveled between sites at speed between 30 and 80 mph, the incorrect match percentage falls significantly, approaching 0 percent for the conditions of this test.

Under dusk illumination, but otherwise identical test conditions, correct matches occurred for 95.15 percent of all vehicles; false matches occurred for 2.02 percent of all vehicles in a sequence of 103 vehicles.

Under conditions of inadequate illumination (night) but otherwise identical test conditions, correct matches occurred for 75.49 percent of all vehicles while false matches occurred for 27.095 percent of all vehicles in a sequence of 102 vehicles.

It was found that supplemental illumination or use of specialized camera technologies will be required for sufficient nighttime vehicle detection and tracking.

On the basis of the results, the V²SAT method has the potential to serve as a reliable basis for non-intrusively tracking the progress of individual vehicles along an appropriately detectorized freeway network under daylight conditions.

Title: V²SAT Final Report: Video Based Vehicle Signature Analysis and Tracking System
Phase 2: Algorithm Development and Preliminary Testing

**Authors: Transportation Electronics Library, Department of Electrical Engineering
California Polytechnic State University, San Luis Obispo.
Loragen Corporation, Advanced Technology Group, San Luis Obispo.**

UCB-ITS-PWP-2001-10

Problem and Findings

This report describes the field tests of the V²SAT video based vehicle signature analysis and tracking system. This system employs video cameras positioned over roadways to obtain images of passing vehicles. The video data is then processed by a digital image analysis to develop a "Video Signature Vector," or VSV. The VSV consists of information such as color of the vehicle, size of the vehicle, and other characteristics like general body shape information.

Using multiple arrays of video cameras placed at various points along a freeway connected to a central computer via a wireless network, VSVs can be compared from the video cameras enabling individual vehicles to be tracked through the instrumented region of freeway. The data can be used to validate traffic flow, generate origin-destination data, validate local modal emission models, and possibly be implemented for law enforcement purposes.

Phase 1 of this research focused on validating the operational concept of the proposed V²SAT method. This included testing the viability of the VSV concept.

The primary focus of this part of the research (Phase 2) was to develop and debug the platform for the field implementation of V²SAT. This platform included software for real-time image processing and storage, refinement of the image analysis algorithms, and the required hardware. The system was then field tested under actual freeway conditions. The test site was a pair of freeway over-crossings 0.34 miles apart. The system was connected using a wireless network.

It was determined that the system had the ability to correctly re-identify vehicles at successive sites was 93.6%. Difficulty was encountered with motorcycles and tandem trucks in particular.

ITS

Title: **Alternative Traffic Signal Illumination: Human Factors Study**
Author: **Theodore E. Cohn, Ph.D., Professor of Vision Science, Visual
 Detection Laboratory, University of California, Berkeley**

UCB-ITS-PRR-98-19 (1998)

Problem

New technologies have produced traffic signals with significant advantages over standard incandescent signals, including greater efficiency and lower costs. But are they as visible to the human observer as the older signals?

Method

We developed what we call a Usability Factor (UF), which compares the visibility of a test lamp to a standard lamp, as perceived by a human observer, when the luminance of the two lamps matches, as measured photometrically. If the UF is greater than one, then less actual measured illumination would be required to render it as visible as a standard light (implying greater energy efficiency); if less than one, more illumination would be needed. If the UF is unity, then photometric measures alone can assess its visibility.

Findings

We found that for a 12-inch red LED lamp, there was no significant difference from a standard lamp. And orange LED pedestrian head was also close; an orange neon pedestrian head had a high UF but the actual illumination is low enough that such a lamp is impractical. An orange fiber-optic pedestrian head had a low UF (so more light is needed to make it visible), a red LED arrow's UF was slightly higher than unity, and a red fiber-optic arrow had a very low UF.

We also conducted extra tests on the 12" red LED, finding that a sun-phantom (produced when the sun is low behind the observer and shining into the lamp) had less effect on the lamp's visibility than on a standard lamp, and that glare and fog seemed to have little effect as well.

The Usability Factor is a useful quality index which can be used in combination with the standard 44-point test or other appropriate photometry-based tests to evaluate the visibility of a lamp.

**Title: Anaheim Advanced Traffic Control System Field Operation Test Task A:
Evaluation of SCOOT Performance**

**Authors: James E. Moore, II, R. Jayakrishnan, M.G. McNally,
C. Arthur MacCarley**

UCB-ITS-PRR-99-26 (1999)

Problem

The city of Anaheim, California, implemented SCOOT (Split, Cycle, and Offset Optimizer Technique) as part of a larger Field Operational Test which included several other related technologies. This part of the FOT was meant to evaluate SCOOT, which controls systems of signals rather than just isolated intersections, in terms of the following issues: its limited implementation as an option for Anaheim traffic controllers, the development of operational policies, and the evaluation of its operational effectiveness.

Evaluation Task A1 assessed the value of existing loop detectors for SCOOT (the detectors were already in place, but closer to intersections than SCOOT is designed to use them), and assess the quality of SCOOT's internal representation of traffic flow. We did this by comparing SCOOT's performance to videotapes of actual conditions at intersections.

Evaluation Task A2 assessed the performance of traffic under SCOOT in terms of delay. We posted observation teams at intersections to measure delay and used floating cars to measure running, stopped, and total travel time, both before and after the implementation of SCOOT, during PM peak and evening off-peak hours, and for special event and nonevent traffic.

Findings and Recommendations

SCOOT successfully models traffic conditions, but there is room for improvement. In general, SCOOT performed better off peak, for special events at smaller-volume intersections, and very well at specific intersections with heavy traffic during special events.

When SCOOT performed worse than the baseline system, it did so rarely more than ten percent, and when it performed better, the difference was normally less than five percent. (It must be kept in mind that the existing traffic control system in Anaheim is considered state-of-the-art, and that SCOOT was using information from loop detectors in nonstandard locations.)

Delays between the two systems were generally comparable, and SCOOT caused no unacceptable delays or catastrophic problems.

**Title: Anaheim Advanced Traffic Control System Field Operational Test
Task B: Assessment of Institutional Issues**
**Authors: M.G. McNally, James E. Moore II, C. Arthur MacCarley,
R. Jayakrishnan**

UCB-ITS-PRR-99-27 (1999)

Problem

The city of Anaheim, California, was committed to implementing three new traffic control technologies: SCOOT (Split, Cycle, and Offset Optimizer Technique), a signal control system developed and used in Britain; a 1.5 Generation Control system whose purpose was to update baseline timing plans for SCOOT from the first generation system already in use, and a video traffic detection system to supplement loop detectors. The project required coordination between a number of agencies and partners, including the city of Anaheim, its systems contractor JHK/Transcore, SCOOT vendor Siemens, video system provider Odetics, Eagle Signal, Caltrans and the FHWA, who funded the Field Operational Test, and PATH.

The purpose of this report is to answer the question: through what structures and methods can the technologies be applied without being confounded or restricted by institutional issues?

Method

Information was gathered through direct observation of project participants, primarily at formal meetings, and detailed interviews of all key project participants. Interview questions covered project goals and objectives, implementation, funding, and working relationships. They addressed administrative, financial, leadership, personnel, legal, liability, and technical issues.

Findings

Numerous institutional problems were identified by participants, some of them interwoven with technical problems. Prime among them was a lack of leadership during a crucial period in the process of implementation, when the Principal Traffic Engineer left and was not replaced for 8 months. Although his duties were reassigned, the lack of someone in a leadership and advocacy role led to several delays, including a long delay before a contract was signed with SCOOT provider Siemens. This caused other delays, and could have ended the project altogether had Caltrans not allowed several extensions.

Other main findings include:

- A strong, proactive project manager is needed.
- Delays caused unanticipated costs that put the project over budget and did not leave enough time for proper training.
- Staff failed to plan adequately for training and maintenance needs, and they overestimated the operators' ability to switch to a new system.
- Unanticipated communication problems included differences between British and American standards, differences between software systems, integrating older systems with SCOOT, and a time difference that created difficulties communicating with the SCOOT vendor.
- Staff was not motivated to fully learn the new system because it wasn't clear to them whether the new system would actually be used after the FOT.
- Everyone interviewed had a different idea of what the FOT's goals were.

Call Number: UCB-ITS-PWP-2001-2

Title: Caltrans TOPS Evaluation: Assessing the Net Benefits of ITS Applications

Authors: David Gillen

Date January 2001

Method

The purpose of the research was to provide the Caltrans Traffic Operations Group and New Technology Group with a measure of the expected net benefits with the application of ITS projects to parts of the California highway system. The value of the research is that it would provide measures of the changes in benefits from ITS projects as the size of the projects change and as projects are introduced in combination with one another.

The outcome of a set of experiments undertaken to assess the net benefits of ITS applications in a stylized urban and near-urban highway network is presented. The work was completed using the IDAS Build I package. Despite the limitations of this first generation package, the research was able to assess a number of different ITS technologies including ramp meters, incident management, integrated technologies and synergies from multiple ITS applications.

Findings

While not able to conduct the experiments originally envisioned and not having been able to utilize Paramics as the preferred simulation tool, the experiments conducted using IDAS were successful. They provided some insight into the application of ITS projects to a highway system. The research examined change in net benefits resulting from expansion of the number of ramp meters as well as a shift in technology from moving from pretimed ramp meters to centrally controlled ramp meters. The research also examined incident management and the change in net benefits as the response time to the incident was reduced. Finally, the research also examined the synergies that might arise as combinations of ITS applications are applied to the highway system.

The research concluded that there are diminishing returns to adding a given technology. With ramp meters, there was a huge transfer in benefits from arterial road users to freeway users since traffic was held on the ramp to increase speeds on the freeway by a small amount. However, when the model was shifted from 5 pre-timed to 5 centrally controlled ramp meters, an increase is seen in the benefit/cost ratio. The conclusion is that the shift from a pre-timed "old technology" ramp meter to a "central control" new technology results in considerable benefits. Furthermore, the benefits from new technology (i.e., ITS) exceed those of expanding the old technology (e.g., increasing the number of pre-timed ramp meters). The increase in benefits is sufficiently large that the "gainers" could compensate the "losers" and still be better off themselves.

Title: Data Utilization at California Transportation Management Centers
Authors Shirley Chan, Elbert Chang, Wei-Hua Lin, Alexander Skarbardonis

UCB-ITS-PRR-98-34 (1998)

Problem

This study examined the operations and functions performed at the Caltrans Transportation management Centers (TMC) with emphasis on the data sources, data processing and performance measures. Currently, much of the investment at the TMCs is in real-time traffic data collection primarily from inductive loop detectors. Much of this data is archived without further analysis due to the staff and budget limitations.

Method

The objective of this study is to evaluate how traffic data from several sources (loop detectors, closed circuit television, cellular phone calls for incidents, airborne reports, freeway service patrol logs, etc.) is currently acquired, processed, used, and stored by the Caltrans TMCs and to assess the potential to improve efficiency in data utilization. A literature review was performed to obtain information on the role and functions of TMCs in California and throughout the country. Additional information was gathered through interviews with the staff of ITS America, metropolitan planning organizations, as well as field visits to various Caltrans TMCs. The research then explored the role of information from new technologies and data processing algorithms in supporting TMC operations.

Findings

TMCs are an important means for managing the transportation system by collecting information in a centralized location and developing coordinated action plans. However, much of the investment is in real-time data collection and information dissemination. Little investment has been made for off-line applications (for example, to predict traffic growth). According to TMC staff members, much of the data is stored in the computer system or archived unanalyzed.

Most TMCs do not have the manpower available to ensure that loop detectors operate properly. Thus the data is often not reliable.

Data from video systems and emerging sources (such as electronic toll collection) need to be integrated into the database to assist in the data checking and verification.

New software and hardware will permit TMCs to have access to all types of traffic data from a single workstation. The new software being developed can potentially reduce the amount of human intervention needed for data analysis and collection and reporting of significant events that require TMC action.

Title: Definition and Measurement of Transportation System Performance
Authors: Joy Dahlgren (California PATH, Institute of Transportation Studies, Berkeley)

UCB-ITS-PRR-98-24 (1998)

Problem

Performance measures are needed to help make decisions regarding the overall level of resources to devote to a transportation system, where to allocate these resources, and how best to use them.

Decisions regarding the level of resources and where to allocate these resources require regular monitoring of the system to reveal opportunities for improvement. The decision of how best to use transportation resources must be more carefully examined in order to evaluate multiple means of addressing transportation needs and their respective costs and benefits to the public.

Method

The overall goal of a transportation system is to maximize the benefit of the system over its costs. Performance measures should therefore relate benefits to costs.

Specific attention is given to intelligent transportation systems which have both the capability to deliver benefits to a transportation system, and the capability to generate useful data on vehicle-miles and travel time within a transportation network.

Findings

The primary costs of transportation: time, money, property damage and injury, environmental degradation, and discomfort, such as the stress or delay caused by difficult driving conditions. Transportation system performance is measured in terms of the amount of transportation provided, which indicates the amount of access provided (person-trips, person-miles, and \$-miles of freight), travel time (both the average and the variation), and the amount of property damage and injury, and public monetary costs. These are the primary determinants of overall benefits and costs. These determinants are measurable and they can be influenced by the actions of transportation agencies.

In order to provide useful data for routine transportation system performance assessment, the following is recommended:

- Limit the number of routine measures, to concentrate resources on the most useful measures.
- Continue research to improve methods for measuring volumes and travel times.
- Develop a prototype travel time and volume measurement system, including data collection, processing, and storage, and characterization of performance.
- Develop schedules for measuring performance that are appropriate for different traffic situations.

Title: Development and Testing of Field-Deployable Real-Time Laser-Based Non-Intrusive Detection System for Measurement of True Travel Time on the Highway

Author: Harry H. Cheng, et al, Integration Engineering Laboratory, Department of Mechanical and Aeronautical Engineering, UC Davis

TR-IEL-2000-101 (2000)

Problem

Reliable, real-time traffic speed information is invaluable for traffic planners. Current methods for measuring travel time do so by measuring speed at one or more points along a link and then extrapolating speed across the entire length of the link. Loops, radar, and video image processing all use extrapolation to deduct travel time. However, when traffic flow slows because of an accident, speed variations along any given link can be quite large. This is when accurate information for making routing decisions is most critical, and the uncertainties caused by extrapolation are magnified.

Vehicle-as-Probe (VAP) methods determine travel time by identifying vehicles at the start of the link and then re-identifying them at the end of the same link, giving true travel time as the time difference between the two. The cost of VAPs is quite high, however, requiring a large number of vehicle tags and tag readers to be effective.

It is possible to identify some distinguishing characteristic on a vehicle at the beginning of a link and then re-identify that same vehicle at the end of a link without the set-up costs of a VAP. If a characteristic can be found that separates cars into 100 possible classifications, a match between upstream and downstream vehicles can be made with high probability. Even more classifications would make the process even more accurate.

Method

This project developed a laser detection system that can directly and accurately determine origin and destination information for vehicles in the traffic stream non-intrusively and without violating privacy. It produces local vehicle speed, vehicle volume, and vehicle classifications, even under high flow conditions. Point-to-point travel time and incident detection can easily be determined.

This system can be mounted above the road, which allows it to be installed and maintained without tearing up the road or disrupting traffic. It operates on a simple “on/off” basis, requiring much less computation for vehicle detection than video methods. It also produces and senses its own signal, so it does not depend on time of day and weather conditions for accuracy (as do video detection systems). There are no moving parts, and power and bandwidth requirements are very low.

The system projects a laser onto the ground, and then collects the reflected light onto a photodiode array. A vehicle is detected when it passes under the beam, based on the absence of the reflected light. With two identical laser/sensor pairs placed close together,

it is possible to measure the speed of both the front and the rear of the vehicle as it triggers each sensor. The length of each vehicle is determined from the speed and the amount of time the vehicle spends under the detector.

Findings

We have built a field prototype detection system and tested it under real traffic conditions. Our test results verify that the principle of this system is technically sound and the software works in most cases. There are a few situations, such as stop-and-go traffic, where the detection of vehicle length does not work well.

We also found that the separating distance of the two laser-sensor detectors was too small in our test, which made the system detect different speeds for the front and the rear of vehicles. Also, the slowness of the analog signal contributed to the error. Both of these problems will be fixed in the next prototype, by putting the pairs farther apart and by using a faster digital signal.

**Title: Evaluation of the Anaheim Advanced Traffic Control System Field
Operational Test: Executive Summary**
Author: M.G. McNally, James E. Moore II, C. Arthur MacCarley, R. Jayakrishnan

UCB-ITS-PRR-99-18 (1999)

Problem

The city of Anaheim, California, experiences heavy traffic on a regular basis. Delays at intersections are a significant problem, and many special events create special traffic problems. The city has an advanced traffic control system, but wanted to test out several new technologies, so this field operational test was set up both to assess the technical performance of these methods and to analyze the institutional issues around their implementation and operation.

The three systems were: SCOOT (Split, Cycle, and Offset Optimizer Technique), a second generation technology for controlling systems of signals as opposed to isolated intersections, already in use in Europe; a 1.5 Generation Control system under development, whose purpose was to update baseline timing plans for the entire system; and a video traffic detection system presented as a low-cost alternative to loop detectors for critical areas.

Method

The evaluation was broken down into three main parts: a performance assessment of the technologies, an assessment of the institutional issues, and a separate evaluation of the video traffic detection system.

For the performance assessment, we looked first at how well SCOOT “sees” traffic and then at how well it performs to control traffic.

Findings

SCOOT is designed to rely on information from loop detectors placed farther away from the intersections than the mid-block locations of the loops already in place in Anaheim. We needed to know whether these loops could provide adequate information to the system, so we compared SCOOT’s estimates of queue length and clearance time to real time video at certain intersections, and identified large inconsistencies. Nevertheless, SCOOT successfully models traffic conditions, in general, but can be improved either by changing the location of loop detectors or by adjusting global control settings to compensate for the actual location of detectors.

To assess SCOOT’s performance, we used teams both at intersections to measure delay and in cars to measure travel time, before and after implementation. We discovered that SCOOT performed better than the existing system during off-peak hours, and very well at certain intersections during special events. However, our findings are inconclusive as to whether SCOOT is better than the system already in place.

To evaluate institutional issues, we used direct observation and interviews, all of which produced subjective information that was structured to provide many different points of view. We looked at implementation, operations, transferability, and maintainability of the system. There was an immediate problem with delaying implementation due to a vacancy in a key position (Principal Traffic Engineer), which led to a lack of experience and authority in the city's relations to the contractor (Siemens). We were not able to adequately evaluate operational issues because of the resulting delays, which led to late delivery, and limited staff training and experience prior to the evaluation. In terms of transferability of technology, we concluded that products that are not widely deployed are essentially still in the research and development process, subject to delays, changes, and cost overruns. This is especially true for the 1.5 GC system. Maintaining the new systems would involve significant costs, and much more training is needed to properly utilize it. Our overall conclusions in regard to institutional issues is that we have no specific recommendation, but costs would be likely to go up if SCOOT were to be expanded beyond its present limited deployment.

The last evaluation task, of the video system which is marketed as a low-cost alternative to loop detectors, found that its user interface is unsophisticated but effective. The system's performance results were good under ideal lighting and light traffic conditions, but not so good in low light, night, rain, or heavy traffic. (The manufacturer, Odetics, says it has since addressed and corrected these issues, but we have not evaluated the new system).

Title: Evaluation of ITS Technology for Bus Transit Systems

Authors: Randolph Hall, Maged Dessouky, Lei Zhang, Ajay Singh, Vishal

Date November 1999

Description of the Research

Recently, bus transit service providers have begun to adopt Intelligent Transportation Systems (ITS) technologies such as Global Positioning Systems (GPS) and Mobile Data Terminals. 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. This research evaluates bus control strategies using ITS against those without ITS. Two levels of ITS are considered: 1) a system with centralized tracking, and 2) a system with information on connecting passengers, as well as centralized tracking. For those strategies using ITS, we develop methods to forecast bus arrival times to a stop and the number of passengers on board the bus.

Conclusions of the Research

Several different ITS strategies were evaluated. In terms of minimizing the average passenger trip time, the ITS strategies outperformed the non-ITS based strategies for the random generated problem sets, though not for one real-life dataset.

Overall, the researchers found it disappointing that ITS did not provide larger time savings in the analysis conducted for this research. A fundamental reason for this is that in many situations, it is optimal to either have a bus leave immediately whether or not connecting buses have arrived, or to wait as long as possible until all connecting buses have arrived. These extreme cases require no communication and no ITS.

ITS was found to be more beneficial for cases in which a connecting bus incurs a small delay and it is more advantageous to wait for its arrival than to depart without the connecting passengers.

The savings per passenger appear to be no more than 1 minute, which translates into annual time savings on the order of 500 to 2000 hours per bus. Savings of this magnitude may be sufficient to justify installation of an ITS system with payback within a few years. More generally, the savings are highly site-specific and should be evaluated on a case-by-case basis. Cost-benefit analysis was not performed as part of this research.

Locator Number:
UCB-ITS-PRR-99-38

Title: Evaluation Methods for Measuring the Value of ITS Services and Benefits from Implementation: Part X Freeway Service Patrols
Authors: David Levinson, Pavithra Kandadai Parthasarathi
Date January 2001

Problem Statement

Incident management programs are one of the key elements of Intelligent Transportation Systems (ITS). The goal of such programs is to clear the incidents from the roadways and return traffic flow to normal as soon as possible. Incident management programs have been introduced in many places to facilitate incident detection and reduce incident duration. They make use of ITS services and coordinate among the various operating agencies to meet the goals of quick detection and clearance of incidents.

Highway assistance services, also called the freeway service patrols (FSPs), are one of the main approaches used by incident management programs. These patrols use vehicles to patrol the heavily traveled segments and congested sections of the freeways that are prone to incidents. The main goals of the FSPs are to help identify incident locations, reduce the incident duration time, get the freeway capacity back to the fullest and to reduce the risks of secondary accidents without any assistance from other agencies. In cases of major incidents, the patrols help assess the equipment and resources needed to clear the incidents, coordinate with other agencies involved, and provide the needed traffic control and buffer between the workers and traffic. They also help detect and verify incidents like major accidents and pass on the required information to the transportation management centers (TMCs). This helps reduce delay, congestion, wasted fuel, emissions and potential for secondary accidents.

Previous analyses of the freeway service patrols include studies conducted by California PATH (Partners for Advanced Transit and Highways) program at the Institute of Transportation Studies (ITS) University of California Berkeley and Texas Transportation Institute concluded that FSPs are cost-effective, successful in their objectives of reducing incident duration and facilitating quick detection, and highly popular among motorists.

This research sought to determine the value that people place on the benefits offered by FSPs in comparison to private assistance services such as the Automobile Association of America (AAA), and how much they would be willing to pay to avoid being stranded when their vehicle breaks down on the freeway. The studies conducted so far have focused on the effectiveness of the freeway service patrol whereas this report analyzes the factors that influence people in choosing to rely on the freeway service patrol.

Findings

This research shows that the probability that an individual would choose the highway assistance services depends on the key attributes like the annual fee of the program, the fee at the time of assistance, the time of waiting for assistance and cost of breakdown. The findings also show that the presence of the highway assistance services in a state does have a small influence on the auto club (AAA) membership.

The researchers also concluded that the data sets for Stated Preference and Revealed Preference analyses were too small. Larger data sets were anticipated to provide better results and clearly indicate the factors influencing people's choices. A pilot survey conducted on a larger scale would likely provide a better evaluation of the factors influencing people's choices related to FSP use.

In addition, the research concluded that the sample set was probably socio-demographically too homogeneous. A larger heterogeneous sample set would provide better indications of the way the socio-demographic variables impact the choices of motorists.

Locator Number:
UCB-ITS-PWP-2001-3

Title: Evaluation of the OCTA Transit Probe System

Authors: Randolph W. Hall, Nilesh Vyas, Chintan Shyani, Vikas Sabnami, Simit

Date: November 1999

Description of the Research

The OCTA (Orange County Transit Authority) Transit Probe Project is a field operation test of an automatic vehicle-location (AVL) system operating in Orange County, California. The system software was designed to estimate roadway congestion levels based on bus travel times over route segments and communicate this information to Caltrans, the City of Anaheim, and the City of Santa Ana.

This report presents the final evaluation of the project, concentrating on the year-long field operational test period. The report provides a detailed description of the system and its design. It also provides analyses of data reliability and accuracy, and analysis of the usefulness of Transit Probe data for predicting automobile travel times. Institutional issues are evaluated, based on interviews with involved personnel, direct observation, and review of project documents. Surveys of bus riders and kiosk users are also documented.

Conclusions of the Research

Bus tracking systems provide many potential benefits related to scheduling, problem response, and bus arrival information for users. However, these benefits cannot be captured without carefully planning operational procedures, data maintenance, system interfaces, and ensuring that the equipment is reliable. These important issues did not receive adequate consideration in the system design phase of the project. Although the evaluation produced important insights as to how bus tracking should be implemented and the likely problems to expect, the OCTA Probe failed to live up to its promise because the system was not used by drivers, dispatchers, planners, schedulers, or the general public.

Transit Probe did not meet reliability standards for an actual deployment. The majority of schedule data points are either missing, undetected, or duplicated, thus confounding data analysis.

Transit Probe never created its intended interfaces to Caltrans, the City of Anaheim, or City of Santa Ana due to a reduction in scope of the deployment and a reduced budget.

Only one public interface kiosk was installed, and though it was well-received in a test evaluation, it wasn't functional until the end of the project and therefore didn't have any positive impact.

Customers perceived that bus schedule adherence had improved during the Transit Probe project, though whether this represents a real improvement or merely public perception is not altogether clear. From bus driver interviews, it seems that the installation of a clock in driver view may have encouraged better schedule adherence. However, drivers generally ignored Transit Probe indicator lights, and therefore the improvement could not have resulted from Transit Probe's schedule adherence capabilities.

The congestion measurement component of Transit Probe was never fully established due to many factors, including: 1) inadequate congestion information dissemination, 2) improperly established baseline bus route segment speeds, 3) inaccurate speed estimation algorithm in Transit Probe, 4) lack of relationship between slow bus speeds and general traffic speed.

In terms of the institutional performance of OCTA Transit Probe, OCTA involved partner agencies commendably while moving the project forward and meeting deadlines during the design phase. However, once the project progressed to the test phase, the organization became rather conventional with a contractor and contract manager and outside participation virtually disappeared.

Locator Number:
UCB-ITS-PRR-99-39

Title: Evaluation of TravInfo Field Operational Test: Final Report

Authors: Youngbin Yim, Mark A. Miller

Date: May 2000

Description of the Research

TravInfo is a regional traveler information system in the San Francisco Bay Area. It was a Field Operational Test (FOT) over a two-year period from September 1996 to September 1998 with funding from the Federal Highway Administration and the California Department of Transportation.

The goal of TravInfo was to broadly disseminate accurate, comprehensive, timely, and reliable information on traffic conditions and multi-modal travel options to the public in the San Francisco Bay Area. Organizationally, TravInfo was structured around a collaborative partnership between public and private participants. Operationally, the system was built on an open-architecture concept to make its regional database easily accessible to all interested parties.

The core of TravInfo was its Traveler Information Center (TIC) which was created for the FOT. The center collects and processes traffic information for dissemination directly to the public through its Traveler Advisory Telephone System (TATS) and to information service providers for dissemination through the Web and other advanced traveler information products.

The FOT attempted to measure how well TravInfo performed in four major areas: building a regional traveler information system with the collaboration of public and private parties; providing improved travel information to the public; stimulating the creation of a commercial market for advanced traveler information products, and ultimately enhancing the entire Bay Area transportation system. This last area of evaluation was ultimately not considered due to insufficient data, difficulty in finding a suitable method of measurement, and insufficient use of advanced traveler information products among the public.

Conclusion of the Research

TravInfo's primary success lay in developing a network of public and private professionals who collaborated on advanced traveler information system projects in a variety of settings and providing a platform for different organizations to create networks and form partnerships.

The major challenges of the TravInfo FOT were notably similar to those of other FOTs. Among them were setting ambitious project goals that were unattainable within the limited time reserved for the field test; underestimating the extensive time required to develop mutual understanding and trust among parties with varying objectives; underestimating the uncertainty of the consumer market for commercialization of traveler information products and services; defining appropriate roles for the parties involved; and appreciating the importance of having enough time and funds to market the product and convince people to use it.

**Locator Number:
UCB-ITS-PRR-2000-7**

Title: Evaluating the Impact of ITS on Personalized Public Transit
Authors: Maged M. Dessouky, Randolph W. Hall, Rutvij Shah, Majhid Aldaihani
Date: March 2001

Problem Statement

The passage of the Americans with Disabilities Act (ADA) has created renewed interest in Demand Responsive Transit (DRT) Services. At the same time, the introduction of Intelligent Transportation Systems (ITS) such as dispatching and scheduling software, automatic vehicle location (AVL) devices, mobile data terminal (MDT), etc., has made such systems less complex to operate.

These advancements in technology have provided the impetus for many vendors to develop specialized software and other equipment to support management of paratransit and DRT services.

The objective of this research is to investigate the use of ITS technologies to improve the service efficiency of DRT providers and to evaluate the different opportunities it creates to improve the overall performance of DRT systems.

As part of the research efforts, the following tasks have been completed:

- Technologies that are currently being implemented and emerging technologies that have the potential to improve system performance were reviewed and identified.
- Commercial scheduling and dispatching software packages were surveyed in order to assess their functionality.
- In-depth phone interviews and site visits of transit agencies were conducted to document how public agencies are adopting such software.
- Travel pattern data from the Antelope Valley Transit Authority of Los Angeles County, a representative paratransit provider, was statistically analyzed.

Findings

The technologies identified as being implemented or considered for implementation by transit providers included AVL, advanced wireless communication, MDT, computerized vehicle navigation, and geographic database. Some emerging technologies such as Wireless Internet Dispatching (WID), superphones, and Personal Data Assistant (PDA) were also recognized as having potential application within ITS.

The review conducted as part of this study shows that the software reviewed by in large has the capabilities to be utilized in DRT service within the paratransit industry. The products reviewed were provided by Strategen Systems, Trapeze Software, Inc., and RouteLogic, Inc. The intent of the research was not to recommend any products, rather just to review their applicability within the paratransit industry.

The results of the in-depth phone interviews and site visits show that utilization of ITS technologies at a paratransit provider in the Santa Clara Valley led to reduced cost, increased efficiency, and no perceived reduction in customer service as indicated by the paratransit users.

Although this study shows the potential benefit of deploying ITS in DRT systems, ITS alone is not a complete solution for meeting the increased demands for these types of services and for satisfying the strict guidelines of the ADA. New innovative services that complement ITS need to be studied.

Locator Number:
UCB-ITS-PWP-2001-12

Title: Freeway Performance Measurement System: Final Report

Authors: Pravin Varaiya
University of California, Berkeley

Date: January 2001

Description of the Research

This report summarizes the design, operation, and implementation of PeMS (Performance Measurement System). Topics covered include the communication and software architecture of PeMS, its applications, observations of PeMS in operation, and an appendix consisting of an empirical study of congestion, capacity, and ramp metering using PeMS.

Conclusions of the Research

PeMS is a low-cost freeway performance measurement system for all of California. PeMS processes 2 GB/day of 30-second loop detector data in real time to produce useful information to travel network managers, traffic engineers, planners, researchers, and travelers.

PeMS utilizes an open communication and software architecture, meaning that the code used to develop the software is publicly accessible and that modifications or add-ons can easily be made to PeMS. A new district can be added to the PeMS system with six person-weeks of effort and no disruption of the district's TMC (Traffic Management Center); data from new traffic loops can be easily added as it is available. PeMS applications are accessed via a Web browser, an interface with which the majority of users will already be familiar.

PeMS is inexpensive, utilizing off-the-shelf products for communication and computation. PeMS uses data retrieved from the existing Caltrans ATM wide area network to which all districts are already connected.

PeMS benefits users in several ways:

- \$ Caltrans managers can instantly obtain a uniform and comprehensive assessment of the performance of the freeway network.
- \$ Caltrans traffic engineers can base their operational decisions on knowledge of the current state of the freeway network.
- \$ Caltrans planners can examine solutions to congestion. Traffic control equipment, such as ramp-metering and changeable message signs, can be optimally placed and evaluated.
- \$ Travelers can use PeMS via products developed by VARs (Value Added Resellers) to choose optimal travel routes.
- \$ PeMS can serve to guide and assess intelligent transportation system (ITS).

Locator Number:
UCB-ITS-PWP-2001-1

Title: Identifying the Onset of Congestion Rapidly with Existing Traffic Detectors
Author: Benjamin Coifman

UCB-ITS-PWP-99-17 (1999)

Problem

Traffic surveillance systems need to reliably identify the presence of congestion, and to respond rapidly when congestion is detected. Loop detectors are good at the first, but not so good at the second task. This paper presents an algorithm using existing dual loop detectors in a new way to improve their performance on these tasks; it promises to be deployable in the short term.

Method and Findings

Loop detectors calculate flow and occupancy at discrete points on a freeway. We generally assume that this information represents the space between links as well. However, under congested conditions this is not always so; the traffic stream can change significantly from moment to moment in both directions, especially when traffic is heavy.

Conventional loop detectors easily identify the presence of congestion, but response time is usually slow. Our method solves this by looking for free-flow traffic instead of congestion. Recognizing that signals emanate from an incident in two directions—a drop in speed moving backwards at about 8 mph, and a drop in flow moving forward at the prevailing traffic speed—the algorithm looks for a fast-moving drop in flow, thus quickly identifying the onset of delay.

The drop in flow is found by identifying long vehicles at a detector station, then looking for a similar vehicle in the same lane upstream within a certain time window, defined by the amount of time it would take the vehicle to travel that far at free-flow speeds. If the vehicle is identified, then the presence of free-flow traffic reveals itself. Since lane changes are less common under free-flow conditions than congestion, the likelihood of identifying the vehicle is higher. Using long vehicles, which can be four times as long as smaller vehicles and thus easier to identify with some certainty, we can quickly ascertain whether free-flow conditions are met, or not.

This work is compatible with existing detector infrastructure, and simple enough to implement on existing Model 170 controllers, which are based on twenty-year-old computer technology. It is intended to augment, not supplant, conventional surveillance strategies to improve performance.

**Title: Los Angeles FOT Spread Spectrum Radio Traffic Signal Interconnect
Evaluation Task: Final Report on Full Deployment
Author: Victor O.K. Li, Senthil Sengodan, Tat-Keung Ken Chan, Lei Zhuge**

UCB-ITS-PWP-98-27 (1998)

Problem

Spread spectrum radio networks (SSRN) are an alternative to hard-wired methods of traffic monitoring and control which take less time and money to build and maintain. How well do they work? Los Angeles needs to connect 2000 intersections to its existing traffic control system (which already controls 2000 intersections via hard-wired links) so USC set up a field operation test in the Mar Vista area to implement and test the reliability and cost effectiveness of SSRN.

The radio links are arranged in a network of cells, each consisting of one headend radio hard-wired to the control center and up to 31 remote radios hard-wired to intersection controllers.

Findings

The overall performance of the system is satisfactory. It can send large amounts of information reliably through the network, with an average signal throughput of 90 percent, which is satisfactory, but can be improved. The automatic network reconfiguration in the presence of failed and poor links also worked well.

Some channels are busier and less reliable than others; in fact one particular channel (7) was very busy with other radio traffic and so was eliminated from the choices used in this area. Some antenna locations work better than others, and antennas that were mounted high enough to create visual line-of-sight connection provided high quality links between units. Some mounting options work better than others, depending on the particular location, although sometimes a choice must be made between signal loss or durability and ease of maintenance. Also, some units had a problem with polarization, which was solved with the use of a special antenna.

Recommendations include the use of an exclusive radio band to increase throughput, and taller posts for antennas to get the best possible line-of-sight connection.

Title: Los Angeles Smart Traveler Field Operational Test Evaluation
Author: Genevieve Giuliano¹, Randolph W. Hall¹, Jacqueline M. Golob²
(1 University of Southern California at Los Angeles; 2 Jacqueline Golob Associates)

UCB-ITS-PRR-95-41 (1995)

Problem

The Los Angeles Smart Traveler Field Operational Test (FOT) is one of the largest and most comprehensive ATIS (Advanced Traveler Information Service) experiments to date. The system is multi-modal and offers traffic, transit, and ride-matching information. The FOT tested the delivery of ATIS services through multi-media kiosks, touch tone phones, and PC modem links.

Traveler information systems are currently being promoted for their potential to support policy efforts aimed at influencing travel behavior. Seeking alternative routes of travel to avoid congestion, changing times of travel, changing travel modes to transit, and ridesharing are all possible means of beneficially influencing both traffic congestion and air quality. The evaluation considered the following:

- Financial impacts
- Functional characteristics
- User acceptance
- Other impacts

Findings

The kiosks provided a new medium for obtaining pre-trip traveler information. They were found to be reasonably user-friendly and made information on all three of the major travel modes accessible in a wide variety of locations. Survey results indicated a high degree of user satisfaction, yet the overall usage rate was low (an average of 25 transactions per day), relative to the cost of providing the kiosk service. Low usage combined with high capital and operating costs yielded a total cost per use of approximately \$2.00 (over a five-year lifetime of the kiosk).

Kiosks placed in office locations had the lowest usage while kiosks placed in Union Station in downtown Los Angeles and kiosks placed in shopping malls had the highest usage. This finding suggests that the kiosks may be used more for non-work related trip information when users have more time, such as for shopping trips or by tourists.

The telephone system called ARMS (Automated Ridematching Services) was found to have very little use (34 persons per week). From a small telephone survey of ARMS users it was concluded that most users used the service to seek regular ridesharing opportunities and not the featured one-time ride service. The survey also suggested that low usage can be attributed to a hesitancy among travelers to take or offer rides to people who are unknown. Most users rely on friends or family members for one-time ridesharing. The researchers concluded that there is not enough interest in ARMS to justify its cost of operation.

The modem service was found to have significant usage (approximately 400 uses per day). This component of the ATIS system did not have the multi-modal component at the time of evaluation and instead only reported Caltrans congestion information. Usage was found to be higher in the mornings and evenings, consistent with commuter trip planning.

Overall conclusions about the project were as follows:

- The management burden associated with this demonstration was a significant. The scope of future demonstrations ought to be no larger than is necessary to adequately test a product or concept.
- Data requirements and management should be established early in the project. Automated data systems generate huge amounts of data. It is essential that summary data requirements be established in the project planning phase.
- Structure and timing of the evaluation should allow for the analysis of the travel impacts of the technology being evaluated. Short term demonstrations do not allow for evaluation of whether the ATIS initiatives are having their desired impact on traveler behavior.

Title: **Measuring the Aggregate Productivity Benefits from ITS Applications: The California Experience**

Authors: **David Gillen, Matt Haynes**

Date **September 2000**

Description of the Research

There are three comprehensive policies contained in California's Transportation Plan (CTP). These policies are to promote economic vitality through mobility and access; to provide safe, convenient and reliable transportation; and to provide environmental protection. Transportation applications such as Intelligent Transportation Systems (ITS) offer much in the way of addressing the policies given in the CTP.

Because investments in ITS technologies will clearly have widely differing impacts, there is an inherent uncertainty in predicting the impacts of a particular ITS strategy in a given location. If better understanding can be gained of the extent to which ITS strategies provide benefits to the economic output of a county or region, then decisions to invest in ITS in the future will be better informed. This study uses measures of productivity to assess the impacts that ITS applications have had in California counties.

Conclusion of the Research

Two related models were used to evaluate the economic benefits of ITS.

The first model was a production function model that represented the way a county assembled and delivered a range of goods and services to the marketplace. Included in the production function were private capital, labor resources, highway capital, and measures of the development and integration of ITS projects into the highway system. Two ITS technologies were considered: ramp meters and changeable message signs. The empirical results show that highway capital provides counties with a competitive advantage creating output gains and a net positive benefit.

The second modeling effort was to develop measures of Total Factor Productivity (TFP). This productivity measure takes account of the aggregate growth in outputs as well as inputs. The research estimates show that ITS adds benefits that should be counted in any project evaluation. The benefits are in the form of improvements in productivity. This leads to cost reduction in the delivery of gross county product.

Further research should focus on answering the following questions: What industries are most affected by ITS applications? Does it matter how many ITS applications are present, in other words, are there diminishing returns to similar ITS projects? Finally, does it matter how ITS projects are combined?

Locator Number:
UCB-ITS-PWP-2000-17

Title: Operations at Regional Travel Information Centers: The Case of the TravInfo Field Operational Test – Final Results

**Authors: Mark A. Miller
Dimitri Loukakos**

Date: September 2000

Description of the Research

TravInfo is a regional traveler information system in the San Francisco Bay Area. It was a Field Operational Test (FOT) over a two-year period from September 1996 to September 1998 with funding from the Federal Highway Administration and the California Department of Transportation (Caltrans). The goal of TravInfo was to broadly disseminate accurate, comprehensive, timely, and reliable information on traffic conditions and multi-modal travel options to the public in the Bay Area. Information was disseminated directly to users via a telephone service and indirectly through information service providers who in turn disseminated the information.

The purpose of this project was to evaluate the operation of TravInfo's Traveler Information Center (TIC) with a focus on its operation by a private sector contractor. This evaluation was performed using various data sources from field observations and field measurements. The evaluation examined TIC effectiveness in terms of system reliability, the communications interface, and operator work setting and performance. The evaluation also examined TIC effectiveness in from an organizational perspective.

Conclusion of the Research

Inductive loop sensor data provided by the Caltrans Traffic Operations System were initially expected to be a major source of data for TravInfo. However, they were not used as extensively as anticipated. Instead, the most significant data source was the California Highway Patrol Computer-Aided Dispatch incident reports. These reports had to be manually entered into the TravInfo system by TIC operators. This process was both time-consuming and difficult to perform along with the other duties of the TIC operators. Automating the data entry process, which was part of the TIC system's original specifications, could speed operators' response times and increase the number of incidents they could process, although it is likely that operators would still need to intervene in the interpretation of some incident reports.

The TravInfo system is not as efficient as originally envisioned because of its heavier-than expected dependence on the manual performance of jobs by the TIC operators. TravInfo needs an automated system that is flexible enough to keep up with rapidly advancing technologies. As the system becomes more automated, the organizational structure of the TIC can become more efficient than it was during the field operational test. The TIC staff should be consulted for ways to improve the system as they are the ones who will ultimately work with it.

**Locator Number:
UCB-ITS-PWP-2000-20**

Title: Paramics API Development Document for Actuated Signal, Signal Coordination and Ramp Control

**Author: Henry X. Liu
Lianyu Chu
Will Recker**

University of California, Irvine

Date: February 2001

Description of the Research

This report discusses the process and technology behind development and expansion of the Paramics software suite.

Paramics is a suite of software tools used to model the movement and behavior of individual vehicles on urban and highway road networks. The Paramics Project Suite consists of four components: Modeler, Processor, Analyzer, and Programmer. The Programmer enables the user to customize many features of the simulation model. Access to the Programmer is provided through an Application Programming Interface, or API.

Conclusion of the Research

The capability to access and modify the Paramics simulation model through an API is essential for research. Such an API should have a dual role:

- § first, to allow researchers to override the simulator's default models, such as car following, lane changing, and route choices, and
- § second, to allow researchers to interface complementary modules, for example ITS applications such as signal optimization, adaptive ramp metering, incident management, and so on, to the simulator.

This report describes three new APIs for complex simulation and modeling in Paramics. These are:

- § **Full-actuated signal control.** This API enables the modeling of a typical intersection with traffic detectors to simulate left-turn vehicle presence detection and vehicle detection for vehicle "through movement" phase.
- § **Actuated signal coordination.** This API enables the simulation of actuated signal coordination designed to allow "platoons" of traffic to form and progress through several signals with minimum stops and delays.
- § **Actuated ramp metering control.** This API enables the simulation of ramp metering systems utilizing a time-based ramp control algorithm.

The research also outlines possible future development of more APIs to handle several specific simulation issues. The proposed APIs can be built upon the APIs developed in this research. Examples suggested include:

- § Actuated ramp metering control rather than time-based metering
- § Actuated signal control utilizing detection methods other than loop detectors, such as machine vision or other "wide area" traffic detection technologies nearing implementation.

**Locator Number:
UCB-ITS-PWP-01-11**

Title: Productivity Benefits and Cost Efficiencies from ITS Applications to Public Transit: The Evaluation of AVL

Authors: David Gillen Elva Cange Doug Johnson

Date September 2000

Description of the Research

Automatic Vehicle Location technology is a component of Intelligent Transportation Systems (ITS) that enables transit agencies to monitor fleet vehicle performance and location. AVL has the potential to improve the on-time rate of public transit and timed transfers, accessibility and accuracy of passenger information, availability of data for transit management and planning, and efficiency and productivity of transit services.

AVL has the potential to increase efficient fleet utilization and reduce expenditure for fuel, labor, and capital. AVL can also facilitate and integrate on-board electronic fare collection among different transit systems within a region. With an AVL system in place, passengers could use a single fare medium for multiple transit systems, resulting in more efficient fare collection and more efficient transfer among transit agencies that share routes or transfer credit.

This research uses information from operations and financial information from the Federal Transit Commission's database and information on AVL applications to explore whether and how AVL applications lead to changes in productivity and resource use.

Conclusion of the Research

The overall assessment of AVL is that it provides sizable benefits for both consumers and transit agencies. The research focused on the cost efficiency improvements from AVL, but some demand side benefits were explored as well.

Higher numbers of passenger trips were reported when AVL was implemented by the transit agency. The most significant improvements were in productivity and cost efficiency. Whether output was measured as passenger oriented or service oriented, productivity was greater with the use of AVL. The sources of the productivity gains came from better use of capital, decreased need for buses, more efficient use of fuel and energy, and reduction in vehicle maintenance and vehicle operations

**Locator Number:
UCB-ITS-PWP-2000-16**

**Title: A Real-Time Laser-Based Prototype Detection System
for Measuring Delineations of Moving Vehicles**

**Authors: Jonathan E. Larson, Kirk Van Katwyk, Cheng Liu, Harry H. Cheng,
Ben Shaw, Joe Palen**

UCB-ITS-PWP-98-20 (1998)

Problem

The goal of this project is to build a system that can gather reliable travel time data non-intrusively for use in traffic planning and ITS. Laser detection systems offer several advantages over other methods like loop detectors: ease of installation and maintenance (no digging or rerouting of traffic required), simple computational needs, and no dependence on existing lighting conditions.

Method

A laser is projected onto the ground, and an optical sensor collects the reflected light, focusing it onto a photo sensor that converts the signal to a readable sample. It can detect a vehicle as it passes under the laser by the absence of reflected light. With two such systems set a known distance apart, the speed of the passing vehicle can be measured, as well as its length (useful for identifying and re-identifying vehicles).

We built and tested an indoor prototype to prove the concept and develop algorithms, and are developing a full-scale system for outdoor testing. This report describes the design and implementation of the components of the lab prototype, the configuration of the field testing system, and software design and implementation.

Findings

The lab prototype can detect the profile and measure the length of a small test vehicle passing at varying speeds with high repeatability.

Problems we encountered include electrical noise and sunlight interfering with sensors; these can be fixed with continued work.

Title: A Review of the Optimized Policies for Adaptive Control Strategy (OPAC)
Author: Lawrence C. Liao

UCB-ITS-PWP-98-9 (1998)

Problem

Optimized Policies for Adaptive Control is a real-time, demand-responsive traffic signal timing optimization algorithm for individual intersections developed at the University of Lowell in the early '80s. It drops the concept of "cycle," instead constituting a sequence of switching decisions at fixed time intervals. The decision each time is whether to extend or terminate the current phase, and is constrained only by minimum and maximum defined phase lengths. It uses online and historical data to optimize the decisions. Although designed for individual intersections, the strategy can be used as a building block for decentralized networks of intersections.

This report reviews the design philosophy and underlying principles of OPAC, describes its development history and how it works, and provides a brief report on how well it performs.

Findings

The results of the field test show that OPAC strategies perform better overall than well-timed actuated signals, especially under heavy traffic conditions. However, it proved very sensitive to intersection discharge rates, so in order for it to perform well those must be accurately estimated.

Title: Simulation of ITS on the Irvine FOT Area Using ‘Paramics 1.5’ Scalable Microscopic Traffic Simulator: Phase I; Model Calibration and Validation
Authors Baher Abdullah, Jiuh-Biing Sheu, Will Recker

UCB-ITS-PRR-99-12 (1999)

Problem

Intelligent Transportation Systems (ITS) appear to provide a set of intuitively promising tools to improve the increasingly complex and rapidly deteriorating transportation systems of today. Comprehensive research tools for quantifying the expected benefits from ITS are, however, still absent.

In order to quantify potential benefits of a given Intelligent Transportation System, traffic simulators are needed that can be used to assess the benefits of ITS in the planning stages, as well as in the implementation stages as a way to generate and evaluate traffic scenarios, optimize control, and predict transportation network behavior.

Method

This report sought to present a list of traffic simulator attributes, or a “wish list” that a useful traffic simulator should possess in order to adequately model Intelligent Transportation Systems.

The research also calibrated, validated, and evaluated one promising traffic simulator called Paramics1.5 developed by Quadstone UK. The evaluation was performed on a model of the transportation network in Irvine, California, composed of a highly congested, non-grid arterial network in a rapidly growing employment center.

Findings

A list of requirements for a traffic flow simulator to successfully model ITS was developed.

Paramics1.5 proved to be an excellent “shell” or “framework” for a comprehensive traffic simulator. However, it also proved to have some limitations.

The most promising aspect of the Paramic1.5 program is its Application Programming Interface, or API, which is currently available and being further enhanced by Quadstone UK and is regarded as the most important capability of the software. A comprehensive API for Paramics1.5 would allow researchers to modify the program and customize it to allow researchers to overcome many of the limitations the program currently has.

Title: Testing a Proposed Decision-Oriented Framework to Understand ITS Deployment Issues: An Examination of the TravInfo ATIS Project
Author: Mark A. Miller

UCB-ITS-PRR-98-35 (1998)

Problem

Deployment is at the forefront of current activity in California in the field of intelligent transportation systems (ITS). It is important to understand, to the extent possible, the multitude of issues associated with ITS deployment in order to increase the likelihood of a successful deployment initiative(s). A review and synthesis of ITS literature has been performed and has resulted in the development of a proposed decision-oriented framework with the purpose of helping users recognize and organize issues for the successful deployment of ITS.

TravInfo was used as a case study for the examination of the decision-oriented framework examined in this report. TravInfo was a Field Operational Test (FOT) sponsored by the Federal Highway Administration involving both public and private sector participants. TravInfo had the purpose of collecting, integrating, and broadly disseminating timely and accurate multi-modal travel information for the San Francisco Bay Area through a range of products to meet various consumer needs.

Findings

The decision-oriented framework developed provides a way to categorize issues when considering the deployment of ITS. However, the categories or dimensions of the framework is recommended not to be used as the sole predictive tool for ITS deployment, nor was it developed for this purpose.

Based on the TravInfo case examination of the decision-oriented framework developed for this study, it was found that overall, the decision-oriented framework provides a useful way to evaluate and bring together issues into a more cohesive whole in order to assess the likelihood of a successful ITS deployment. Some refinements to the framework are suggested which could lead to an improved product.

Title: TravInfo Evaluation: Institutional Element Phase 1 Results
Author: Randolph Hall, Y. B. Yim, Brian Pfeifle, Stein Weissenberger

UCB-ITS-PWP-95-01 (1995)

Problem and Method

TravInfo is a field operational test (FOT) of advanced traveler information systems (ATIS) for the San Francisco Bay Area. TravInfo aims to develop a multi-modal traveler information system for the San Francisco Bay Area, combining public and private sector talents.

This report outlines the TravInfo organizational structure, TravInfo goals, and roles of the participating organizations. This report also identifies institutional, legal, and technical barriers that present challenges to the fulfillment of the TravInfo objectives.

As part of this study, a wave of institutional interviews was conducted as part of the TravInfo evaluation. Twenty-one core participants were interviewed, including most of the Management Board and Steering Committee members, and most of the project staff. The results of these interviews provide an insight into the effectiveness of TravInfo and areas in which it can be improved.

Findings

From the interviews, it is clear that TravInfo has been quite effective in achieving one of its foremost goals: developing partnership between the public and private sectors.

At the same time, there appears to be considerable opportunity to improve the organization's efficiency. In particular, interviewee responses indicated some confusion about the roles of the various committees within the TravInfo project.

Interviewees were nearly unanimous that TravInfo is working toward the right goals, though many felt the project is overly ambitious.

Title: TravInfo Evaluation: Institutional Element Phase 2 Results
Author: Randolph Hall, Dimitri Loukakos, Stein Weissenberger, Y. B. Yim

UCB-ITS-PWP-96-14 (1996)

Problem and Method

TravInfo is a field operational test (FOT) of advanced traveler information systems (ATIS) for the San Francisco Bay Area. TravInfo aims to develop a multi-modal traveler information system for the San Francisco Bay Area, combining public and private sector talents.

This report presents the results of year two of the institutional evaluation, which is part of the overall TravInfo evaluation. Nineteen core participants were interviewed, including all of the Management Board and most of the Steering Committee members and project staff. Separately, twenty Advisory Committee members were interviewed.

Findings

During first year of the FOT, organizational issues, principally defining the roles of the various committees and working groups within the TravInfo project, were paramount. The first year evaluation of TravInfo is presented in UCB-ITS-PWP-95-01.

The second year of the TravInfo project, reviewed in this paper, was dominated by implementation issues, chief among which were: resolution of public/private controversies in the design of TravInfo and the attempt to ensure the completion of the Caltrans Traffic Operations System (TOS) for meeting the TravInfo schedule.

Based on the interviews and observations conducted as part of this study, it is clear that the TravInfo organization has been effective at resolving these issues.

The Steering and Advisory Committees also provided an open forum for resolving issues in the TravInfo organization. In its first year, the Steering Committee was criticized for inefficiency and lack of focus. In the second year, it appears that the Steering Committee has found its focus and is resolving public/private sector issues by establishing a clear and balanced vision for the public and private sectors.

The delay of the Traffic Operations System, one of the implementation goals of TravInfo, was affected by a rigid procurement structure that did not allow for quick resolution of problems facing the TOS implementation. In addition, concerns were voiced by some interviewees regarding the data coverage provided by the TOS. However, TravInfo developed a multi-tiered strategy to provide data to compensate for the limitations of the TOS, and Caltrans will continue to expand the data coverage of the TOS during the TravInfo FOT effort.

Title: TravInfo Evaluation (Technology Element) Traveler Information Center (TIC) Study: Operator Interface Analysis-Phase III
Author: Mark Miller, Dimitri Loukakos

UCB-ITS-PWP-98-22 (1998)

Problem and Method

TravInfo is a field operational test (FOT) of advanced traveler information systems (ATIS) for the San Francisco Bay Area. The project seeks to compile, integrate, and broadly distribute timely and accurate multi-modal traveler information through commercial products and services. The public sector component centers on the Traveler Information Center (TIC), which collects and integrates both static and dynamic traveler information.

This study examines the technology component of the TravInfo project, and more specifically, the role of the operator in the flow of information through the TIC, the operators' tasks and responsibilities and the operators' physical environment.

This report focuses on the physical environment of the TIC operations including the TIC computer interface and the physical surroundings of the operators' workstation environment. The work was accomplished by analyzing the TIC operator interface design and by surveying operators. This study builds on work reported in UCB-ITS-PWP-98-7.

Findings

The first part of this evaluation considered the operator interface. Overall, the operator interface was found to serve its general purpose of allowing operators to perform their data monitoring and entry tasks relatively quickly. However, the general computer interface was found to not support the tasks of the operators as much as it could. The chief problems were:

- Fill-in form interfaces appeared not to be designed with consideration for operator tasks
- Some of the most commonly used windows had several shortcomings
- The two most important menus were not ordered in a logical manner
- There was no logical grouping of related fill-in form interfaces, and moreover, there are ambiguous terms and non-mutually exclusive attributes within certain fields
- There was a lack of organization across all windows.

Other general areas of weakness in the operator interface included the following:

- User compatibility: There should have been more consideration of specific operator duties.
- Consistency: The fill-in form formatting is not always consistent among forms.
- Responsiveness: There is no feedback on the progress of system processing, and the system is often slow due to lack of processing power.

The second part of this evaluation considered the operators' working environment. A checklist was developed to identify operator environment characteristics which may help or hinder the TIC operators' job performance. These were:

- Illumination, noise levels, and climate control (e.g., heat, air conditioning, air quality)
- Visual display elements of the computer screen
- Keyboard characteristics
- Furniture
- Work surface
- Seating
- Accessories

The study found that only three changes would lead to a more productive work environment. These were: thermal and air quality, general layout of work surface, and cubicle height or sense of connectedness with other operators. All other characteristics were found to be generally acceptable to the operators.

Title: TravInfo Evaluation (Technology Element) Traveler Information Center (TIC) Study: Operator Interface Component-Phase IV: Institutional Analysis

Author: Mark A. Miller, Dimitri Loukakos

UCB-ITS-PWP-98-30 (1998)

Problem and Method

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). 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. The public sector component centers on the Traveler Information Center (TIC), which collects and integrates both static and dynamic traveler information. This study focuses on the operator interface element of the TIC.

This study considers the role of the human operator in the flow of information through the TIC, the operators' tasks and responsibilities, and the operators' physical environment. The evaluation was conducted through an analysis of responses to questions during in-person interviews of TIC operators, supervisors, and management.

Previous reports which considered the operator interface of the TIC are:UCB-ITS-PWP-98-7, and UCB-ITS-PWP-98-22

Findings

Overwhelmingly, all survey respondents felt that the TIC was effective in achieving its goal of providing timely, complete, user-friendly, and accurate information to the public and private sectors, given the constraints and available resources. The barriers to meeting the goal of the TIC included:

- uncertain availability of reliable and accurate automated data
- delays related to ongoing contractual issues between the Metropolitan Transportation Commission and the system developer, and
- a computer interface that both did not adequately meet TIC operator needs and responsibilities and did not have the level of automation that was originally envisioned.

Some problems were found that negatively impacted operator effectiveness which could have been addressed earlier and more completely by TIC operations. These included lack of operator quality-control measures until the FOT was 75 percent complete and insufficiently frequent communication among the TIC staff on a range of subjects.

However, areas of success were also found which contributed to operational effectiveness. These included overall quality of staff in terms of skills, attitude, and responsiveness to emergency conditions; inter-organizational cooperation; and quality of some of the data sources.

Call Number: UCB-ITS-PWP-2000-2

Title: TravInfo Field Operational Test Institutional Evaluation Final Results

Authors: Youngbin Yim Elizabeth Deakin

Date February 2000

Problem

TravInfo is a regional traveler information system in the San Francisco Bay Area. The goal of TravInfo was to broadly disseminate accurate, comprehensive, timely, and reliable information on traffic conditions and multi-modal travel options to the public in the Bay Area through a public-private partnership.

The institutional evaluation of TravInfo was one of four test elements which comprised the TravInfo Field Operational Test (FOT). The other elements were technology assessment, traveler response, and transportation network performance. The transportation network performance test was not performed because of the lack of traffic data to realistically measure the changes in traffic flow during the field test.

The institutional evaluation measured the performance of TranInfo's public-private partnership at the organizational level. It examined how well TravInfo's institutional organization worked to achieve its objectives, what benefits the project partners were able to gain from the field test, and what institutional challenges they had to overcome.

Findings

TravInfo's organizational structure was unique, with a high degree of openness in the public-private partnership. TravInfo meetings were conducted as open forums to encourage the entrepreneurial participation of the advanced traveler information industry as well as the active participation of local public agencies. The ultimate responsibility for TravInfo lay with the public sector in the form of the Management Board, the members of which came from regional transportation agencies.

The TravInfo organization was effective in appropriately utilizing public and private sector talent. By placing the Metropolitan Transportation Commission, which is the transportation planning organization for the nine-county Bay Area, in a leadership role, the project recognized the importance of consensus building.

The project helped foster constructive relationships among the projects principal public participants. The project also fostered alliances among many of the private participants.

The project also encountered many challenges. Two major setbacks were insufficient coverage of the Bay Area transportation network by the data supplied to the TravInfo Traveler Information Center (TIC) and an inefficient system design that required the TIC to be considerably more dependent on manual operations than expected.

Title: TravInfo Field Operational Test Evaluation: Information Service Providers Customer Survey

Authors: Youngbin Yim

Date: May 2000

Description of the Research

TravInfo is a regional traveler information system in the San Francisco Bay Area. The goal of TravInfo was to broadly disseminate accurate, comprehensive, timely, and reliable information on traffic conditions and multi-modal travel options to the public in the Bay Area through a public-private partnership.

As part of the TravInfo Field Operation Test (FOT), a regional Traffic Information Center (TIC) was created. Since September 1996, the center has been disseminating traveler information to the public through the Traveler Advisory Telephone System (TATS) and to information service providers (ISPs). Presently, three ISPs rely exclusively on TravInfo for travel data which they disseminate through Web sites.

Three privately offered traffic Web sites were evaluated from the user perspective. These Web sites disseminate traffic information on major freeways and the transit schedules of 27 Bay Area transit services. Though all three services receive the same data from the TIC, they all display the information differently.

Conclusion of the Research

The key finding of the survey of users of the three traffic Web sites considered is that Web site service may significantly influence travel behavior. Of those users who received incident reports, 80% modified their trips. This trend is considerably different from the studies of radio/television listeners or telephone information callers. 25% of those who obtained pre-trip incident information from radio or television modified their trips; 50% of those who obtained pre-trip traffic information from TravInfo TATS modified their trips. Possible reasons include:

- § People who retrieve Web site information have more travel options than those who obtain information from other sources.
- § The Web site information is more understandable than the information disseminated through other media.
- § People perceived that the quality of the Web site information is better than other sources in terms of its usefulness and reliability, although both the TravInfo telephone system and Web sites disseminate the similar information to users.
- § Web site users are more receptive to traffic reports than are those who use other information sources.

These reasons are somewhat conjectural and should be validated. However, it is important to note that nearly half of the Web site users believe that their decision to change travel plans on the basis of the Web site information resulted in substantial time savings.

Most of the Web site users are commuters with full-time jobs. Because of their employment status (high income professionals or managers), their arrival time at work is flexible and they have a varying degree of travel options, either by taking alternate routes or by changing their departure time. Most Web site customers are solo drivers whose primary commute is the freeway, which is understandable because the Web site service provides primarily freeway traffic conditions.

**Locator Number:
UCB-ITS-PWP-2000-5**

**Title: TravInfo Evaluation (Technology Element) Traveler Information Center (TIC) Study:
Operator Response Time Analysis**

**Authors: Mark A. Miller
Dimitri Loukakos**

Date: August 2000

Description of the Research

TravInfo is an advanced traveler information system for the San Francisco Bay Area that began operation in September 1996 under a public/private partnership seeking to compile, integrate, and broadly disseminate timely and accurate multi-modal traveler information through commercial products and services. The public sector component centers on the Traveler Information Center (TIC), TravInfo's information gathering, processing, and dissemination hub.

During the Field Operational Test (FOT) of TravInfo, the TIC was evaluated with respect to system reliability, the communications interface, the operator interface, and operator response time. This report documents the analysis of operator response time.

The report focused on incident information generated by the California Highway Patrol's Computer-Aided Dispatch (CAD) system. Operator response time is defined as the time elapsed once information is collected from CAD until it is disseminated to the public via the Travelers Advisory Telephone System (TATS).

Conclusion of the Research

Operator response time is a significant part of TravInfo evaluation because the TIC operations are substantially less automated than originally envisioned and thus depend heavily on operator performance.

Operator response times remained stable during the FOT with an overall average operator response time of approximately 11 minutes, though there were significant response time differences among the operators. The findings indicate that improvement is needed in both overall operator work efficiency and operator response time.

Once TravInfo transitions from its FOT phase and enters its more permanent phase, operations will become substantially more automated. This should have a significant impact on reducing operator response times as well as increasing overall operator productivity.

**Locator Number:
UCB-ITS-PWP-2000-9**

Call Number: UCB-ITS-PWP-2001-7

Title: TravInfo Evaluation: Traveler Response Element; TravInfo 817-1717 Caller Study; Phase 2 Results

Authors: Ronald Koo, Y. B. Youngbin Kim

Date: February 2001

Problem

TravInfo is a Field Operational Test (FOT) sponsored by the Federal Highway Administration (FHWA) of the US Department of Transportation and the California Department of Transportation (Caltrans). Its objective is to provide benefits to San Francisco Bay Area travelers and to stimulate the deployment of privately offered traveler information products and services. In operation since September 1996, TravInfo disseminates free, current traffic information and multi-modal travel options to Bay Area travelers through a landline telephone system called TravInfo Traveler Advisory Telephone System (TATS) and through the Internet via Information Service Providers. As part of the TravInfo FOT evaluation project, two surveys of the TravInfo TATS callers were conducted, the first survey in April 1997 and the second survey in April 1999. This paper reports the findings of the second survey.

The purpose of the first TravInfo TATS caller survey was to establish a baseline profile of the callers with respect to their call and travel behavior. The purpose of the second survey was to assess the changes in callers' behavior and to measure the effectiveness of TATS in helping callers make informed travel decisions. The first survey was conducted seven months after TravInfo began in operation and the second survey was conducted seven months after the field test was concluded. The effectiveness of the TravInfo telephone system was measured by the satisfaction of callers with the TravInfo TATS service, the impact on their travel behavior, and the benefits perceived by them.

Findings

The results of the second survey are quite similar to those of the first survey. This may be due to the fact that during the two years between surveys, not much behavioral change could take place. However, one noticeable change was found: in the second survey; greater number of calls were made from a vehicle via cellular phones en route (46.8% in the second survey versus 31.5% in the first survey) among callers seeking traffic information. The other noticeable change was mode shift: it appeared that more people switched their mode from personal vehicle to public transit in the second survey. However, the sample size is too small to make any definitive conclusion.

Other important findings include:

In the first and second surveys, an overwhelming majority of the callers in the first and second surveys were satisfied with the information they obtained from TravInfo 817-1717. In both surveys, callers found that TravInfo TATS traffic information was more useful, reliable and accurate than radio or television reports. Both surveys showed that about half of the TATS traffic information callers changed their travel behavior as a result of TravInfo TATS information regarding a traffic problem. However, the effects of the TravInfo TATS service on mode shifts was minor even though three times as many people switched to public transit from personal vehicle when they learned of traffic congestion. The second survey also indicated that TravInfo TATS has been effective in providing quality information and in attaining a high level of customer satisfaction although its customer base has not increased significantly. As with the first survey, the second survey showed that TATS has attracted a segment of the driving population that rarely relies on traffic reports in making travel decisions and seldom or never listen to radio traffic reports. Most participants in the transit survey group said they would use TATS in the future because of its easy access to information via a single telephone number while the traffic survey group said they would use it again and recommend it to others because of its most current traffic information pertaining to their own trip. Transit information callers are interested in the availability of the service and service schedules while traffic information callers are interested in getting traffic conditions to avoid congestion. Therefore, very few calls were rerouted from traffic calls to transit calls or visa versa. However, it was apparent that the transit survey group favored TravInfo TATS having a single phone number for getting all travel related information.

Signal

Title: **Alternative Traffic Signal Illumination: Human Factors Study**
Author: **Theodore E. Cohn, Ph.D., Professor of Vision Science, Visual**
 Detection Laboratory, University of California, Berkeley

UCB-ITS-PRR-98-19 (1998)

Problem

New technologies have produced traffic signals with significant advantages over standard incandescent signals, including greater efficiency and lower costs. But are they as visible to the human observer as the older signals?

Method

We developed what we call a Usability Factor (UF), which compares the visibility of a test lamp to a standard lamp, as perceived by a human observer, when the luminance of the two lamps matches, as measured photometrically. If the UF is greater than one, then less actual measured illumination would be required to render it as visible as a standard light (implying greater energy efficiency); if less than one, more illumination would be needed. If the UF is unity, then photometric measures alone can assess its visibility.

Findings

We found that for a 12-inch red LED lamp, there was no significant difference from a standard lamp. And orange LED pedestrian head was also close; an orange neon pedestrian head had a high UF but the actual illumination is low enough that such a lamp is impractical. An orange fiber-optic pedestrian head had a low UF (so more light is needed to make it visible), a red LED arrow's UF was slightly higher than unity, and a red fiber-optic arrow had a very low UF.

We also conducted extra tests on the 12" red LED, finding that a sun-phantom (produced when the sun is low behind the observer and shining into the lamp) had less effect on the lamp's visibility than on a standard lamp, and that glare and fog seemed to have little effect as well.

The Usability Factor is a useful quality index which can be used in combination with the standard 44-point test or other appropriate photometry-based tests to evaluate the visibility of a lamp.

**Title: Anaheim Advanced Traffic Control System Field Operation Test Task A:
Evaluation of SCOOT Performance**

**Authors: James E. Moore, II, R. Jayakrishnan, M.G. McNally,
C. Arthur MacCarley**

UCB-ITS-PRR-99-26 (1999)

Problem

The city of Anaheim, California, implemented SCOOT (Split, Cycle, and Offset Optimizer Technique) as part of a larger Field Operational Test which included several other related technologies. This part of the FOT was meant to evaluate SCOOT, which controls systems of signals rather than just isolated intersections, in terms of the following issues: its limited implementation as an option for Anaheim traffic controllers, the development of operational policies, and the evaluation of its operational effectiveness.

Evaluation Task A1 assessed the value of existing loop detectors for SCOOT (the detectors were already in place, but closer to intersections than SCOOT is designed to use them), and assess the quality of SCOOT's internal representation of traffic flow. We did this by comparing SCOOT's performance to videotapes of actual conditions at intersections.

Evaluation Task A2 assessed the performance of traffic under SCOOT in terms of delay. We posted observation teams at intersections to measure delay and used floating cars to measure running, stopped, and total travel time, both before and after the implementation of SCOOT, during PM peak and evening off-peak hours, and for special event and nonevent traffic.

Findings and Recommendations

SCOOT successfully models traffic conditions, but there is room for improvement. In general, SCOOT performed better off peak, for special events at smaller-volume intersections, and very well at specific intersections with heavy traffic during special events.

When SCOOT performed worse than the baseline system, it did so rarely more than ten percent, and when it performed better, the difference was normally less than five percent. (It must be kept in mind that the existing traffic control system in Anaheim is considered state-of-the-art, and that SCOOT was using information from loop detectors in nonstandard locations.)

Delays between the two systems were generally comparable, and SCOOT caused no unacceptable delays or catastrophic problems.

**Title: Anaheim Advanced Traffic Control System Field Operational Test
Task B: Assessment of Institutional Issues**
**Authors: M.G. McNally, James E. Moore II, C. Arthur MacCarley,
R. Jayakrishnan**

UCB-ITS-PRR-99-27 (1999)

Problem

The city of Anaheim, California, was committed to implementing three new traffic control technologies: SCOOT (Split, Cycle, and Offset Optimizer Technique), a signal control system developed and used in Britain; a 1.5 Generation Control system whose purpose was to update baseline timing plans for SCOOT from the first generation system already in use, and a video traffic detection system to supplement loop detectors. The project required coordination between a number of agencies and partners, including the city of Anaheim, its systems contractor JHK/Transcore, SCOOT vendor Siemens, video system provider Odetics, Eagle Signal, Caltrans and the FHWA, who funded the Field Operational Test, and PATH.

The purpose of this report is to answer the question: through what structures and methods can the technologies be applied without being confounded or restricted by institutional issues?

Method

Information was gathered through direct observation of project participants, primarily at formal meetings, and detailed interviews of all key project participants. Interview questions covered project goals and objectives, implementation, funding, and working relationships. They addressed administrative, financial, leadership, personnel, legal, liability, and technical issues.

Findings

Numerous institutional problems were identified by participants, some of them interwoven with technical problems. Prime among them was a lack of leadership during a crucial period in the process of implementation, when the Principal Traffic Engineer left and was not replaced for 8 months. Although his duties were reassigned, the lack of someone in a leadership and advocacy role led to several delays, including a long delay before a contract was signed with SCOOT provider Siemens. This caused other delays, and could have ended the project altogether had Caltrans not allowed several extensions.

Other main findings include:

- A strong, proactive project manager is needed.
- Delays caused unanticipated costs that put the project over budget and did not leave enough time for proper training.
- Staff failed to plan adequately for training and maintenance needs, and they overestimated the operators' ability to switch to a new system.
- Unanticipated communication problems included differences between British and American standards, differences between software systems, integrating older systems with SCOOT, and a time difference that created difficulties communicating with the SCOOT vendor.
- Staff was not motivated to fully learn the new system because it wasn't clear to them whether the new system would actually be used after the FOT.
- Everyone interviewed had a different idea of what the FOT's goals were.

Title: Anaheim Advanced Traffic Control System Field Operational Test
Task C: Video Traffic Detection System
Author: C. Arthur MacCarley

UCB-ITS-PRR-98-32 (1998)

Problem

As one part of the City of Anaheim's Advanced Traffic Control Field Test (in partner with Caltrans, FHWA, and JHK Consulting), we conducted an evaluation of a video detection system marketed by Odetics, Inc. as a low-cost alternative to loop detectors. Using video cameras, the system detects vehicles at intersection approaches in "virtual detection windows" for signal phase actuation. It can be set up and calibrated in the field using only a TV monitor and a PC mouse; up to four detection window setups can be stored; and it can also be set up and calibrated remotely. The user interface is simple but effective.

Method

Nine vehicle detection event classes and six phase actuation event classes were defined for this test, with different lighting, weather, and traffic conditions. Videotapes acquired in the field were slowed down, analyzed, and compared to the system's detection results.

Findings

In general, we found that detection was good under ideal lighting and light traffic conditions, but degraded at higher traffic levels and low light, night, and rainy conditions.

65% of vehicles were detected properly, which is similar to the performance of loop detectors. 80.9% were detected adequately for the purpose of signal phase actuation, and there was an average 8.3% false and latch detection rate (latch detection happens when the system detects a vehicle but fails to notice when it has moved on).

The manufacturer, Odetics, says it has since replaced both hardware and software to address these problems, but we have not tested the new system.

Title: **Development and Testing of Field-Deployable Real-Time Laser-Based Non-Intrusive Detection System for Measurement of True Travel Time on the Highway**

Author: **Harry H. Cheng, et al, Integration Engineering Laboratory, Department of Mechanical and Aeronautical Engineering, UC Davis**

TR-IEL-2000-101 (2000)

Problem

Reliable, real-time traffic speed information is invaluable for traffic planners. Current methods for measuring travel time do so by measuring speed at one or more points along a link and then extrapolating speed across the entire length of the link. Loops, radar, and video image processing all use extrapolation to deduct travel time. However, when traffic flow slows because of an accident, speed variations along any given link can be quite large. This is when accurate information for making routing decisions is most critical, and the uncertainties caused by extrapolation are magnified.

Vehicle-as-Probe (VAP) methods determine travel time by identifying vehicles at the start of the link and then re-identifying them at the end of the same link, giving true travel time as the time difference between the two. The cost of VAPs is quite high, however, requiring a large number of vehicle tags and tag readers to be effective.

It is possible to identify some distinguishing characteristic on a vehicle at the beginning of a link and then re-identify that same vehicle at the end of a link without the set-up costs of a VAP. If a characteristic can be found that separates cars into 100 possible classifications, a match between upstream and downstream vehicles can be made with high probability. Even more classifications would make the process even more accurate.

Method

This project developed a laser detection system that can directly and accurately determine origin and destination information for vehicles in the traffic stream non-intrusively and without violating privacy. It produces local vehicle speed, vehicle volume, and vehicle classifications, even under high flow conditions. Point-to-point travel time and incident detection can easily be determined.

This system can be mounted above the road, which allows it to be installed and maintained without tearing up the road or disrupting traffic. It operates on a simple “on/off” basis, requiring much less computation for vehicle detection than video methods. It also produces and senses its own signal, so it does not depend on time of day and weather conditions for accuracy (as do video detection systems). There are no moving parts, and power and bandwidth requirements are very low.

The system projects a laser onto the ground, and then collects the reflected light onto a photodiode array. A vehicle is detected when it passes under the beam, based on the absence of the reflected light. With two identical laser/sensor pairs placed close together,

it is possible to measure the speed of both the front and the rear of the vehicle as it triggers each sensor. The length of each vehicle is determined from the speed and the amount of time the vehicle spends under the detector.

Findings

We have built a field prototype detection system and tested it under real traffic conditions. Our test results verify that the principle of this system is technically sound and the software works in most cases. There are a few situations, such as stop-and-go traffic, where the detection of vehicle length does not work well.

We also found that the separating distance of the two laser-sensor detectors was too small in our test, which made the system detect different speeds for the front and the rear of vehicles. Also, the slowness of the analog signal contributed to the error. Both of these problems will be fixed in the next prototype, by putting the pairs farther apart and by using a faster digital signal.

Title: The Effects of Data Inaccuracy on the Performance of Traffic Signal Timing Plans

**Authors: Wei-Hua Lin, Virginia Polytechnic State University, Blacksburg.
Lawrence C. Liao, ITS, University of California Berkeley.**

UCB-ITS-PWP-98-6 (1998)

Problem

A variety of traffic signal timing systems are currently in use in the transportation network. The accuracy of the timing systems in use depends heavily on the accuracy in predicting vehicle arrivals. With less accurate systems, traffic may pile up behind lights that don't change often enough, or just a few vehicles may have to wait a long time for a light to change even when there is no cross traffic.

This study made no valuation of the various signal timing systems. Rather, it sought to quantify when and how the performance of a signal timing plan will degrade when vehicle arrival information that is inaccurate to varying degrees is used to calibrate the plan. The study also sought to explore the level of improvement that can be achieved if very accurate vehicle arrival information can be obtained for the calibration of signal timing plans.

Method

An isolated intersection (i.e., not an arterial or network) was used as a model. The intersection was assumed to have no left or right turns. The performance of signal timing plans was then evaluated for a calibration that uses imperfect vehicle arrival information at this intersection.

In reality, vehicle arrival rates vary with time of day, whereas arrival distributions vary spatially from intersection to intersection. To account for these variations, this study included sensitivity analysis based on 18 vehicle arrival rate and distribution scenarios. The paper further discusses the methodology used to complete the study, including selection of a delay formula, use of variance-to-mean ratios, and detailed description of the 18 different vehicle arrival rate scenarios used as signal timing system calibrations.

Findings

Overall, the change in signal timing delay is insignificant when less accurate data are used to calibrate a signal timing plan. The effect of over- or under-estimation of traffic flow on total vehicle delays at the timed traffic signal increases with flow level. When traffic flow is low, less than a 1% increase in delay is observed. When flow is moderately heavy, less than a 4% increase in delay is observed. Significant increase in delay (greater than 10%) is observed only when the flow level is underestimated in a situation of high flow.

Underestimation of flow can also result in an increase in queue length and the number of stops. The increase in total number of stops is minor for critical intersections (less than

5%) but large for non-critical intersections (greater than 10% when the measured flow deviates from the actual flow by 10%).

In general, the performance of a signal timing plan is more sensitive to the accuracy of input data when applied to an intersection with balanced flow than to an intersection with unbalanced flow.

**Title: Evaluation of the Anaheim Advanced Traffic Control System Field
Operational Test: Executive Summary**
Author: M.G. McNally, James E. Moore II, C. Arthur MacCarley, R. Jayakrishnan

UCB-ITS-PRR-99-18 (1999)

Problem

The city of Anaheim, California, experiences heavy traffic on a regular basis. Delays at intersections are a significant problem, and many special events create special traffic problems. The city has an advanced traffic control system, but wanted to test out several new technologies, so this field operational test was set up both to assess the technical performance of these methods and to analyze the institutional issues around their implementation and operation.

The three systems were: SCOOT (Split, Cycle, and Offset Optimizer Technique), a second generation technology for controlling systems of signals as opposed to isolated intersections, already in use in Europe; a 1.5 Generation Control system under development, whose purpose was to update baseline timing plans for the entire system; and a video traffic detection system presented as a low-cost alternative to loop detectors for critical areas.

Method

The evaluation was broken down into three main parts: a performance assessment of the technologies, an assessment of the institutional issues, and a separate evaluation of the video traffic detection system.

For the performance assessment, we looked first at how well SCOOT “sees” traffic and then at how well it performs to control traffic.

Findings

SCOOT is designed to rely on information from loop detectors placed farther away from the intersections than the mid-block locations of the loops already in place in Anaheim. We needed to know whether these loops could provide adequate information to the system, so we compared SCOOT’s estimates of queue length and clearance time to real time video at certain intersections, and identified large inconsistencies. Nevertheless, SCOOT successfully models traffic conditions, in general, but can be improved either by changing the location of loop detectors or by adjusting global control settings to compensate for the actual location of detectors.

To assess SCOOT’s performance, we used teams both at intersections to measure delay and in cars to measure travel time, before and after implementation. We discovered that SCOOT performed better than the existing system during off-peak hours, and very well at certain intersections during special events. However, our findings are inconclusive as to whether SCOOT is better than the system already in place.

To evaluate institutional issues, we used direct observation and interviews, all of which produced subjective information that was structured to provide many different points of view. We looked at implementation, operations, transferability, and maintainability of the system. There was an immediate problem with delaying implementation due to a vacancy in a key position (Principal Traffic Engineer), which led to a lack of experience and authority in the city's relations to the contractor (Siemens). We were not able to adequately evaluate operational issues because of the resulting delays, which led to late delivery, and limited staff training and experience prior to the evaluation. In terms of transferability of technology, we concluded that products that are not widely deployed are essentially still in the research and development process, subject to delays, changes, and cost overruns. This is especially true for the 1.5 GC system. Maintaining the new systems would involve significant costs, and much more training is needed to properly utilize it. Our overall conclusions in regard to institutional issues is that we have no specific recommendation, but costs would be likely to go up if SCOOT were to be expanded beyond its present limited deployment.

The last evaluation task, of the video system which is marketed as a low-cost alternative to loop detectors, found that its user interface is unsophisticated but effective. The system's performance results were good under ideal lighting and light traffic conditions, but not so good in low light, night, rain, or heavy traffic. (The manufacturer, Odetics, says it has since addressed and corrected these issues, but we have not evaluated the new system).

Title: Identifying the Onset of Congestion Rapidly with Existing Traffic Detectors
Author: Benjamin Coifman

UCB-ITS-PWP-99-17 (1999)

Problem

Traffic surveillance systems need to reliably identify the presence of congestion, and to respond rapidly when congestion is detected. Loop detectors are good at the first, but not so good at the second task. This paper presents an algorithm using existing dual loop detectors in a new way to improve their performance on these tasks; it promises to be deployable in the short term.

Method and Findings

Loop detectors calculate flow and occupancy at discrete points on a freeway. We generally assume that this information represents the space between links as well. However, under congested conditions this is not always so; the traffic stream can change significantly from moment to moment in both directions, especially when traffic is heavy.

Conventional loop detectors easily identify the presence of congestion, but response time is usually slow. Our method solves this by looking for free-flow traffic instead of congestion. Recognizing that signals emanate from an incident in two directions—a drop in speed moving backwards at about 8 mph, and a drop in flow moving forward at the prevailing traffic speed—the algorithm looks for a fast-moving drop in flow, thus quickly identifying the onset of delay.

The drop in flow is found by identifying long vehicles at a detector station, then looking for a similar vehicle in the same lane upstream within a certain time window, defined by the amount of time it would take the vehicle to travel that far at free-flow speeds. If the vehicle is identified, then the presence of free-flow traffic reveals itself. Since lane changes are less common under free-flow conditions than congestion, the likelihood of identifying the vehicle is higher. Using long vehicles, which can be four times as long as smaller vehicles and thus easier to identify with some certainty, we can quickly ascertain whether free-flow conditions are met, or not.

This work is compatible with existing detector infrastructure, and simple enough to implement on existing Model 170 controllers, which are based on twenty-year-old computer technology. It is intended to augment, not supplant, conventional surveillance strategies to improve performance.

Title: An Investigation in the Use of Inductive Loop Signatures for Vehicle Classification
Author: Carlos Sun
Date: March 2000
UCB-ITS-PRR-2000-4

Problem:

If we could accurately sort the vehicles that use our highways into predefined classes, we could improve vehicle reidentification algorithms and traffic simulation models, gaining useful information to benefit highway maintenance, vehicle emissions management, highway design, traffic safety, and automatic toll collection systems. If we could do this using the current inductive loop technology already in place, we could gain all these benefits immediately, and with simpler equipment than is used by other commercially available systems.

Method and Results:

Using different pattern recognition techniques, we tested vehicle classification algorithms on the SR-24 freeway. We used existing loop detectors that can output a vehicle inductive signature. We divided vehicles into seven classes (car, SUV/pickup, van, limousine, bus, two-axle trucks, and larger trucks) to test two classification methods. The first method, a heuristic discriminant algorithm, used multi-objective optimization for training the heuristic algorithm. Some advantages of using heuristic algorithms include smaller data transmission and storage requirements, and a sequential discrimination procedure in which each stage can be individually fine-tuned. We developed three different heuristic algorithms which yielded 81 to 91% accuracy.

The second method used self-organizing feature maps (SOFM), which are artificial neural networks. A large advantage of using SOFM is that it needs only a small training data set to produce similarly high rates—more than 80% accuracy.

We also developed a speed measurement system using single loops, since it's necessary to accurately estimate speed in order to be able to judge a vehicle's size. Our method produced more accurate results than previous single loop estimation methods.

Different technologies work best with classification schemes suited to their particular method of signal detection; for this reason, using a combination of technologies will probably produce even more consistently accurate results.

**Title: Los Angeles FOT Spread Spectrum Radio Traffic Signal Interconnect
Evaluation Task: Final Report on Full Deployment
Author: Victor O.K. Li, Senthil Sengodan, Tat-Keung Ken Chan, Lei Zhuge**

UCB-ITS-PWP-98-27 (1998)

Problem

Spread spectrum radio networks (SSRN) are an alternative to hard-wired methods of traffic monitoring and control which take less time and money to build and maintain. How well do they work? Los Angeles needs to connect 2000 intersections to its existing traffic control system (which already controls 2000 intersections via hard-wired links) so USC set up a field operation test in the Mar Vista area to implement and test the reliability and cost effectiveness of SSRN.

The radio links are arranged in a network of cells, each consisting of one headend radio hard-wired to the control center and up to 31 remote radios hard-wired to intersection controllers.

Findings

The overall performance of the system is satisfactory. It can send large amounts of information reliably through the network, with an average signal throughput of 90 percent, which is satisfactory, but can be improved. The automatic network reconfiguration in the presence of failed and poor links also worked well.

Some channels are busier and less reliable than others; in fact one particular channel (7) was very busy with other radio traffic and so was eliminated from the choices used in this area. Some antenna locations work better than others, and antennas that were mounted high enough to create visual line-of-sight connection provided high quality links between units. Some mounting options work better than others, depending on the particular location, although sometimes a choice must be made between signal loss or durability and ease of maintenance. Also, some units had a problem with polarization, which was solved with the use of a special antenna.

Recommendations include the use of an exclusive radio band to increase throughput, and taller posts for antennas to get the best possible line-of-sight connection.

Title: Mobile Surveillance & Wireless Communication Systems Field Operation Test

- 1) Executive Summary (UCB-ITS-PRR-99-6)**
- 2) FOT Objectives, Organization, System Design, Results, Conclusions, and Recommendations (UCB-ITS-PRR-99-7)**
- 3) Appendices A-J Containing Evaluation Data Gathered During the Anaheim Special Event and I-5 Tests (UCB-ITS-PRR-99-8)**

Author: Lawrence A. Klein

Date: 1999

Problem

Traffic monitoring can be difficult in areas where permanent detectors, electrical power, and communications systems are not available. This research sought to evaluate the performance of wireless traffic detection and communications systems.

Method

The researchers designed and built six surveillance and three ramp meter trailers, a video and data retransmission (or relay) site, and video and data reception facilities at the Caltrans District 12 and Anaheim Traffic Management Center (TMCs) and the University of California at Irvine Institute of Transportation Studies Laboratory. The system was evaluated in two different types of tests. The Anaheim Special Event Test assessed the surveillance trailers in an application that transmitted video imagery in support of arterial traffic control during a special event. The Interstate-5 (I-5) Test examined the use of the mobile surveillance and ramp meter trailers to transmit video imagery and data in support of freeway ramp metering.

Findings

Several difficulties were encountered with the trailers. These include:

- **Frequent discharge of electrical systems.** This was remedied with a complete redesign of the generator, battery, charging, and power architecture systems.
- **Difficult logistics and setup with the use of the trailers.** Several weeks and multiple personnel were required to select sites, perform signal strength testing, secure permits, and determine the best way to position the trailers. Moving a trailer a few kilometers and deploying it took about an hour. On construction sites, contractors need to be made aware of the surveillance trailers' use so that space can be allocated for them and thereby reduce the need for the trailers to be repositioned. Supplemental relay sites would also reduce logistics problems.
- **Strong winds occasionally moved antennae off mark.**

The video system used tended to over-report mainline volume. This is due in part to the maximum height at which the video detectors can be mounted on the portable trailers. In particular, tall vehicles tended to be counted as multiple vehicles; tall vehicles also tended to obscure smaller vehicles and cause them to be underreported. A method of compensating for vehicle overcount by the system studied is needed in order to report more accurate traffic volumes.

The ramp signals responded properly to vehicle demand an average of 85 percent of the time. This is not adequate for ramp-metering operation. Positioning the video camera closer to the ramp may reduce this error. Increasing the camera's field of view and using optical recognition logic may further reduce the error.

Fuel (LPG) consumption of a surveillance trailer was estimated at 0.46 gallons/hour. With an LPG cost of \$1.75/gallon, fuel for continuous surveillance trailer operation is estimated at \$0.80/hr.

Title: Paramics API Development Document for Actuated Signal, Signal Coordination and Ramp Control

**Author: Henry X. Liu
Lianyu Chu
Will Recker**

University of California, Irvine

Date: February 2001

Description of the Research

This report discusses the process and technology behind development and expansion of the Paramics software suite.

Paramics is a suite of software tools used to model the movement and behavior of individual vehicles on urban and highway road networks. The Paramics Project Suite consists of four components: Modeler, Processor, Analyzer, and Programmer. The Programmer enables the user to customize many features of the simulation model. Access to the Programmer is provided through an Application Programming Interface, or API.

Conclusion of the Research

The capability to access and modify the Paramics simulation model through an API is essential for research. Such an API should have a dual role:

- § first, to allow researchers to override the simulator's default models, such as car following, lane changing, and route choices, and
- § second, to allow researchers to interface complementary modules, for example ITS applications such as signal optimization, adaptive ramp metering, incident management, and so on, to the simulator.

This report describes three new APIs for complex simulation and modeling in Paramics. These are:

- § **Full-actuated signal control.** This API enables the modeling of a typical intersection with traffic detectors to simulate left-turn vehicle presence detection and vehicle detection for vehicle "through movement" phase.
- § **Actuated signal coordination.** This API enables the simulation of actuated signal coordination designed to allow "platoons" of traffic to form and progress through several signals with minimum stops and delays.
- § **Actuated ramp metering control.** This API enables the simulation of ramp metering systems utilizing a time-based ramp control algorithm.

The research also outlines possible future development of more APIs to handle several specific simulation issues. The proposed APIs can be built upon the APIs developed in this research. Examples suggested include:

- § Actuated ramp metering control rather than time-based metering
- § Actuated signal control utilizing detection methods other than loop detectors, such as machine vision or other "wide area" traffic detection technologies nearing implementation.

**Locator Number:
UCB-ITS-PWP-01-11**

**Title: A Real-Time Laser-Based Prototype Detection System
for Measuring Delineations of Moving Vehicles**

**Authors: Jonathan E. Larson, Kirk Van Katwyk, Cheng Liu, Harry H. Cheng,
Ben Shaw, Joe Palen**

UCB-ITS-PWP-98-20 (1998)

Problem

The goal of this project is to build a system that can gather reliable travel time data non-intrusively for use in traffic planning and ITS. Laser detection systems offer several advantages over other methods like loop detectors: ease of installation and maintenance (no digging or rerouting of traffic required), simple computational needs, and no dependence on existing lighting conditions.

Method

A laser is projected onto the ground, and an optical sensor collects the reflected light, focusing it onto a photo sensor that converts the signal to a readable sample. It can detect a vehicle as it passes under the laser by the absence of reflected light. With two such systems set a known distance apart, the speed of the passing vehicle can be measured, as well as its length (useful for identifying and re-identifying vehicles).

We built and tested an indoor prototype to prove the concept and develop algorithms, and are developing a full-scale system for outdoor testing. This report describes the design and implementation of the components of the lab prototype, the configuration of the field testing system, and software design and implementation.

Findings

The lab prototype can detect the profile and measure the length of a small test vehicle passing at varying speeds with high repeatability.

Problems we encountered include electrical noise and sunlight interfering with sensors; these can be fixed with continued work.

Title: A Review of the Optimized Policies for Adaptive Control Strategy (OPAC)
Author: Lawrence C. Liao

UCB-ITS-PWP-98-9 (1998)

Problem

Optimized Policies for Adaptive Control is a real-time, demand-responsive traffic signal timing optimization algorithm for individual intersections developed at the University of Lowell in the early '80s. It drops the concept of "cycle," instead constituting a sequence of switching decisions at fixed time intervals. The decision each time is whether to extend or terminate the current phase, and is constrained only by minimum and maximum defined phase lengths. It uses online and historical data to optimize the decisions. Although designed for individual intersections, the strategy can be used as a building block for decentralized networks of intersections.

This report reviews the design philosophy and underlying principles of OPAC, describes its development history and how it works, and provides a brief report on how well it performs.

Findings

The results of the field test show that OPAC strategies perform better overall than well-timed actuated signals, especially under heavy traffic conditions. However, it proved very sensitive to intersection discharge rates, so in order for it to perform well those must be accurately estimated.

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

Problem Addressed by Research:

An over-saturated freeway exit ramp that causes congestion in the exit lane also causes slow-down in the adjacent lanes, and can create a serious bottleneck on all lanes of the freeway.

Method:

We observed the La Paz Road off ramp from Interstate 5 in Orange County using videotapes, a probe vehicle, and loop detectors (which worked intermittently).

Findings:

In this particular case, the bottleneck did not seem to be caused by drivers squeezing into the exit lane at the last opportunity; this happened at a very low rate and rarely affected through-moving traffic. Non-exiting drivers simply seemed unwilling to drive fast while next to stop-and-go-traffic in the exit lane, which slowed all the lanes until they reached the off ramp.

When the traffic signal downstream of the off ramp provided right-of-way to exiting vehicles, no queue formed in the off ramp and no bottleneck arose; the traffic on the entire freeway had a very high flow. This particular traffic signal has a queue elimination strategy, triggered by a particular loop detector on the exit ramp. Such a strategy is very valuable, since it can prevent a bottleneck which might affect all lanes of the freeway. Where complete elimination of exit queues may not be feasible, these observations suggest that at least some improvement in freeway conditions can be realized by keeping these queues as small as possible.

Title: Vehicle Lateral Warning, Guidance and Control Based on Magnetic Markers: PATH Report of AHSRA Smart Cruise 21 Proving Tests

Authors: Han-Shue Tan, Bénédicte Bougler

Date: January 2001

Problem Statement

PATH tested a vehicle that provides automatic steering control, driver lane guidance control, and lane departure warning at the test track of PWRI in Tsukuba City, Japan for the “Smart Cruise 21” proving tests. The steering warning/guidance/control system developed by PATH includes magnetic sensors to detect the vehicle lateral deviation relative to the magnetic markers installed on the roadway; an antenna to receive the radio-wave control point marker information; an automatic steering actuator; a display screen showing the anticipated position of the vehicle to support the driver in steering the vehicle; and a speaker to provide an audio warning signal to the driver when the car is off-course. This system addresses prevention of overshooting on a curve, support for prevention of lane departure under expressway speed condition, and support for prevention of lane departure under fog and rain condition. Only the issues related to steering control are addressed; throttle and brake are controlled by the driver.

This report focuses on the discussions of the following five proving test items that are related to the magnetic markers sensing system:

1. Capabilities of the PATH steering warning/guidance/control system based on the benchmark test results to support the prevention of overshooting on curve, prevention of lane departure under expressway speed condition, and prevention of lane departure under fog condition.
2. Results from the PATH Demo2000 scenarios to further substantiate the steering effectiveness of the magnetic marker based lateral warning/guidance/control system.
3. Presentation of the proving test results of the PATH steering warning/guidance/control system without the knowledge of the road curvature information.
4. Comparisons of the performance of the PATH steering warning/guidance/control system with respect to 2m, 4m, and 6m magnetic marker spacing.
5. Discussions on the effects of different magnetic markers (nail and plate types) on the PATH and AHSRA magnetic sensing system, as well as on noise characteristics observed on the North Loop of the test track.

Findings

1. The capability of the steering warning/guidance/control system based primarily on the magnetic markers was shown to be effective to support automated steering control, driver steering control based on the display screen information alone, and driver steering control based on lane departure warnings alone.
2. The results from the PATH Demo 2000 scenario proved to be very successful. No failures occurred during four days of demonstration and five days of rehearsal. The Demo 2000 scenario included automated steering around the entire test track at various speeds and road curvatures, obstacle detection, switching between manual and automated steering, and steering guidance in zero visibility conditions.
3. The dynamic performance of the PATH guidance/control/warning system is very similar with or without the knowledge of road curvature.
4. Satisfactory performance for the proving test can be obtained using 2-meter magnetic marker spacing. The performance degradation from 2m spacing to 4m spacing is relatively small except at very low speed or sharp curves. Noticeable performance degradation can be observed from 4m to 6m marker spacing especially at lower vehicle speeds. High speed on a straight curve is the least sensitive to the increase of the marker spacing, except at very large departure angles. Low speed on sharp curves is the most sensitive to an increase in marker spacing.
5. a) A “noisy section” exists on the North Loop of the test track. The earth field “noises” in the “noisy section” are observed to be greater than those from the normal section. b) The results do not show a clear distinction between the nail and plate type magnets. However, this may not be true for the AHSRA sensors when the vehicle height is changing. c) AHSRA sensor measurement is not smooth when the magnet is directly between two sensors—this was the reason PATH used only the PATH magnetic sensors for the proving tests.

Locator Number:

UCB-ITS-PWP-2001-6

Title: Videobased Vehicle Signature Analysis and Tracking Phase 1: Verification of Concept and Preliminary Testing

Author: C. Arthur MacCarley, California Polytechnic State University, San Luis Obispo

UCB-ITS-PWP-98-10 (1998)

Problem

There is currently no way to automatically identify and track vehicles traveling on California freeways. With such a system, the California Department of Transportation could obtain data on vehicle flow patterns on California's freeways and arterial roadways to better manage traffic.

In order to meet this interest, a detection system must provide:

- 1) reliable detection and re-identification of a wide variety of vehicles under all possible traffic flow, environmental, and light conditions;
- 2) operate at very low power consumption to permit autonomous battery-only or photovoltaic (solar-powered) operation; and
- 3) be of low to moderate cost.

This report discusses Phase 1 of the research to address this problem. Phase 1 involves preliminary work to test the accuracy, reliability, and robustness of the basic technologies (a combination of video sensing, software processing of the video signal, and wireless transmission of data to other detection modules for a network of connected detection modules) upon which the detection method is based. Together, the technologies are termed Video-based Vehicle Signature Analysis and Tracking (V²SAT).

Phase 2 involves the development of experimental hardware and software for automated detection.

Phase 3 involves the design, development, and testing of a production prototype module. Based on the prototype, several such modules will be built, deployed, and tested.

Phase 4 involves the development of the wireless network components for telemetry between individual modules and local site transponders and the hardware and software components for telephone/modem communication between overcrossing transponders and a central correlation computer.

The proposed system is comprised of:

1. a detection module located on a physical structure (such as a freeway overpass) directly above each traffic lane; multiple modules make up a "site"
2. a local transponder/repeater, one per site, which receives data from up to ten modules and retransmits data via modem and telephone line to a network hub

3. a network hub, which receives the data stream from all detector modules and correlates the data to track vehicles through the monitored area

Method

The sensor is a simple video camera. The image is processed using filters and an efficient detection algorithm to develop a Vehicle Signature Vector (VSV), which is comprised of various measurements of the vehicle dimensions.

For Phase 1, two time-synchronized video systems were deployed at consecutive overcrossings spaced 0.5 to 0.6 miles apart on US Highway 101 in three different locations in the California Central Coast area. Data was collected on three different dates to cover four different illumination conditions.

Videotaped images from the field were then analyzed manually in the laboratory to test the accuracy and repeatability of the optical signature vector as a means for classifying and re-detecting vehicles. The analysis also sought to assess the general usability of the vector as a means for classifying a range of vehicles by dimensional measurements.

Findings

Under daylight conditions (midday and afternoon), an average of 98 percent of all vehicles were detected at the second site, for a sequence of 200 vehicles. For this data set and conditions, the method incorrectly matched the vehicle with the incorrect vehicle 0.87 percent of the time. Under daylight conditions, when a “reasonable time of arrival” window was used to admit only vehicles that could have traveled between sites at speed between 30 and 80 mph, the incorrect match percentage falls significantly, approaching 0 percent for the conditions of this test.

Under dusk illumination, but otherwise identical test conditions, correct matches occurred for 95.15 percent of all vehicles; false matches occurred for 2.02 percent of all vehicles in a sequence of 103 vehicles.

Under conditions of inadequate illumination (night) but otherwise identical test conditions, correct matches occurred for 75.49 percent of all vehicles while false matches occurred for 27.095 percent of all vehicles in a sequence of 102 vehicles.

It was found that supplemental illumination or use of specialized camera technologies will be required for sufficient nighttime vehicle detection and tracking.

On the basis of the results, the V²SAT method has the potential to serve as a reliable basis for non-intrusively tracking the progress of individual vehicles along an appropriately detectorized freeway network under daylight conditions.

System Performance

**Title: Anaheim Advanced Traffic Control System Field Operation Test Task A:
Evaluation of SCOOT Performance**

**Authors: James E. Moore, II, R. Jayakrishnan, M.G. McNally,
C. Arthur MacCarley**

UCB-ITS-PRR-99-26 (1999)

Problem

The city of Anaheim, California, implemented SCOOT (Split, Cycle, and Offset Optimizer Technique) as part of a larger Field Operational Test which included several other related technologies. This part of the FOT was meant to evaluate SCOOT, which controls systems of signals rather than just isolated intersections, in terms of the following issues: its limited implementation as an option for Anaheim traffic controllers, the development of operational policies, and the evaluation of its operational effectiveness.

Evaluation Task A1 assessed the value of existing loop detectors for SCOOT (the detectors were already in place, but closer to intersections than SCOOT is designed to use them), and assess the quality of SCOOT's internal representation of traffic flow. We did this by comparing SCOOT's performance to videotapes of actual conditions at intersections.

Evaluation Task A2 assessed the performance of traffic under SCOOT in terms of delay. We posted observation teams at intersections to measure delay and used floating cars to measure running, stopped, and total travel time, both before and after the implementation of SCOOT, during PM peak and evening off-peak hours, and for special event and nonevent traffic.

Findings and Recommendations

SCOOT successfully models traffic conditions, but there is room for improvement. In general, SCOOT performed better off peak, for special events at smaller-volume intersections, and very well at specific intersections with heavy traffic during special events.

When SCOOT performed worse than the baseline system, it did so rarely more than ten percent, and when it performed better, the difference was normally less than five percent. (It must be kept in mind that the existing traffic control system in Anaheim is considered state-of-the-art, and that SCOOT was using information from loop detectors in nonstandard locations.)

Delays between the two systems were generally comparable, and SCOOT caused no unacceptable delays or catastrophic problems.

**Title: Anaheim Advanced Traffic Control System Field Operational Test
Task C: Video Traffic Detection System
Author: C. Arthur MacCarley**

UCB-ITS-PRR-98-32 (1998)

Problem

As one part of the City of Anaheim's Advanced Traffic Control Field Test (in partner with Caltrans, FHWA, and JHK Consulting), we conducted an evaluation of a video detection system marketed by Odetics, Inc. as a low-cost alternative to loop detectors. Using video cameras, the system detects vehicles at intersection approaches in "virtual detection windows" for signal phase actuation. It can be set up and calibrated in the field using only a TV monitor and a PC mouse; up to four detection window setups can be stored; and it can also be set up and calibrated remotely. The user interface is simple but effective.

Method

Nine vehicle detection event classes and six phase actuation event classes were defined for this test, with different lighting, weather, and traffic conditions. Videotapes acquired in the field were slowed down, analyzed, and compared to the system's detection results.

Findings

In general, we found that detection was good under ideal lighting and light traffic conditions, but degraded at higher traffic levels and low light, night, and rainy conditions.

65% of vehicles were detected properly, which is similar to the performance of loop detectors. 80.9% were detected adequately for the purpose of signal phase actuation, and there was an average 8.3% false and latch detection rate (latch detection happens when the system detects a vehicle but fails to notice when it has moved on).

The manufacturer, Odetics, says it has since replaced both hardware and software to address these problems, but we have not tested the new system.

Title: Definition and Measurement of Transportation System Performance
Authors: Stephen G. Ritchie and Carlos Sun (University of California, Irvine)

UCB-ITS-PRR-98-33 (1998)

Problem

The research sought to improve traffic incident detection and congestion monitoring for more accurate and reliable measurement of traffic system performance.

Method

This project presents a new set of advanced traffic surveillance techniques based on inductive loop detector (ILD) technology currently in widespread use. The emphasis is on applying new algorithms to inductive loop detector data to obtain vehicle "signatures." By correlating the vehicle signature data from two sets of loop detectors, one "upstream" and one "downstream," data can be obtained on the traffic characteristics of a section of the transportation network.

The research included development of a process for extracting vehicle feature vehicle pattern matching information from the inductive loop detector data so that information on traffic density and travel time data could be obtained. A video system was used to validate the inductive loop detector data and vehicle pattern matching accuracy.

Findings

The section-related data generated by the system developed for this research project provides a quantitative measure of traffic density, which can be used as a direct measure of traffic demand. Traffic density also gives a good idea of the "closeness" of vehicles, which can reveal the psychological comfort of drivers. For example, the stress level associated with free-flowing traffic is much less than that of "stop-and-go" traffic.

Title: Definition and Measurement of Transportation System Performance
Authors: Joy Dahlgren (California PATH, Institute of Transportation Studies, Berkeley)

UCB-ITS-PRR-98-24 (1998)

Problem

Performance measures are needed to help make decisions regarding the overall level of resources to devote to a transportation system, where to allocate these resources, and how best to use them.

Decisions regarding the level of resources and where to allocate these resources require regular monitoring of the system to reveal opportunities for improvement. The decision of how best to use transportation resources must be more carefully examined in order to evaluate multiple means of addressing transportation needs and their respective costs and benefits to the public.

Method

The overall goal of a transportation system is to maximize the benefit of the system over its costs. Performance measures should therefore relate benefits to costs.

Specific attention is given to intelligent transportation systems which have both the capability to deliver benefits to a transportation system, and the capability to generate useful data on vehicle-miles and travel time within a transportation network.

Findings

The primary costs of transportation: time, money, property damage and injury, environmental degradation, and discomfort, such as the stress or delay caused by difficult driving conditions. Transportation system performance is measured in terms of the amount of transportation provided, which indicates the amount of access provided (person-trips, person-miles, and \$-miles of freight), travel time (both the average and the variation), and the amount of property damage and injury, and public monetary costs. These are the primary determinants of overall benefits and costs. These determinants are measurable and they can be influenced by the actions of transportation agencies.

In order to provide useful data for routine transportation system performance assessment, the following is recommended:

- Limit the number of routine measures, to concentrate resources on the most useful measures.
- Continue research to improve methods for measuring volumes and travel times.
- Develop a prototype travel time and volume measurement system, including data collection, processing, and storage, and characterization of performance.
- Develop schedules for measuring performance that are appropriate for different traffic situations.

Title: **The Effects of Data Inaccuracy on the Performance of Traffic Signal Timing Plans**

Author: **Wei-Hua Lin, Virginia Polytech University**

UCB-ITS-PWP-98-6 (February 1998)

Problem

To design a traffic signal timing plan, engineers need to know when and how many vehicles arrive at an intersection from all directions. This information comes from a wide variety of surveillance systems, and various techniques are used to predict, in real time, when vehicles will arrive.

Traffic signal controls have evolved from fixed plans based on data about traffic flow at different times of day to more sophisticated plans that combine historical information with real-time traffic information and computerized optimization and prediction programs.

Data collection is either off-line (historical) or on-line (using advanced field collection devices) but both systems require some form of prediction of traffic flow based on estimations. In addition, the optimization models of the later-generation, more sophisticated, strategies introduce several more levels of uncertainty. We set out not to compare the various strategies but to see how exact the information used must be in order for them to work well.

Method

We created eighteen base scenarios using two basic assumptions (isolated intersections with no turns). Each scenario had different arrival characteristics and different traffic conditions. We then created, for each scenario, an optimal plan with perfect information (that is, every prediction of a vehicle arriving was accurate and timely), and a less than optimal plan with imperfect information (where predictions didn't always match what actually happened).

The goal of the signal timing plans was to minimize total delay. We also used total delay, queue length, and the total number of stops to evaluate the performance of each plan.

The eighteen base scenarios included nine intersections where the flows from all approaches were similar and nine where the flows were unbalanced. There were three different flow levels (light, medium, and high) and three different variance-to-mean ratios (also light, medium, and high). So each scenario is a combination of a unique flow balance, level, and variance-to-mean ratio.

Findings

Overall the change in delay is insignificant when less accurate information is used to calibrate the signal timing plan, except in the case where the flow level is high, but underestimated in the plan (then delay can increase more than 10%).

In some cases a decrease in delay is observed, suggesting that sometimes the optimal plan is not as good as one calibrated with imperfect information.

There is a slight decrease in the total number of stops and queue length when the flow level is overestimated, and underestimation can increase both measures.

In general, the performance of a signal timing plan is more sensitive to the accuracy of the information used to calibrate it at intersections with balanced flows than at intersections with unbalanced flows.

**Title: Evaluation of the Anaheim Advanced Traffic Control System Field
Operational Test: Executive Summary
Author: M.G. McNally, James E. Moore II, C. Arthur MacCarley, R. Jayakrishnan**

UCB-ITS-PRR-99-18 (1999)

Problem

The city of Anaheim, California, experiences heavy traffic on a regular basis. Delays at intersections are a significant problem, and many special events create special traffic problems. The city has an advanced traffic control system, but wanted to test out several new technologies, so this field operational test was set up both to assess the technical performance of these methods and to analyze the institutional issues around their implementation and operation.

The three systems were: SCOOT (Split, Cycle, and Offset Optimizer Technique), a second generation technology for controlling systems of signals as opposed to isolated intersections, already in use in Europe; a 1.5 Generation Control system under development, whose purpose was to update baseline timing plans for the entire system; and a video traffic detection system presented as a low-cost alternative to loop detectors for critical areas.

Method

The evaluation was broken down into three main parts: a performance assessment of the technologies, an assessment of the institutional issues, and a separate evaluation of the video traffic detection system.

For the performance assessment, we looked first at how well SCOOT “sees” traffic and then at how well it performs to control traffic.

Findings

SCOOT is designed to rely on information from loop detectors placed farther away from the intersections than the mid-block locations of the loops already in place in Anaheim. We needed to know whether these loops could provide adequate information to the system, so we compared SCOOT’s estimates of queue length and clearance time to real time video at certain intersections, and identified large inconsistencies. Nevertheless, SCOOT successfully models traffic conditions, in general, but can be improved either by changing the location of loop detectors or by adjusting global control settings to compensate for the actual location of detectors.

To assess SCOOT’s performance, we used teams both at intersections to measure delay and in cars to measure travel time, before and after implementation. We discovered that SCOOT performed better than the existing system during off-peak hours, and very well at certain intersections during special events. However, our findings are inconclusive as to whether SCOOT is better than the system already in place.

To evaluate institutional issues, we used direct observation and interviews, all of which produced subjective information that was structured to provide many different points of view. We looked at implementation, operations, transferability, and maintainability of the system. There was an immediate problem with delaying implementation due to a vacancy in a key position (Principal Traffic Engineer), which led to a lack of experience and authority in the city's relations to the contractor (Siemens). We were not able to adequately evaluate operational issues because of the resulting delays, which led to late delivery, and limited staff training and experience prior to the evaluation. In terms of transferability of technology, we concluded that products that are not widely deployed are essentially still in the research and development process, subject to delays, changes, and cost overruns. This is especially true for the 1.5 GC system. Maintaining the new systems would involve significant costs, and much more training is needed to properly utilize it. Our overall conclusions in regard to institutional issues is that we have no specific recommendation, but costs would be likely to go up if SCOOT were to be expanded beyond its present limited deployment.

The last evaluation task, of the video system which is marketed as a low-cost alternative to loop detectors, found that its user interface is unsophisticated but effective. The system's performance results were good under ideal lighting and light traffic conditions, but not so good in low light, night, rain, or heavy traffic. (The manufacturer, Odetics, says it has since addressed and corrected these issues, but we have not evaluated the new system).

Title: Evaluating the Impact of ITS on Personalized Public Transit
Authors: Maged M. Dessouky, Randolph W. Hall, Rutvij Shah, Majhid Aldaihani
Date: March 2001

Problem Statement

The passage of the Americans with Disabilities Act (ADA) has created renewed interest in Demand Responsive Transit (DRT) Services. At the same time, the introduction of Intelligent Transportation Systems (ITS) such as dispatching and scheduling software, automatic vehicle location (AVL) devices, mobile data terminal (MDT), etc., has made such systems less complex to operate.

These advancements in technology have provided the impetus for many vendors to develop specialized software and other equipment to support management of paratransit and DRT services.

The objective of this research is to investigate the use of ITS technologies to improve the service efficiency of DRT providers and to evaluate the different opportunities it creates to improve the overall performance of DRT systems.

As part of the research efforts, the following tasks have been completed:

- Technologies that are currently being implemented and emerging technologies that have the potential to improve system performance were reviewed and identified.
- Commercial scheduling and dispatching software packages were surveyed in order to assess their functionality.
- In-depth phone interviews and site visits of transit agencies were conducted to document how public agencies are adopting such software.
- Travel pattern data from the Antelope Valley Transit Authority of Los Angeles County, a representative paratransit provider, was statistically analyzed.

Findings

The technologies identified as being implemented or considered for implementation by transit providers included AVL, advanced wireless communication, MDT, computerized vehicle navigation, and geographic database. Some emerging technologies such as Wireless Internet Dispatching (WID), superphones, and Personal Data Assistant (PDA) were also recognized as having potential application within ITS.

The review conducted as part of this study shows that the software reviewed by in large has the capabilities to be utilized in DRT service within the paratransit industry. The products reviewed were provided by Strategen Systems, Trapeze Software, Inc., and RouteLogic, Inc. The intent of the research was not to recommend any products, rather just to review their applicability within the paratransit industry.

The results of the in-depth phone interviews and site visits show that utilization of ITS technologies at a paratransit provider in the Santa Clara Valley led to reduced cost, increased efficiency, and no perceived reduction in customer service as indicated by the paratransit users.

Although this study shows the potential benefit of deploying ITS in DRT systems, ITS alone is not a complete solution for meeting the increased demands for these types of services and for satisfying the strict guidelines of the ADA. New innovative services that complement ITS need to be studied.

Locator Number:
UCB-ITS-PWP-2001-12

Title: Evaluation of ITS Technology for Bus Transit Systems

Authors: Randolph Hall, Maged Dessouky, Lei Zhang, Ajay Singh, Vishal

Date November 1999

Description of the Research

Recently, bus transit service providers have begun to adopt Intelligent Transportation Systems (ITS) technologies such as Global Positioning Systems (GPS) and Mobile Data Terminals. 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. This research evaluates bus control strategies using ITS against those without ITS. Two levels of ITS are considered: 1) a system with centralized tracking, and 2) a system with information on connecting passengers, as well as centralized tracking. For those strategies using ITS, we develop methods to forecast bus arrival times to a stop and the number of passengers on board the bus.

Conclusions of the Research

Several different ITS strategies were evaluated. In terms of minimizing the average passenger trip time, the ITS strategies outperformed the non-ITS based strategies for the random generated problem sets, though not for one real-life dataset.

Overall, the researchers found it disappointing that ITS did not provide larger time savings in the analysis conducted for this research. A fundamental reason for this is that in many situations, it is optimal to either have a bus leave immediately whether or not connecting buses have arrived, or to wait as long as possible until all connecting buses have arrived. These extreme cases require no communication and no ITS.

ITS was found to be more beneficial for cases in which a connecting bus incurs a small delay and it is more advantageous to wait for its arrival than to depart without the connecting passengers.

The savings per passenger appear to be no more than 1 minute, which translates into annual time savings on the order of 500 to 2000 hours per bus. Savings of this magnitude may be sufficient to justify installation of an ITS system with payback within a few years. More generally, the savings are highly site-specific and should be evaluated on a case-by-case basis. Cost-benefit analysis was not performed as part of this research.

Locator Number:
UCB-ITS-PRR-99-38

Title: Evaluation of the OCTA Transit Probe System

Authors: Randolph W. Hall, Nilesh Vyas, Chintan Shyani, Vikas Sabnami, Simit
Date: November 1999

Description of the Research

The OCTA (Orange County Transit Authority) Transit Probe Project is a field operation test of an automatic vehicle-location (AVL) system operating in Orange County, California. The system software was designed to estimate roadway congestion levels based on bus travel times over route segments and communicate this information to Caltrans, the City of Anaheim, and the City of Santa Ana.

This report presents the final evaluation of the project, concentrating on the year-long field operational test period. The report provides a detailed description of the system and its design. It also provides analyses of data reliability and accuracy, and analysis of the usefulness of Transit Probe data for predicting automobile travel times. Institutional issues are evaluated, based on interviews with involved personnel, direct observation, and review of project documents. Surveys of bus riders and kiosk users are also documented.

Conclusions of the Research

Bus tracking systems provide many potential benefits related to scheduling, problem response, and bus arrival information for users. However, these benefits cannot be captured without carefully planning operational procedures, data maintenance, system interfaces, and ensuring that the equipment is reliable. These important issues did not receive adequate consideration in the system design phase of the project. Although the evaluation produced important insights as to how bus tracking should be implemented and the likely problems to expect, the OCTA Probe failed to live up to its promise because the system was not used by drivers, dispatchers, planners, schedulers, or the general public.

Transit Probe did not meet reliability standards for an actual deployment. The majority of schedule data points are either missing, undetected, or duplicated, thus confounding data analysis.

Transit Probe never created its intended interfaces to Caltrans, the City of Anaheim, or City of Santa Ana due to a reduction in scope of the deployment and a reduced budget.

Only one public interface kiosk was installed, and though it was well-received in a test evaluation, it wasn't functional until the end of the project and therefore didn't have any positive impact.

Customers perceived that bus schedule adherence had improved during the Transit Probe project, though whether this represents a real improvement or merely public perception is not altogether clear. From bus driver interviews, it seems that the installation of a clock in driver view may have encouraged better schedule adherence. However, drivers generally ignored Transit Probe indicator lights, and therefore the improvement could not have resulted from Transit Probe's schedule adherence capabilities.

The congestion measurement component of Transit Probe was never fully established due to many factors, including: 1) inadequate congestion information dissemination, 2) improperly established baseline bus route segment speeds, 3) inaccurate speed estimation algorithm in Transit Probe, 4) lack of relationship between slow bus speeds and general traffic speed.

In terms of the institutional performance of OCTA Transit Probe, OCTA involved partner agencies commendably while moving the project forward and meeting deadlines during the design phase. However, once the project progressed to the test phase, the organization became rather conventional with a contractor and contract manager and outside participation virtually disappeared.

Locator Number:
UCB-ITS-PRR-99-39

Title: Freeway Performance Measurement System: Final Report

Authors: Pravin Varaiya
University of California, Berkeley

Date January 2001

Description of the Research

This report summarizes the design, operation, and implementation of PeMS (Performance Measurement System). Topics covered include the communication and software architecture of PeMS, its applications, observations of PeMS in operation, and an appendix consisting of an empirical study of congestion, capacity, and ramp metering using PeMS.

Conclusions of the Research

PeMS is a low-cost freeway performance measurement system for all of California. PeMS processes 2 GB/day of 30-second loop detector data in real time to produce useful information to travel network managers, traffic engineers, planners, researchers, and travelers.

PeMS utilizes an open communication and software architecture, meaning that the code used to develop the software is publicly accessible and that modifications or add-ons can easily be made to PeMS. A new district can be added to the PeMS system with six person-weeks of effort and no disruption of the district's TMC (Traffic Management Center); data from new traffic loops can be easily added as it is available. PeMS applications are accessed via a Web browser, an interface with which the majority of users will already be familiar.

PeMS is inexpensive, utilizing off-the-shelf products for communication and computation. PeMS uses data retrieved from the existing Caltrans ATM wide area network to which all districts are already connected.

PeMS benefits users in several ways:

- \$ Caltrans managers can instantly obtain a uniform and comprehensive assessment of the performance of the freeway network.
- \$ Caltrans traffic engineers can base their operational decisions on knowledge of the current state of the freeway network.
- \$ Caltrans planners can examine solutions to congestion. Traffic control equipment, such as ramp-metering and changeable message signs, can be optimally placed and evaluated.
- \$ Travelers can use PeMS via products developed by VARs (Value Added Resellers) to choose optimal travel routes.
- \$ PeMS can serve to guide and assess intelligent transportation system (ITS).

Locator Number:
UCB-ITS-PWP-2001-1

Title: Incident Dispatching, Clearance and Delay

Author: Randolph Hall

Date: August 2000

UCB-ITS-PWP-2000-14

Problem Addressed by Research:

Dispatchers for mobile emergency crews, such as police and freeway service patrol trucks, frequently must make a choice between sending the closest available crew or waiting for one that's closer, but busy.

Method:

This paper builds a simplified model (i.e., one emergency vehicle per incident, one incident at a time, evenly spaced highway interchanges) to help formulate the best dispatch strategies to use when incidents cause delay. The model considers different crew deployment methods: individual, non-overlapping beats; and rolling beats, first with fixed spacing between emergency vehicles and then with random spacing between vehicles based on Poisson process locations.

The model's purpose is to determine the relationships between system parameters (such as spacing between interchanges and the time needed to maneuver through an interchange) and system performance. Our objective is to minimize traffic delay at incidents. Our model considers the distance of response vehicles to the incident, whether the vehicle is on the same side of the highway as the incident, the position of interchanges, and the presence of congestion.

Findings and Recommendations:

A response system using individual, set beats causes longer waits but is more stable than a system using rolling beats.

Any robust dispatching strategy must look for a balance between certainty in response time and stability in the system. Limiting response distance and allowing some calls to queue is essential to stability. Waiting for the closer, but busy, vehicle can reduce service time and keep the dispatch system stable at higher use levels, but it can also add uncertainty about the length of expected delay. As more variation is introduced, it becomes more advantageous to go ahead and dispatch the available but more distant vehicle, rather than wait.

**Title: Los Angeles FOT Spread Spectrum Radio Traffic Signal Interconnect
Evaluation Task: Final Report on Full Deployment
Author: Victor O.K. Li, Senthil Sengodan, Tat-Keung Ken Chan, Lei Zhuge**

UCB-ITS-PWP-98-27 (1998)

Problem

Spread spectrum radio networks (SSRN) are an alternative to hard-wired methods of traffic monitoring and control which take less time and money to build and maintain. How well do they work? Los Angeles needs to connect 2000 intersections to its existing traffic control system (which already controls 2000 intersections via hard-wired links) so USC set up a field operation test in the Mar Vista area to implement and test the reliability and cost effectiveness of SSRN.

The radio links are arranged in a network of cells, each consisting of one headend radio hard-wired to the control center and up to 31 remote radios hard-wired to intersection controllers.

Findings

The overall performance of the system is satisfactory. It can send large amounts of information reliably through the network, with an average signal throughput of 90 percent, which is satisfactory, but can be improved. The automatic network reconfiguration in the presence of failed and poor links also worked well.

Some channels are busier and less reliable than others; in fact one particular channel (7) was very busy with other radio traffic and so was eliminated from the choices used in this area. Some antenna locations work better than others, and antennas that were mounted high enough to create visual line-of-sight connection provided high quality links between units. Some mounting options work better than others, depending on the particular location, although sometimes a choice must be made between signal loss or durability and ease of maintenance. Also, some units had a problem with polarization, which was solved with the use of a special antenna.

Recommendations include the use of an exclusive radio band to increase throughput, and taller posts for antennas to get the best possible line-of-sight connection.

Title: Operations at Regional Travel Information Centers: The Case of the TravInfo Field Operational Test – Final Results

**Authors: Mark A. Miller
Dimitri Loukakos**

Date: September 2000

Description of the Research

TravInfo is a regional traveler information system in the San Francisco Bay Area. It was a Field Operational Test (FOT) over a two-year period from September 1996 to September 1998 with funding from the Federal Highway Administration and the California Department of Transportation (Caltrans). The goal of TravInfo was to broadly disseminate accurate, comprehensive, timely, and reliable information on traffic conditions and multi-modal travel options to the public in the Bay Area. Information was disseminated directly to users via a telephone service and indirectly through information service providers who in turn disseminated the information.

The purpose of this project was to evaluate the operation of TravInfo's Traveler Information Center (TIC) with a focus on its operation by a private sector contractor. This evaluation was performed using various data sources from field observations and field measurements. The evaluation examined TIC effectiveness in terms of system reliability, the communications interface, and operator work setting and performance. The evaluation also examined TIC effectiveness in from an organizational perspective.

Conclusion of the Research

Inductive loop sensor data provided by the Caltrans Traffic Operations System were initially expected to be a major source of data for TravInfo. However, they were not used as extensively as anticipated. Instead, the most significant data source was the California Highway Patrol Computer-Aided Dispatch incident reports. These reports had to be manually entered into the TravInfo system by TIC operators. This process was both time-consuming and difficult to perform along with the other duties of the TIC operators. Automating the data entry process, which was part of the TIC system's original specifications, could speed operators' response times and increase the number of incidents they could process, although it is likely that operators would still need to intervene in the interpretation of some incident reports.

The TravInfo system is not as efficient as originally envisioned because of its heavier-than expected dependence on the manual performance of jobs by the TIC operators. TravInfo needs an automated system that is flexible enough to keep up with rapidly advancing technologies. As the system becomes more automated, the organizational structure of the TIC can become more efficient than it was during the field operational test. The TIC staff should be consulted for ways to improve the system as they are the ones who will ultimately work with it.

**Locator Number:
UCB-ITS-PWP-2000-20**

Title: Productivity Benefits and Cost Efficiencies from ITS Applications to Public Transit: The Evaluation of AVL

Authors: David Gillen Elva Cange Doug Johnson

Date September 2000

Description of the Research

Automatic Vehicle Location technology is a component of Intelligent Transportation Systems (ITS) that enables transit agencies to monitor fleet vehicle performance and location. AVL has the potential to improve the on-time rate of public transit and timed transfers, accessibility and accuracy of passenger information, availability of data for transit management and planning, and efficiency and productivity of transit services.

AVL has the potential to increase efficient fleet utilization and reduce expenditure for fuel, labor, and capital. AVL can also facilitate and integrate on-board electronic fare collection among different transit systems within a region. With an AVL system in place, passengers could use a single fare medium for multiple transit systems, resulting in more efficient fare collection and more efficient transfer among transit agencies that share routes or transfer credit.

This research uses information from operations and financial information from the Federal Transit Commission's database and information on AVL applications to explore whether and how AVL applications lead to changes in productivity and resource use.

Conclusion of the Research

The overall assessment of AVL is that it provides sizable benefits for both consumers and transit agencies. The research focused on the cost efficiency improvements from AVL, but some demand side benefits were explored as well.

Higher numbers of passenger trips were reported when AVL was implemented by the transit agency. The most significant improvements were in productivity and cost efficiency. Whether output was measured as passenger oriented or service oriented, productivity was greater with the use of AVL. The sources of the productivity gains came from better use of capital, decreased need for buses, more efficient use of fuel and energy, and reduction in vehicle maintenance and vehicle operations.

**Locator Number:
UCB-ITS-PWP-2000-16**

Call Number: UCB-ITS-PWP-2000-2

Title: TravInfo Field Operational Test Institutional Evaluation Final Results

Authors: Youngbin Yim Elizabeth Deakin

Date: February 2000

Problem

TravInfo is a regional traveler information system in the San Francisco Bay Area. The goal of TravInfo was to broadly disseminate accurate, comprehensive, timely, and reliable information on traffic conditions and multi-modal travel options to the public in the Bay Area through a public-private partnership.

The institutional evaluation of TravInfo was one of four test elements which comprised the TravInfo Field Operational Test (FOT). The other elements were technology assessment, traveler response, and transportation network performance. The transportation network performance test was not performed because of the lack of traffic data to realistically measure the changes in traffic flow during the field test.

The institutional evaluation measured the performance of TranInfo's public-private partnership at the organizational level. It examined how well TravInfo's institutional organization worked to achieve its objectives, what benefits the project partners were able to gain from the field test, and what institutional challenges they had to overcome.

Findings

TravInfo's organizational structure was unique, with a high degree of openness in the public-private partnership. TravInfo meetings were conducted as open forums to encourage the entrepreneurial participation of the advanced traveler information industry as well as the active participation of local public agencies. The ultimate responsibility for TravInfo lay with the public sector in the form of the Management Board, the members of which came from regional transportation agencies.

The TravInfo organization was effective in appropriately utilizing public and private sector talent. By placing the Metropolitan Transportation Commission, which is the transportation planning organization for the nine-county Bay Area, in a leadership role, the project recognized the importance of consensus building.

The project helped foster constructive relationships among the projects principal public participants. The project also fostered alliances among many of the private participants.

The project also encountered many challenges. Two major setbacks were insufficient coverage of the Bay Area transportation network by the data supplied to the TravInfo Traveler Information Center (TIC) and an inefficient system design that required the TIC to be considerably more dependent on manual operations than expected.

Title: TravInfo Evaluation (Technology Element) Traveler Information Center (TIC) Study: Operator Interface Analysis-Phase III

Author: Mark Miller, Dimitri Loukakos

UCB-ITS-PWP-98-22 (1998)

Problem and Method

TravInfo is a field operational test (FOT) of advanced traveler information systems (ATIS) for the San Francisco Bay Area. The project seeks to compile, integrate, and broadly distribute timely and accurate multi-modal traveler information through commercial products and services. The public sector component centers on the Traveler Information Center (TIC), which collects and integrates both static and dynamic traveler information.

This study examines the technology component of the TravInfo project, and more specifically, the role of the operator in the flow of information through the TIC, the operators' tasks and responsibilities and the operators' physical environment.

This report focuses on the physical environment of the TIC operations including the TIC computer interface and the physical surroundings of the operators' workstation environment. The work was accomplished by analyzing the TIC operator interface design and by surveying operators. This study builds on work reported in UCB-ITS-PWP-98-7.

Findings

The first part of this evaluation considered the operator interface. Overall, the operator interface was found to serve its general purpose of allowing operators to perform their data monitoring and entry tasks relatively quickly. However, the general computer interface was found to not support the tasks of the operators as much as it could. The chief problems were:

- Fill-in form interfaces appeared not to be designed with consideration for operator tasks
- Some of the most commonly used windows had several shortcomings
- The two most important menus were not ordered in a logical manner
- There was no logical grouping of related fill-in form interfaces, and moreover, there are ambiguous terms and non-mutually exclusive attributes within certain fields
- There was a lack of organization across all windows.

Other general areas of weakness in the operator interface included the following:

- User compatibility: There should have been more consideration of specific operator duties.
- Consistency: The fill-in form formatting is not always consistent among forms.
- Responsiveness: There is no feedback on the progress of system processing, and the system is often slow due to lack of processing power.

The second part of this evaluation considered the operators' working environment. A checklist was developed to identify operator environment characteristics which may help or hinder the TIC operators' job performance. These were:

- Illumination, noise levels, and climate control (e.g., heat, air conditioning, air quality)
- Visual display elements of the computer screen
- Keyboard characteristics
- Furniture
- Work surface
- Seating
- Accessories

The study found that only three changes would lead to a more productive work environment. These were: thermal and air quality, general layout of work surface, and cubicle height or sense of connectedness with other operators. All other characteristics were found to be generally acceptable to the operators.

Call Number: UCB-ITS-PWP-2000-2

Title: TravInfo Field Operational Test Institutional Evaluation Final Results

Authors: Youngbin Yim Elizabeth Deakin

Date February 2000

Problem

TravInfo is a regional traveler information system in the San Francisco Bay Area. The goal of TravInfo was to broadly disseminate accurate, comprehensive, timely, and reliable information on traffic conditions and multi-modal travel options to the public in the Bay Area through a public-private partnership.

The institutional evaluation of TravInfo was one of four test elements which comprised the TravInfo Field Operational Test (FOT). The other elements were technology assessment, traveler response, and transportation network performance. The transportation network performance test was not performed because of the lack of traffic data to realistically measure the changes in traffic flow during the field test.

The institutional evaluation measured the performance of TranInfo's public-private partnership at the organizational level. It examined how well TravInfo's institutional organization worked to achieve its objectives, what benefits the project partners were able to gain from the field test, and what institutional challenges they had to overcome.

Findings

TravInfo's organizational structure was unique, with a high degree of openness in the public-private partnership. TravInfo meetings were conducted as open forums to encourage the entrepreneurial participation of the advanced traveler information industry as well as the active participation of local public agencies. The ultimate responsibility for TravInfo lay with the public sector in the form of the Management Board, the members of which came from regional transportation agencies.

The TravInfo organization was effective in appropriately utilizing public and private sector talent. By placing the Metropolitan Transportation Commission, which is the transportation planning organization for the nine-county Bay Area, in a leadership role, the project recognized the importance of consensus building.

The project helped foster constructive relationships among the projects principal public participants. The project also fostered alliances among many of the private participants.

The project also encountered many challenges. Two major setbacks were insufficient coverage of the Bay Area transportation network by the data supplied to the TravInfo Traveler Information Center (TIC) and an inefficient system design that required the TIC to be considerably more dependent on manual operations than expected.

Title: Vehicle Lateral Warning, Guidance and Control Based on Magnetic Markers: PATH Report of AHSRA Smart Cruise 21 Proving Tests

Authors: Han-Shue Tan, Bénédicte Bougler

Date: January 2001

Problem Statement

PATH tested a vehicle that provides automatic steering control, driver lane guidance control, and lane departure warning at the test track of PWRI in Tsukuba City, Japan for the “Smart Cruise 21” proving tests. The steering warning/guidance/control system developed by PATH includes magnetic sensors to detect the vehicle lateral deviation relative to the magnetic markers installed on the roadway; an antenna to receive the radio-wave control point marker information; an automatic steering actuator; a display screen showing the anticipated position of the vehicle to support the driver in steering the vehicle; and a speaker to provide an audio warning signal to the driver when the car is off-course. This system addresses prevention of overshooting on a curve, support for prevention of lane departure under expressway speed condition, and support for prevention of lane departure under fog and rain condition. Only the issues related to steering control are addressed; throttle and brake are controlled by the driver.

This report focuses on the discussions of the following five proving test items that are related to the magnetic markers sensing system:

1. Capabilities of the PATH steering warning/guidance/control system based on the benchmark test results to support the prevention of overshooting on curve, prevention of lane departure under expressway speed condition, and prevention of lane departure under fog condition.
2. Results from the PATH Demo2000 scenarios to further substantiate the steering effectiveness of the magnetic marker based lateral warning/guidance/control system.
3. Presentation of the proving test results of the PATH steering warning/guidance/control system without the knowledge of the road curvature information.
4. Comparisons of the performance of the PATH steering warning/guidance/control system with respect to 2m, 4m, and 6m magnetic marker spacing.
5. Discussions on the effects of different magnetic markers (nail and plate types) on the PATH and AHSRA magnetic sensing system, as well as on noise characteristics observed on the North Loop of the test track.

Findings

1. The capability of the steering warning/guidance/control system based primarily on the magnetic markers was shown to be effective to support automated steering control, driver steering control based on the display screen information alone, and driver steering control based on lane departure warnings alone.
2. The results from the PATH Demo 2000 scenario proved to be very successful. No failures occurred during four days of demonstration and five days of rehearsal. The Demo 2000 scenario included automated steering around the entire test track at various speeds and road curvatures, obstacle detection, switching between manual and automated steering, and steering guidance in zero visibility conditions.
3. The dynamic performance of the PATH guidance/control/warning system is very similar with or without the knowledge of road curvature.
4. Satisfactory performance for the proving test can be obtained using 2-meter magnetic marker spacing. The performance degradation from 2m spacing to 4m spacing is relatively small except at very low speed or sharp curves. Noticeable performance degradation can be observed from 4m to 6m marker spacing especially at lower vehicle speeds. High speed on a straight curve is the least sensitive to the increase of the marker spacing, except at very large departure angles. Low speed on sharp curves is the most sensitive to an increase in marker spacing.
5. a) A “noisy section” exists on the North Loop of the test track. The earth field “noises” in the “noisy section” are observed to be greater than those from the normal section. b) The results do not show a clear distinction between the nail and plate type magnets. However, this may not be true for the AHSRA sensors when the vehicle height is changing. c) AHSRA sensor measurement is not smooth when the magnet is directly between two sensors—this was the reason PATH used only the PATH magnetic sensors for the proving tests.

Locator Number:
UCB-ITS-PWP-2001-6

Traveler Information

Title: Automated Travel Time Measurement Using Vehicle Lengths From Loop Detector Speed Traps

Author: Benjamin Coifman, Civil Engineering, Ohio State University

UCB-ITS-PRR-2000-12 (2000)

Problem

Travel time data is a useful tool for traffic engineers, offering the possibility of better incident detection, ramp meter control, and traveler information. It will become even more useful as input for emerging technologies such as dynamic traffic assignment; more importantly, it can be used now to quantify the benefit of such new technologies before making significant infrastructure investments.

This report presents a method of measuring travel time using existing loop detector infrastructure, inexpensive computers, and real traffic data.

Method and Findings

This method uses an algorithm to match vehicles detected at one loop detector station with the same vehicle at the next station; the difference in time between stations is the actual travel time of that vehicle.

Because the loop detectors measure effective vehicle length, it is possible to distinguish individual vehicles as they pass over it. However, such a length measurement may be accurate to only two feet, depending on the speed of traffic, making it difficult to match pairs from one detector to another. It is simple to eliminate unlikely matches from this scenario; however, the data produces a series of “possible matches” that must then be distinguished in order to make sense of the information.

To eliminate false matches, the algorithm matches platoons where vehicles pass both detectors in the same relative order. The platoon should produce a contiguous sequence of possible matches; if these are long enough, the problem posed by false matches can be eliminated.

Three closely related algorithms use different strategies to eliminate spurious sequences due to false matches. The algorithms were used to measure travel times on a large data set and the average measurement error for the different algorithms ranged between 0.7 percent and 4.5 percent, corresponding to an average segment velocity error between 0.4 mph and 1.5 mph.

Title: Daily Activity and Multimodal Travel Planner: Phase II Final Report
Authors: Ryuchi Kitamura, Cynthia Chen, Jiayu Chen (Institute for Transportation Studies, University of California, Davis)

UCB-ITS-PRR-99-1 (1999)

Problem and Findings

Movement is restricted by the available time and the travel speed of an individual. By developing efficient travel itineraries, the traveler can optimally visit multiple locations with minimal waste. This project sought to develop an information system and a software product known as the "Itinerary Planner" that can assist travelers in optimizing an itinerary that may include visits to multiple locations and that may use multiple modes.

The Itinerary Planner utilizes both highway and transit databases and accounts for user preferences and constraints as it interactively builds an itinerary comprised of a set of sequenced *activity locations* to visit and *trips* which connect these locations. The Itinerary Planner considers trip attributes, such as travel time, travel cost, and waiting time and weighs the various attributes according to user preferences input by the user. Often, an itinerary that is optimal in all attributes does not exist, so the consideration of user preferences (for example, time over cost) is important.

The Itinerary Planner prototype was developed for San Francisco, and makes use of the multiple available modes of travel found in the San Francisco area: travel time by taxi, travel time by transit, travel time by cable car, travel cost, walk time, number of transfers, and waiting time. User considerations related to these modes are also considered in the software, for example, whether the user can or is willing to walk a given distance.

The prototype is developed as a public-access terminal. The beginning of each itinerary is therefore the location of the terminal. The terminal provides the user with a visual display of the itinerary with different colors used to indicate different modes. The terminal also provides the user with written directions, including which mode to take where and how long each trip segment is expected to take.

This project primarily sought to develop the Itinerary Planner prototype. The software is still in the prototype stages and though it provided very promising results, it has not been extensively tested.

Title: Daily Activity and Multimodal Travel Planner: Phase 1 Report
Author: Ryuichi Kitamura, Cynthia Chen, University of California, Davis

UCB-ITS-PWP-98-23 (1998)

Problem and Method

The objective of this project is to develop an advanced traveler information systems (ATIS) tool that can assist the traveler in developing an efficient itinerary in which multiple locations can be visited efficiently and with minimal waste. Also in the scope of this project is the development of an information system that will aid the traveler in using public transit in a complex tour in which multiple locations are visited. Underlying this are the beliefs that the availability of information affects the decision to use public transit and that people will make complex tours by public transit if they are shown that it is possible and convenient to do so.

The product developed to meet this objective is called the Travel Planner. The Travel Planner consists of two stages: first it is developed as a public kiosk, and second, as a personal unit. The inputs to and outputs from the Planner are identical in both stages. The critical difference is that the kiosk serves many anonymous users and does not retain personal preferences while the personal unit serves as a transportation guide for a specific user and therefore is able to store information about the user's preferences and travel history.

This report (Phase 1) presents the development of the prototype for the public kiosk Planner. The prototype is based on two primary assumptions. First, it assumes that the user will not use a private auto. Second, it assumes that all destination locations are uniquely specified by the user.

Findings

The prototype Travel Planner was lab tested for the downtown area of the city of San Francisco. The prototype was limited to a set of 25 possible travel locations within the area. The network in this area consists of five MUNI (bus) lines, one cable-car line, and streets for walking and taxi with access to various attraction points (included in the 25 possible travel locations). This simplified prototype allowed for simpler programming and more timely user testing.

To use the Travel Planner, a user enters travel requirements such as travel destinations, when the user must be at the travel destination(s), how much time the user will spend at the destination(s), and whether certain destinations must be visited before others. The Travel Planner then evaluates each possible sequence, takes into account the feasibility of the possible sequences, and then selects the first and second best solutions. The Planner then outputs the best solution itinerary as a map with marked locations. If requested by the user, the alternate (second-best solution) itinerary can be output.

Several problems were found by the researchers as part of this test, mostly related to sensitivity of the Travel Planner algorithms. For example, when the number of visits

selected by the user is relatively small, one or two itineraries in particular sequences appear to dominate. Similar problems occur with transportation mode. These problems can be addressed in the subsequent stage of Travel Planner development.

Title: Evaluation of TravInfo Field Operational Test: Final Report

Authors: Youngbin Yim, Mark A. Miller

Date: May 2000

Description of the Research

TravInfo is a regional traveler information system in the San Francisco Bay Area. It was a Field Operational Test (FOT) over a two-year period from September 1996 to September 1998 with funding from the Federal Highway Administration and the California Department of Transportation.

The goal of TravInfo was to broadly disseminate accurate, comprehensive, timely, and reliable information on traffic conditions and multi-modal travel options to the public in the San Francisco Bay Area. Organizationally, TravInfo was structured around a collaborative partnership between public and private participants. Operationally, the system was built on an open-architecture concept to make its regional database easily accessible to all interested parties.

The core of TravInfo was its Traveler Information Center (TIC) which was created for the FOT. The center collects and processes traffic information for dissemination directly to the public through its Traveler Advisory Telephone System (TATS) and to information service providers for dissemination through the Web and other advanced traveler information products.

The FOT attempted to measure how well TravInfo performed in four major areas: building a regional traveler information system with the collaboration of public and private parties; providing improved travel information to the public; stimulating the creation of a commercial market for advanced traveler information products, and ultimately enhancing the entire Bay Area transportation system. This last area of evaluation was ultimately not considered due to insufficient data, difficulty in finding a suitable method of measurement, and insufficient use of advanced traveler information products among the public.

Conclusion of the Research

TravInfo's primary success lay in developing a network of public and private professionals who collaborated on advanced traveler information system projects in a variety of settings and providing a platform for different organizations to create networks and form partnerships.

The major challenges of the TravInfo FOT were notably similar to those of other FOTs. Among them were setting ambitious project goals that were unattainable within the limited time reserved for the field test; underestimating the extensive time required to develop mutual understanding and trust among parties with varying objectives; underestimating the uncertainty of the consumer market for commercialization of traveler information products and services; defining appropriate roles for the parties involved; and appreciating the importance of having enough time and funds to market the product and convince people to use it.

**Locator Number:
UCB-ITS-PRR-2000-7**

Title: Los Angeles Smart Traveler Field Operational Test Evaluation
Author: Genevieve Giuliano¹, Randolph W. Hall¹, Jacqueline M. Golob²
(1 University of Southern California at Los Angeles; 2 Jacqueline Golob Associates)

UCB-ITS-PRR-95-41 (1995)

Problem

The Los Angeles Smart Traveler Field Operational Test (FOT) is one of the largest and most comprehensive ATIS (Advanced Traveler Information Service) experiments to date. The system is multi-modal and offers traffic, transit, and ride-matching information. The FOT tested the delivery of ATIS services through multi-media kiosks, touch tone phones, and PC modem links.

Traveler information systems are currently being promoted for their potential to support policy efforts aimed at influencing travel behavior. Seeking alternative routes of travel to avoid congestion, changing times of travel, changing travel modes to transit, and ridesharing are all possible means of beneficially influencing both traffic congestion and air quality. The evaluation considered the following:

- Financial impacts
- Functional characteristics
- User acceptance
- Other impacts

Findings

The kiosks provided a new medium for obtaining pre-trip traveler information. They were found to be reasonably user-friendly and made information on all three of the major travel modes accessible in a wide variety of locations. Survey results indicated a high degree of user satisfaction, yet the overall usage rate was low (an average of 25 transactions per day), relative to the cost of providing the kiosk service. Low usage combined with high capital and operating costs yielded a total cost per use of approximately \$2.00 (over a five-year lifetime of the kiosk).

Kiosks placed in office locations had the lowest usage while kiosks placed in Union Station in downtown Los Angeles and kiosks placed in shopping malls had the highest usage. This finding suggests that the kiosks may be used more for non-work related trip information when users have more time, such as for shopping trips or by tourists.

The telephone system called ARMS (Automated Ridematching Services) was found to have very little use (34 persons per week). From a small telephone survey of ARMS users it was concluded that most users used the service to seek regular ridesharing opportunities and not the featured one-time ride service. The survey also suggested that low usage can be attributed to a hesitancy among travelers to take or offer rides to people who are unknown. Most users rely on friends or family members for one-time ridesharing. The researchers concluded that there is not enough interest in ARMS to justify its cost of operation.

The modem service was found to have significant usage (approximately 400 uses per day). This component of the ATIS system did not have the multi-modal component at the time of evaluation and instead only reported Caltrans congestion information. Usage was found to be higher in the mornings and evenings, consistent with commuter trip planning.

Overall conclusions about the project were as follows:

- The management burden associated with this demonstration was a significant. The scope of future demonstrations ought to be no larger than is necessary to adequately test a product or concept.
- Data requirements and management should be established early in the project. Automated data systems generate huge amounts of data. It is essential that summary data requirements be established in the project planning phase.
- Structure and timing of the evaluation should allow for the analysis of the travel impacts of the technology being evaluated. Short term demonstrations do not allow for evaluation of whether the ATIS initiatives are having their desired impact on traveler behavior.

Title: Operations at Regional Travel Information Centers: The Case of the TravInfo Field Operational Test – Final Results

**Authors: Mark A. Miller
Dimitri Loukakos**

Date: September 2000

Description of the Research

TravInfo is a regional traveler information system in the San Francisco Bay Area. It was a Field Operational Test (FOT) over a two-year period from September 1996 to September 1998 with funding from the Federal Highway Administration and the California Department of Transportation (Caltrans). The goal of TravInfo was to broadly disseminate accurate, comprehensive, timely, and reliable information on traffic conditions and multi-modal travel options to the public in the Bay Area. Information was disseminated directly to users via a telephone service and indirectly through information service providers who in turn disseminated the information.

The purpose of this project was to evaluate the operation of TravInfo's Traveler Information Center (TIC) with a focus on its operation by a private sector contractor. This evaluation was performed using various data sources from field observations and field measurements. The evaluation examined TIC effectiveness in terms of system reliability, the communications interface, and operator work setting and performance. The evaluation also examined TIC effectiveness in from an organizational perspective.

Conclusion of the Research

Inductive loop sensor data provided by the Caltrans Traffic Operations System were initially expected to be a major source of data for TravInfo. However, they were not used as extensively as anticipated. Instead, the most significant data source was the California Highway Patrol Computer-Aided Dispatch incident reports. These reports had to be manually entered into the TravInfo system by TIC operators. This process was both time-consuming and difficult to perform along with the other duties of the TIC operators. Automating the data entry process, which was part of the TIC system's original specifications, could speed operators' response times and increase the number of incidents they could process, although it is likely that operators would still need to intervene in the interpretation of some incident reports.

The TravInfo system is not as efficient as originally envisioned because of its heavier-than expected dependence on the manual performance of jobs by the TIC operators. TravInfo needs an automated system that is flexible enough to keep up with rapidly advancing technologies. As the system becomes more automated, the organizational structure of the TIC can become more efficient than it was during the field operational test. The TIC staff should be consulted for ways to improve the system as they are the ones who will ultimately work with it.

**Locator Number:
UCB-ITS-PWP-2000-20**

Title: TravInfo Evaluation: Institutional Element Phase 1 Results
Author: Randolph Hall, Y. B. Yim, Brian Pfeifle, Stein Weissenberger

UCB-ITS-PWP-95-01 (1995)

Problem and Method

TravInfo is a field operational test (FOT) of advanced traveler information systems (ATIS) for the San Francisco Bay Area. TravInfo aims to develop a multi-modal traveler information system for the San Francisco Bay Area, combining public and private sector talents.

This report outlines the TravInfo organizational structure, TravInfo goals, and roles of the participating organizations. This report also identifies institutional, legal, and technical barriers that present challenges to the fulfillment of the TravInfo objectives.

As part of this study, a wave of institutional interviews was conducted as part of the TravInfo evaluation. Twenty-one core participants were interviewed, including most of the Management Board and Steering Committee members, and most of the project staff. The results of these interviews provide an insight into the effectiveness of TravInfo and areas in which it can be improved.

Findings

From the interviews, it is clear that TravInfo has been quite effective in achieving one of its foremost goals: developing partnership between the public and private sectors.

At the same time, there appears to be considerable opportunity to improve the organization's efficiency. In particular, interviewee responses indicated some confusion about the roles of the various committees within the TravInfo project.

Interviewees were nearly unanimous that TravInfo is working toward the right goals, though many felt the project is overly ambitious.

Title: TravInfo Evaluation: Value Added Reseller (VAR) Study

Author: Dimitri Loukakos, Randolph Hall, Stein Weissenberger, Y. B. Yim

UCB-ITS-PWP-96-13 (1996)

Problem and Method

TravInfo is a field operational test (FOT) of advanced traveler information systems (ATIS) for the San Francisco Bay Area. TravInfo aims to develop a multi-modal traveler information system for the San Francisco Bay Area, combining public and private sector talents. Private sector participation includes "Value-Added Resellers" (VARs) who will refine information generated by the TravInfo system and broadly disseminate it to end users.

Managers, responsible for products and/or marketing, at 17 of 20 registered VAR participants along with 16 non-registered VARs were interviewed in the fall of 1995.

Findings

From the interviews, it is clear that TravInfo has been effective in stimulating VAR business opportunities, as well as in resolving the issue of potential competition with the private sector.

At the same time, the results of the interviews indicate that the future is uncertain. VAR participation in TravInfo will depend on their satisfaction with TravInfo data and operations. Furthermore, many of the participants are involved primarily to test the ATIS market and their continued participation will depend on the size of the market they find for ATIS products and services.

Title: TravInfo Evaluation: Institutional Element Phase 2 Results
Author: Randolph Hall, Dimitri Loukakos, Stein Weissenberger, Y. B. Yim

UCB-ITS-PWP-96-14 (1996)

Problem and Method

TravInfo is a field operational test (FOT) of advanced traveler information systems (ATIS) for the San Francisco Bay Area. TravInfo aims to develop a multi-modal traveler information system for the San Francisco Bay Area, combining public and private sector talents.

This report presents the results of year two of the institutional evaluation, which is part of the overall TravInfo evaluation. Nineteen core participants were interviewed, including all of the Management Board and most of the Steering Committee members and project staff. Separately, twenty Advisory Committee members were interviewed.

Findings

During first year of the FOT, organizational issues, principally defining the roles of the various committees and working groups within the TravInfo project, were paramount. The first year evaluation of TravInfo is presented in UCB-ITS-PWP-95-01.

The second year of the TravInfo project, reviewed in this paper, was dominated by implementation issues, chief among which were: resolution of public/private controversies in the design of TravInfo and the attempt to ensure the completion of the Caltrans Traffic Operations System (TOS) for meeting the TravInfo schedule.

Based on the interviews and observations conducted as part of this study, it is clear that the TravInfo organization has been effective at resolving these issues.

The Steering and Advisory Committees also provided an open forum for resolving issues in the TravInfo organization. In its first year, the Steering Committee was criticized for inefficiency and lack of focus. In the second year, it appears that the Steering Committee has found its focus and is resolving public/private sector issues by establishing a clear and balanced vision for the public and private sectors.

The delay of the Traffic Operations System, one of the implementation goals of TravInfo, was affected by a rigid procurement structure that did not allow for quick resolution of problems facing the TOS implementation. In addition, concerns were voiced by some interviewees regarding the data coverage provided by the TOS. However, TravInfo developed a multi-tiered strategy to provide data to compensate for the limitations of the TOS, and Caltrans will continue to expand the data coverage of the TOS during the TravInfo FOT effort.

Title: TravInfo Evaluation (Technology Element)

Traveler Information Center (TIC) Study (September 1996–June 1997)

Authors: Mark A. Miller, Dimitri Loukakos

UCB-ITS-PWP-98-7 (1998)

Problems and Findings

TravInfo is a field operational test (FOT) of advanced traveler information systems (ATIS) for the San Francisco Bay Area. The project seeks to compile, integrate, and broadly distribute timely and accurate multi-modal traveler information through commercial products and services. The evaluation of the TravInfo system consists of four major elements: (1) institutional, (2) technology, (3) traveler response, and (4) network performance. This paper focused on the technology component of the TravInfo project.

The technology evaluation covered in this paper consists of four elements: systems reliability, communications interface, operator interface, and response time analysis.

System Reliability

Issues in the primarily software, TransView, were the major factor contributing to a loss in reliability of the TravInfo system. The system reliability problems encountered were found to be of serious or critical nature.

Communications Interface

The communications interface is divided into two distinct groups: Traveler Advisory Telephone System (TATS), utilized primarily by the traveling public, and LDS (Landline Data System), utilized by the private sector for electronic traveler information devices.

The demand for access to the TravInfo communications interface was consistently within capacity for the period of this study. TATS access was fairly constant, with some increase in usage due to media reports about the system. TATS usage is disproportionately high for Oakland residents because AC Transit uses the TATS line as a customer information service. However, total usage, even for the disproportionately heavy Oakland region, was well within capacity.

The LDS system experienced problems due to some system reliability issues – problems with the update of data originating in the software led to LDS users (private sector users of the travel data) having to download data several times.

This report goes on to summarize call volume, LDS logons, user preferences by region, and other uses of the TravInfo system. The report also summarizes how certain data are incorporated into the TranInfo system. Finally, “choke points” in the flow and delivery of information in the TravInfo system are identified.

Conclusion

The researchers conclude that the TravInfo system successfully collects and integrates traveler information with the exception of problems encountered with the accuracy and reliability of loop detector data. However, the system falls far short of reaching the

number of intended TATS users, even with an accompanying media campaign to make potential users aware of the TravInfo system.

Use of the TravInfo system was also far short of expectation for the private sector LDS participants. This is concluded to be a result of unreliable loop detector data, which the private sector uses to assess congestion and suggest alternate travel routes.

Approximately 85% of the LDS data accessed was speed and congestion data provided by loop detectors, 75% of which had critical data accuracy problems.

Title: TravInfo Evaluation (Technology Element) Traveler Information Center (TIC) Study: System Reliability and Communications Interface (9/96–12/97)
Author: Mark Miller, Dimitri Loukakos

UCB-ITS-PWP-98-21 (1998)

Problem and Method

TravInfo is a field operational test (FOT) of advanced traveler information systems (ATIS) for the San Francisco Bay Area. The project seeks to compile, integrate, and broadly distribute timely and accurate multi-modal traveler information through commercial products and services. The public sector component centers on the Traveler Information Center (TIC), which collects and integrates both static and dynamic traveler information.

This study focused on the technology component of the TravInfo project. The technology evaluation covered in this paper consists of four elements: systems reliability, communications interface, operator interface, and response time analysis. This study focused particularly on system reliability and the communications interface during the period July through December 1997. Study results from the period September 1996 to June 1997 are reported in UCB-ITS-PWP-98-7.

The communications interface is divided into two distinct groups: Traveler Advisory Telephone System (TATS), utilized primarily by the traveling public to access traffic and transit information, and LDS (Landline Data System), utilized primarily by the private sector to download traffic information to add value to it and re-sell to the public.

Findings

During the period between July and December 1997, 38 new or non-recurring internal problems were experienced at the TIC. These problems were quite different than those experienced during the period September 1996 to June 1997. These problems were classified as critical, major, and minor with a frequency of occurrence of 39.5, 44.7, and 15.8 percent, respectively.

With the exception of the month of September 1997 during which the Bay Area Rapid Transit (BART) system workers were on strike causing an initial surge in call volume, the volume of TATS has remained fairly constant (50,000 to 60,000 calls per month). Call volume was at about 3 percent of the TATS system capacity except during the first two days of the BART strike when it rose to as high as 75 percent during peak hours.

LDS usage was fairly limited and well below capacity during the period of study. Access by the private sector participants is essentially limited to three providers, one of which accounts for approximately 90 percent of the total data accessed. The TravInfo system has not yet stimulated development of publicly available ATIS products. Troubling for TravInfo is the fact that between 55 and 85 percent of the data accessed is speed and congestion data, which relies on loop detector data, 75 percent of which have critical accuracy problems.

Usage of TravInfo has fallen well short of that envisioned in the general goals set out for the TravInfo Field Operational Test. Collection of data has been satisfactory, with the exception of serious problems in loop detector data quality. However, dissemination of the data, as reflected in TATS usage, fell far short of the study's goal.

Title: TravInfo Evaluation: The Target Study Phase 1 Results

Author: Ronald Koo, Youngbin Yim, Randolph Hall

UCB-ITS-PWP-98-24 (1998)

Problem and Method

TravInfo is a federally funded Field Operational Test (FOT) of an open-access traveler information system for the San Francisco Bay Area. In operation since September 1996, TravInfo Traveler Advisory Telephone System (TATS) disseminates real-time traffic information and multi-modal travel options to Bay Area travelers through a landline telephone system.

This research examined commuter response to traffic information on incidents along US-101 south of San Francisco. The purpose of the Target Study was to assess the impact of TravInfo on a selected corridor in the presence of incidents under which TravInfo impacts/benefits are likely to be greatest. A panel survey approach was chosen to assess changes in travel behavior over time. A panel was created of 563 southbound and 526 northbound commuters whose primary commute route includes the selected US-101 freeway segment during morning peak hours between 6–10 a.m.

Findings

During the study, two significant incidents occurred in the study area: a multiple-vehicle injury accident on southbound US-101 in San Mateo blocked the left two of four lanes causing a backup of approximately 5 miles. Within three weeks of the southbound accident, a jack-knifed semi in South San Francisco blocked the number 5 lane and South Airport Boulevard on-ramp. Both accidents took over 30 minutes to clear and had significant effects on traffic conditions.

Approximately 15 percent of the total sample population actually modified their travel on the morning of each respective incident. About half of the participants recall hearing about the incidents, mostly from commercial radio broadcast. Approximately one third modified their travel behavior on the morning of the incidents. Over two thirds of the participants reported that they encountered congestion on the morning of the incident. Most survey participants (91.5 percent of southbound and 84.6 percent of northbound) were unfamiliar with the TravInfo TATS service.

The results of the survey suggest that individual incidents do not affect traveler behavior significantly. Even though a fair portion of commuters were aware of traffic problems on the mornings of the incidents, relatively few actually modified their trip. It does not seem to be the case that commuters do not care about being slowed down by traffic congestion, rather, the likely explanation for the lack of response to incident information is that commuters generally do not believe that changing their travel plans, in particular taking an alternate route, will result in shorter travel times.

Title: TravInfo Evaluation Traveler Response Element: TravInfo 817-1717 Caller Study Phase 1 Results
Author: Youngbin Yim, Randolph Hall, Ronald Koo, Mark A. Miller

UCB-ITS-PWP-98-25 (1998)

Problem and Method

TravInfo is a federally funded Field Operational Test (FOT) of an open-access traveler information system for the San Francisco Bay Area. In operation since September 1996, TravInfo Traveler Advisory Telephone System (TATS) disseminates real-time traffic information and multi-modal travel options to Bay Area travelers through a landline telephone system.

The purpose of this research was to measure the effectiveness of TATS in helping callers make informed travel decisions. The initial survey was conducted seven months after TravInfo began operation. The effectiveness of TATS was measured by the satisfaction of callers with the service, the impact on their travel behavior, and the benefits perceived by them. TATS callers made use of either traffic information or transit information services.

Findings

Key findings of the research are:

An overwhelming majority of the callers were satisfied with the information they obtained from TATS and they mostly (60.4 percent) found the TATS information more useful, reliable, and accurate than radio. Nearly half (46.7 percent) of callers who learned about traffic problems from TATS changed their travel behavior.

TATS has attracted a segment of the driving population which rarely relies on radio or television reports in making travel decisions. Nearly half of the traffic information callers (48.3 percent) seldom or never listen to radio reports. The majority of the traffic information callers (86.2 percent) were repeat users; 51.3 percent of transit information callers were repeat users.

Most participants (98.3 percent of the traffic information survey group and 88 percent of the transit information survey group) said they would use TATS in the future.

Approximately one third (30.5 percent) of the traffic information survey group requested information via cellular phone *en route*. TATS was found to be better utilized than the traffic information systems offered by cellular providers (GTE Mobilnet, Cellular One).

Title: TravInfo Evaluation (Technology Element) Traveler Information Center (TIC) Study: Operator Interface Component-Phase IV: Institutional Analysis

Author: Mark A. Miller, Dimitri Loukakos

UCB-ITS-PWP-98-30 (1998)

Problem and Method

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). 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. The public sector component centers on the Traveler Information Center (TIC), which collects and integrates both static and dynamic traveler information. This study focuses on the operator interface element of the TIC.

This study considers the role of the human operator in the flow of information through the TIC, the operators' tasks and responsibilities, and the operators' physical environment. The evaluation was conducted through an analysis of responses to questions during in-person interviews of TIC operators, supervisors, and management.

Previous reports which considered the operator interface of the TIC are:UCB-ITS-PWP-98-7, and UCB-ITS-PWP-98-22

Findings

Overwhelmingly, all survey respondents felt that the TIC was effective in achieving its goal of providing timely, complete, user-friendly, and accurate information to the public and private sectors, given the constraints and available resources. The barriers to meeting the goal of the TIC included:

- uncertain availability of reliable and accurate automated data
- delays related to ongoing contractual issues between the Metropolitan Transportation Commission and the system developer, and
- a computer interface that both did not adequately meet TIC operator needs and responsibilities and did not have the level of automation that was originally envisioned.

Some problems were found that negatively impacted operator effectiveness which could have been addressed earlier and more completely by TIC operations. These included lack of operator quality-control measures until the FOT was 75 percent complete and insufficiently frequent communication among the TIC staff on a range of subjects.

However, areas of success were also found which contributed to operational effectiveness. These included overall quality of staff in terms of skills, attitude, and responsiveness to emergency conditions; inter-organizational cooperation; and quality of some of the data sources.

Title: TravInfo Evaluation (Technology Element) Traveler Information Center (TIC) Study: Operator Interface Analysis-Phase III
Author: Mark Miller, Dimitri Loukakos

UCB-ITS-PWP-98-22 (1998)

Problem and Method

TravInfo is a field operational test (FOT) of advanced traveler information systems (ATIS) for the San Francisco Bay Area. The project seeks to compile, integrate, and broadly distribute timely and accurate multi-modal traveler information through commercial products and services. The public sector component centers on the Traveler Information Center (TIC), which collects and integrates both static and dynamic traveler information.

This study examines the technology component of the TravInfo project, and more specifically, the role of the operator in the flow of information through the TIC, the operators' tasks and responsibilities and the operators' physical environment.

This report focuses on the physical environment of the TIC operations including the TIC computer interface and the physical surroundings of the operators' workstation environment. The work was accomplished by analyzing the TIC operator interface design and by surveying operators. This study builds on work reported in UCB-ITS-PWP-98-7.

Findings

The first part of this evaluation considered the operator interface. Overall, the operator interface was found to serve its general purpose of allowing operators to perform their data monitoring and entry tasks relatively quickly. However, the general computer interface was found to not support the tasks of the operators as much as it could. The chief problems were:

- Fill-in form interfaces appeared not to be designed with consideration for operator tasks
- Some of the most commonly used windows had several shortcomings
- The two most important menus were not ordered in a logical manner
- There was no logical grouping of related fill-in form interfaces, and moreover, there are ambiguous terms and non-mutually exclusive attributes within certain fields
- There was a lack of organization across all windows.

Other general areas of weakness in the operator interface included the following:

- User compatibility: There should have been more consideration of specific operator duties.
- Consistency: The fill-in form formatting is not always consistent among forms.
- Responsiveness: There is no feedback on the progress of system processing, and the system is often slow due to lack of processing power.

The second part of this evaluation considered the operators' working environment. A checklist was developed to identify operator environment characteristics which may help or hinder the TIC operators' job performance. These were:

- Illumination, noise levels, and climate control (e.g., heat, air conditioning, air quality)
- Visual display elements of the computer screen
- Keyboard characteristics
- Furniture
- Work surface
- Seating
- Accessories

The study found that only three changes would lead to a more productive work environment. These were: thermal and air quality, general layout of work surface, and cubicle height or sense of connectedness with other operators. All other characteristics were found to be generally acceptable to the operators.

Call Number: UCB-ITS-PWP-2000-2

Title: TravInfo Field Operational Test Institutional Evaluation Final Results

Authors: Youngbin Yim Elizabeth Deakin

Date February 2000

Problem

TravInfo is a regional traveler information system in the San Francisco Bay Area. The goal of TravInfo was to broadly disseminate accurate, comprehensive, timely, and reliable information on traffic conditions and multi-modal travel options to the public in the Bay Area through a public-private partnership.

The institutional evaluation of TravInfo was one of four test elements which comprised the TravInfo Field Operational Test (FOT). The other elements were technology assessment, traveler response, and transportation network performance. The transportation network performance test was not performed because of the lack of traffic data to realistically measure the changes in traffic flow during the field test.

The institutional evaluation measured the performance of TranInfo's public-private partnership at the organizational level. It examined how well TravInfo's institutional organization worked to achieve its objectives, what benefits the project partners were able to gain from the field test, and what institutional challenges they had to overcome.

Findings

TravInfo's organizational structure was unique, with a high degree of openness in the public-private partnership. TravInfo meetings were conducted as open forums to encourage the entrepreneurial participation of the advanced traveler information industry as well as the active participation of local public agencies. The ultimate responsibility for TravInfo lay with the public sector in the form of the Management Board, the members of which came from regional transportation agencies.

The TravInfo organization was effective in appropriately utilizing public and private sector talent. By placing the Metropolitan Transportation Commission, which is the transportation planning organization for the nine-county Bay Area, in a leadership role, the project recognized the importance of consensus building.

The project helped foster constructive relationships among the projects principal public participants. The project also fostered alliances among many of the private participants.

The project also encountered many challenges. Two major setbacks were insufficient coverage of the Bay Area transportation network by the data supplied to the TravInfo Traveler Information Center (TIC) and an inefficient system design that required the TIC to be considerably more dependent on manual operations than expected.

Title: TravInfo Field Operational Test Evaluation: Target Study Final Results
Authors: Ronald Koo Youngbin Yim
Date: March 2000

Problem

TravInfo is a regional traveler information system in the San Francisco Bay Area. The goal of TravInfo was to broadly disseminate accurate, comprehensive, timely, and reliable information on traffic conditions and multi-modal travel options to the public in the Bay Area through a public-private partnership.

The TravInfo Field Operational Test (FOT) was comprised of four elements: institutional evaluation, technology assessment, traveler response, and transportation network performance. The traveler response evaluation had four coordinated studies:

1. Broad Area,
2. Target,
3. TravInfo Traveler Advisory Telephone Information System (TATS), and
4. Information Service Provider (ISP) Customer Studies.

This paper presents the final results of the Target Study, a case study of commuter response to traffic information on incidents along US-101 south of San Francisco. This corridor was selected because it offers several alternate roadways and mass-transit options for commuters who utilize it.

The Target Study objectives are to understand the extent to which incident information influences travel decisions, to measure the effects of incident information on overall travel patterns, and to assess the benefits of incident reports to travelers.

Findings

Within three to four days following a major traffic incident along the highway segment, a sample of commuters who used the highway during the time of the resulting congestion was interviewed. At the time of publication, four such incidents had been covered.

Results included the following:

Generally, commuters have the opportunity to obtain traffic information both before departure and en route. However, those who obtain information don't necessarily use it, and those who endure bad traffic one day may not be affected enough by it to obtain more information the next day.

Of those respondents who actually encountered traffic on US-101, 64.8% said that they were no more likely to obtain traffic information prior to departure, and 54% said that they were no more likely to obtain traffic information after departure.

Of those who obtained traffic information, 36.8% thought the information helped them save time and 9% thought the information made them waste time. Over half (52.3%) were unsure.

Of those who said the information they received made them waste time, half (50.0%) said they were nonetheless more likely to obtain traffic information during their commute in the future. Of those who said the information saved time, 66% said they were nonetheless more likely to obtain traffic information during their commute in the future. Of those who were unsure of whether the information saved them time, 63% said they were no more likely to obtain traffic information en route in the future.

Of travelers who obtained traffic information, only 17% changed their departure time, 9% changed their mode of travel, and 24% took an alternate route.

Locator Number:
UCB-ITS-PWP-2000-3

Title: TravInfo Field Operational Test Evaluation: Information Service Providers Customer Survey

Authors: Youngbin Yim

Date: May 2000

Description of the Research

TravInfo is a regional traveler information system in the San Francisco Bay Area. The goal of TravInfo was to broadly disseminate accurate, comprehensive, timely, and reliable information on traffic conditions and multi-modal travel options to the public in the Bay Area through a public-private partnership.

As part of the TravInfo Field Operation Test (FOT), a regional Traffic Information Center (TIC) was created. Since September 1996, the center has been disseminating traveler information to the public through the Traveler Advisory Telephone System (TATS) and to information service providers (ISPs). Presently, three ISPs rely exclusively on TravInfo for travel data which they disseminate through Web sites.

Three privately offered traffic Web sites were evaluated from the user perspective. These Web sites disseminate traffic information on major freeways and the transit schedules of 27 Bay Area transit services. Though all three services receive the same data from the TIC, they all display the information differently.

Conclusion of the Research

The key finding of the survey of users of the three traffic Web sites considered is that Web site service may significantly influence travel behavior. Of those users who received incident reports, 80% modified their trips. This trend is considerably different from the studies of radio/television listeners or telephone information callers. 25% of those who obtained pre-trip incident information from radio or television modified their trips; 50% of those who obtained pre-trip traffic information from TravInfo TATS modified their trips. Possible reasons include:

- § People who retrieve Web site information have more travel options than those who obtain information from other sources.
- § The Web site information is more understandable than the information disseminated through other media.
- § People perceived that the quality of the Web site information is better than other sources in terms of its usefulness and reliability, although both the TravInfo telephone system and Web sites disseminate the similar information to users.
- § Web site users are more receptive to traffic reports than are those who use other information sources.

These reasons are somewhat conjectural and should be validated. However, it is important to note that nearly half of the Web site users believe that their decision to change travel plans on the basis of the Web site information resulted in substantial time savings.

Most of the Web site users are commuters with full-time jobs. Because of their employment status (high income professionals or managers), their arrival time at work is flexible and they have a varying degree of travel options, either by taking alternate routes or by changing their departure time. Most Web site customers are solo drivers whose primary commute is the freeway, which is understandable because the Web site service provides primarily freeway traffic conditions.

**Locator Number:
UCB-ITS-PWP-2000-5**

**Title: TravInfo Evaluation (Technology Element) Traveler Information Center (TIC) Study:
Operator Response Time Analysis**

**Authors: Mark A. Miller
Dimitri Loukakos**

Date: August 2000

Description of the Research

TravInfo is an advanced traveler information system for the San Francisco Bay Area that began operation in September 1996 under a public/private partnership seeking to compile, integrate, and broadly disseminate timely and accurate multi-modal traveler information through commercial products and services. The public sector component centers on the Traveler Information Center (TIC), TravInfo's information gathering, processing, and dissemination hub.

During the Field Operational Test (FOT) of TravInfo, the TIC was evaluated with respect to system reliability, the communications interface, the operator interface, and operator response time. This report documents the analysis of operator response time.

The report focused on incident information generated by the California Highway Patrol's Computer-Aided Dispatch (CAD) system. Operator response time is defined as the time elapsed once information is collected from CAD until it is disseminated to the public via the Travelers Advisory Telephone System (TATS).

Conclusion of the Research

Operator response time is a significant part of TravInfo evaluation because the TIC operations are substantially less automated than originally envisioned and thus depend heavily on operator performance.

Operator response times remained stable during the FOT with an overall average operator response time of approximately 11 minutes, though there were significant response time differences among the operators. The findings indicate that improvement is needed in both overall operator work efficiency and operator response time.

Once TravInfo transitions from its FOT phase and enters its more permanent phase, operations will become substantially more automated. This should have a significant impact on reducing operator response times as well as increasing overall operator productivity.

**Locator Number:
UCB-ITS-PWP-2000-9**

Title: TravInfo Evaluation: Traveler Response Element Broad Area Study: Phase 2 Results
Analysis of Wave-2 Survey

Authors: Y.B. Youngbin Yim

Date: January 2001

Problem Statement

TravInfo is a federally funded Field Operational Test (FOT) to deploy real-time traveler information in the San Francisco Bay Area. It aimed to develop a multi-modal traveler information system for the San Francisco Bay Area, combining public and private sector talents. The Broad Area Study was part of the TravInfo FOT evaluation. It addressed issues on how travelers obtain traffic/transit information and how the information influences travel behavior. Two waves of telephone surveys of Bay Area households were conducted, one in 1995 eight months prior to the start of the FOT, and one in 1998 three months after completion of the FOT.

The purposes of the Broad Area Study were to establish a baseline traveler behavior of Bay Area households based on traveler information and to assess the impact of traveler information on the entire Bay Area traveling population.

Findings

The surveys showed that there was little change in the way people obtain traveler information as a result of TravInfo. However, based on traffic information, more people modified their travel behavior in 1998 (after completion of the FOT) than did in 1995 (before the start of the FOT). As shown in the 1995 survey, most people changed departure time or took an alternate route. Mode shift (opting for a different method of transportation than usual) was fairly negligible in both surveys.

Another key finding was that two thirds of Bay Area travelers acquire traffic information at least when they expect a traffic problem; the vast majority of them listen to radio traffic reports, more frequently en route than do before leaving home or leaving for home. Regular users and occasional users of traveler information are evenly divided.

The 1998 survey showed that approximately 15 percent of Bay Area motorists modified their travel behavior each day; of those who learned about traffic problems on their planned routes from the radio, about 25 percent changed their travel behavior. In most cases, people tended to take an alternate route or change their departure time.

The surveys also showed that mode choice is closely related to auto ownership, income, gender, commute, miles driven, travel distance, and age group. Auto ownership, being male, higher number of miles driven per year, and higher disposable income all were associated with less likelihood to share rides. Being female, having a regular commute, longer travel distance, and being in the younger (18-24) or older (45-55) age brackets all were associated with higher likelihood to share rides.

Locator Number:

UCB-ITS-PWP-2001-4

Call Number: UCB-ITS-PWP-2001-5

Title: TravInfo Evaluation: Traveler Response Element Willingness to Pay for Traveler Information: Analysis of Wave 2 Broad Area Survey

Authors: Louis Wolinetz, Asad J. Khattak, Y.B. Youngbin Yim
Date: January 2001

Problem

TravInfo is a federally funded Field Operational Test (FOT) to deploy real-time traveler information in the San Francisco Bay Area.

Real-time traveler information is presently available free of charge in many US urban areas. Commercial radio/television stations, highway advisory radio, changeable message signs, in-vehicle devices, and the Internet all provide individuals with travel information. Substantial government resources are invested in the collection, processing, and dissemination of this information. The rationale is that information can help travelers make better decisions that ultimately reduce traffic congestion and pollution. However, the personal benefits of certain types of high quality travel information may motivate individuals to pay for that information.

The Broad Area study is part of the TravInfo FOT evaluation. For the Broad Area study, two household surveys were conducted, one in November 1995, eight months prior to the start of the TravInfo FOT, and the other one in November 1998, three months after the FOT was completed. This research examines the willingness of users to pay for the traveler information offered by TravInfo. The data utilized are from the second survey (1000 San Francisco Bay Area Residents), conducted in 1998.

The data were collected through a computer-assisted telephone interview in which respondents were chosen through random digit dialing. The study analyzes respondents' willingness to pay for a hypothetical ATIS (Advanced Traveler Information System) that provides: 1) Automatic notification of unexpected congestion on respondents' usual route, 2) Estimated time of delay from this congestion, 3) Automatic alternate route planning around this congestion, and 4) Estimated travel time on respondents' usual route and any planned alternate routes.

Findings

Of the original 1000 respondents, 342 did not receive transit or traffic reports from any source and so were not asked for their willingness to pay for ATIS. Of the remaining 658 respondents, 73% would be willing to pay for ATIS, 22% would not, and 5.2% weren't sure or didn't know.

Many respondents were not entirely averse to paying for quality travel information. Almost all "information seeking" respondents (97%) acknowledged a willingness to pay at least some fee for ATIS. The majority (77%) preferred to pay on a per-call basis as opposed to a monthly fee. 53% were willing to pay up to one dollar per call; 38% were willing to pay \$7 per month.

Respondents indicated that the most desirable information options were constant updates, alternate route information, in-car computer information, and delay and route time information.

It is still not clear whether ATIS user fees could cover the costs of such a system. It is also unclear whether public provision through taxpayer dollars is the best way to produce ATIS, given that the goals of decreasing congestion and improving mobility are in the public interest for economic and air quality reasons. Given that survey respondents indicate some willingness to pay a fee, partial funding of ATIS could be possible for appropriately customized high-quality content. More research is needed, particularly in the form of ATIS demonstration projects that do charge a fee so that real data can be generated rather than that generated by preference surveys.

Call Number: UCB-ITS-PWP-2001-7

Title: TravInfo Evaluation: Traveler Response Element; TravInfo 817-1717 Caller Study; Phase 2 Results

Authors: Ronald Koo, Y. B. Youngbin Kim

Date: February 2001

Problem

TravInfo is a Field Operational Test (FOT) sponsored by the Federal Highway Administration (FHWA) of the US Department of Transportation and the California Department of Transportation (Caltrans). Its objective is to provide benefits to San Francisco Bay Area travelers and to stimulate the deployment of privately offered traveler information products and services. In operation since September 1996, TravInfo disseminates free, current traffic information and multi-modal travel options to Bay Area travelers through a landline telephone system called TravInfo Traveler Advisory Telephone System (TATS) and through the Internet via Information Service Providers. As part of the TravInfo FOT evaluation project, two surveys of the TravInfo TATS callers were conducted, the first survey in April 1997 and the second survey in April 1999. This paper reports the findings of the second survey.

The purpose of the first TravInfo TATS caller survey was to establish a baseline profile of the callers with respect to their call and travel behavior. The purpose of the second survey was to assess the changes in callers' behavior and to measure the effectiveness of TATS in helping callers make informed travel decisions. The first survey was conducted seven months after TravInfo began in operation and the second survey was conducted seven months after the field test was concluded. The effectiveness of the TravInfo telephone system was measured by the satisfaction of callers with the TravInfo TATS service, the impact on their travel behavior, and the benefits perceived by them.

Findings

The results of the second survey are quite similar to those of the first survey. This may be due to the fact that during the two years between surveys, not much behavioral change could take place. However, one noticeable change was found: in the second survey; greater number of calls were made from a vehicle via cellular phones en route (46.8% in the second survey versus 31.5% in the first survey) among callers seeking traffic information. The other noticeable change was mode shift: it appeared that more people switched their mode from personal vehicle to public transit in the second survey. However, the sample size is too small to make any definitive conclusion.

Other important findings include:

In the first and second surveys, an overwhelming majority of the callers in the first and second surveys were satisfied with the information they obtained from TravInfo 817-1717. In both surveys, callers found that TravInfo TATS traffic information was more useful, reliable and accurate than radio or television reports. Both surveys showed that about half of the TATS traffic information callers changed their travel behavior as a result of TravInfo TATS information regarding a traffic problem. However, the effects of the TravInfo TATS service on mode shifts was minor even though three times as many people switched to public transit from personal vehicle when they learned of traffic congestion. The second survey also indicated that TravInfo TATS has been effective in providing quality information and in attaining a high level of customer satisfaction although its customer base has not increased significantly. As with the first survey, the second survey showed that TATS has attracted a segment of the driving population that rarely relies on traffic reports in making travel decisions and seldom or never listen to radio traffic reports. Most participants in the transit survey group said they would use TATS in the future because of its easy access to information via a single telephone number while the traffic survey group said they would use it again and recommend it to others because of its most current traffic information pertaining to their own trip. Transit information callers are interested in the availability of the service and service schedules while traffic information callers are interested in getting traffic conditions to avoid congestion. Therefore, very few calls were rerouted from traffic calls to transit calls or visa versa. However, it was apparent that the transit survey group favored TravInfo TATS having a single phone number for getting all travel related information.

Video

Title: Advanced Image Sensing Methods for Traffic Surveillance and Detection
Author: Art MacCarley (California Polytechnic State University, San Luis Obispo)

UCB-ITS-PRR-99-11 (1999)

Problem and Method

This study sought to assess advanced imaging technologies for application to roadway surveillance and detection. A major motivation for this study was the possibility of improved effectiveness under foggy or dusty conditions by using wavelengths longer than those of the visible spectrum.

Current electronic imaging methods used to detect vehicles on roadways utilize conventional video equipment which must have adequate lighting, whether natural or artificial, and fairly clear atmospheric conditions. During times of low light or during smoky, dusty, or foggy atmospheric conditions, these systems may be inadequate. Yet, it is in these conditions of low visibility that the greatest need for traffic detection may exist in order to advise motorists of impending dangerous traffic situations.

This project studied several alternatives to visible spectrum imaging technology which have superior ability to operate in conditions of low light or less than ideal atmospheric conditions. The most promising technologies are *infrared (IR) sensitive cameras* and *passive millimeter-wave radiometric imaging*.

In order to use these new technologies, computer vision applications were developed and used to compare videotaped or digitally-stored imagery from field work using these systems. The concept of using more than one of these technologies simultaneously was also evaluated.

Findings

The non-visible spectrum imaging technologies evaluated in this study both provide advantages for detection in low light and low visibility situations. However, the cost of these systems is currently very high, making their implementation unlikely for most situations. However, certain situations were identified for which non-visible spectrum imaging technologies may be good candidates:

- § Roadways characterized by frequent, dense fog, smoke, or dust in combination with recurrent hazardous traffic patterns, where surveillance could reduce traffic incidents.
- § Situations in which the temperature information provided by non-visible spectrum imaging is useful, such as for detection of overheated truck brakes.
- § Machine vision applications in which the shadow and glare reflection features of IR imaging are required for proper detection or measurement.

**Title: Anaheim Advanced Traffic Control System Field Operation Test Task A:
Evaluation of SCOOT Performance**

**Authors: James E. Moore, II, R. Jayakrishnan, M.G. McNally,
C. Arthur MacCarley**

UCB-ITS-PRR-99-26 (1999)

Problem

The city of Anaheim, California, implemented SCOOT (Split, Cycle, and Offset Optimizer Technique) as part of a larger Field Operational Test which included several other related technologies. This part of the FOT was meant to evaluate SCOOT, which controls systems of signals rather than just isolated intersections, in terms of the following issues: its limited implementation as an option for Anaheim traffic controllers, the development of operational policies, and the evaluation of its operational effectiveness.

Evaluation Task A1 assessed the value of existing loop detectors for SCOOT (the detectors were already in place, but closer to intersections than SCOOT is designed to use them), and assess the quality of SCOOT's internal representation of traffic flow. We did this by comparing SCOOT's performance to videotapes of actual conditions at intersections.

Evaluation Task A2 assessed the performance of traffic under SCOOT in terms of delay. We posted observation teams at intersections to measure delay and used floating cars to measure running, stopped, and total travel time, both before and after the implementation of SCOOT, during PM peak and evening off-peak hours, and for special event and nonevent traffic.

Findings and Recommendations

SCOOT successfully models traffic conditions, but there is room for improvement. In general, SCOOT performed better off peak, for special events at smaller-volume intersections, and very well at specific intersections with heavy traffic during special events.

When SCOOT performed worse than the baseline system, it did so rarely more than ten percent, and when it performed better, the difference was normally less than five percent. (It must be kept in mind that the existing traffic control system in Anaheim is considered state-of-the-art, and that SCOOT was using information from loop detectors in nonstandard locations.)

Delays between the two systems were generally comparable, and SCOOT caused no unacceptable delays or catastrophic problems.

**Title: Anaheim Advanced Traffic Control System Field Operational Test
Task B: Assessment of Institutional Issues**
**Authors: M.G. McNally, James E. Moore II, C. Arthur MacCarley,
R. Jayakrishnan**

UCB-ITS-PRR-99-27 (1999)

Problem

The city of Anaheim, California, was committed to implementing three new traffic control technologies: SCOOT (Split, Cycle, and Offset Optimizer Technique), a signal control system developed and used in Britain; a 1.5 Generation Control system whose purpose was to update baseline timing plans for SCOOT from the first generation system already in use, and a video traffic detection system to supplement loop detectors. The project required coordination between a number of agencies and partners, including the city of Anaheim, its systems contractor JHK/Transcore, SCOOT vendor Siemens, video system provider Odetics, Eagle Signal, Caltrans and the FHWA, who funded the Field Operational Test, and PATH.

The purpose of this report is to answer the question: through what structures and methods can the technologies be applied without being confounded or restricted by institutional issues?

Method

Information was gathered through direct observation of project participants, primarily at formal meetings, and detailed interviews of all key project participants. Interview questions covered project goals and objectives, implementation, funding, and working relationships. They addressed administrative, financial, leadership, personnel, legal, liability, and technical issues.

Findings

Numerous institutional problems were identified by participants, some of them interwoven with technical problems. Prime among them was a lack of leadership during a crucial period in the process of implementation, when the Principal Traffic Engineer left and was not replaced for 8 months. Although his duties were reassigned, the lack of someone in a leadership and advocacy role led to several delays, including a long delay before a contract was signed with SCOOT provider Siemens. This caused other delays, and could have ended the project altogether had Caltrans not allowed several extensions.

Other main findings include:

- A strong, proactive project manager is needed.
- Delays caused unanticipated costs that put the project over budget and did not leave enough time for proper training.
- Staff failed to plan adequately for training and maintenance needs, and they overestimated the operators' ability to switch to a new system.
- Unanticipated communication problems included differences between British and American standards, differences between software systems, integrating older systems with SCOOT, and a time difference that created difficulties communicating with the SCOOT vendor.
- Staff was not motivated to fully learn the new system because it wasn't clear to them whether the new system would actually be used after the FOT.
- Everyone interviewed had a different idea of what the FOT's goals were.

Title: Anaheim Advanced Traffic Control System Field Operational Test
Task C: Video Traffic Detection System
Author: C. Arthur MacCarley

UCB-ITS-PRR-98-32 (1998)

Problem

As one part of the City of Anaheim's Advanced Traffic Control Field Test (in partner with Caltrans, FHWA, and JHK Consulting), we conducted an evaluation of a video detection system marketed by Odetics, Inc. as a low-cost alternative to loop detectors. Using video cameras, the system detects vehicles at intersection approaches in "virtual detection windows" for signal phase actuation. It can be set up and calibrated in the field using only a TV monitor and a PC mouse; up to four detection window setups can be stored; and it can also be set up and calibrated remotely. The user interface is simple but effective.

Method

Nine vehicle detection event classes and six phase actuation event classes were defined for this test, with different lighting, weather, and traffic conditions. Videotapes acquired in the field were slowed down, analyzed, and compared to the system's detection results.

Findings

In general, we found that detection was good under ideal lighting and light traffic conditions, but degraded at higher traffic levels and low light, night, and rainy conditions.

65% of vehicles were detected properly, which is similar to the performance of loop detectors. 80.9% were detected adequately for the purpose of signal phase actuation, and there was an average 8.3% false and latch detection rate (latch detection happens when the system detects a vehicle but fails to notice when it has moved on).

The manufacturer, Odetics, says it has since replaced both hardware and software to address these problems, but we have not tested the new system.

Title: Data Utilization at California Transportation Management Centers
Authors Shirley Chan, Elbert Chang, Wei-Hua Lin, Alexander Skarbardonis

UCB-ITS-PRR-98-34 (1998)

Problem

This study examined the operations and functions performed at the Caltrans Transportation management Centers (TMC) with emphasis on the data sources, data processing and performance measures. Currently, much of the investment at the TMCs is in real-time traffic data collection primarily from inductive loop detectors. Much of this data is archived without further analysis due to the staff and budget limitations.

Method

The objective of this study is to evaluate how traffic data from several sources (loop detectors, closed circuit television, cellular phone calls for incidents, airborne reports, freeway service patrol logs, etc.) is currently acquired, processed, used, and stored by the Caltrans TMCs and to assess the potential to improve efficiency in data utilization. A literature review was performed to obtain information on the role and functions of TMCs in California and throughout the country. Additional information was gathered through interviews with the staff of ITS America, metropolitan planning organizations, as well as field visits to various Caltrans TMCs. The research then explored the role of information from new technologies and data processing algorithms in supporting TMC operations.

Findings

TMCs are an important means for managing the transportation system by collecting information in a centralized location and developing coordinated action plans. However, much of the investment is in real-time data collection and information dissemination. Little investment has been made for off-line applications (for example, to predict traffic growth). According to TMC staff members, much of the data is stored in the computer system or archived unanalyzed.

Most TMCs do not have the manpower available to ensure that loop detectors operate properly. Thus the data is often not reliable.

Data from video systems and emerging sources (such as electronic toll collection) need to be integrated into the database to assist in the data checking and verification.

New software and hardware will permit TMCs to have access to all types of traffic data from a single workstation. The new software being developed can potentially reduce the amount of human intervention needed for data analysis and collection and reporting of significant events that require TMC action.

Title: Definition and Measurement of Transportation System Performance
Authors: Stephen G. Ritchie and Carlos Sun (University of California, Irvine)

UCB-ITS-PRR-98-33 (1998)

Problem

The research sought to improve traffic incident detection and congestion monitoring for more accurate and reliable measurement of traffic system performance.

Method

This project presents a new set of advanced traffic surveillance techniques based on inductive loop detector (ILD) technology currently in widespread use. The emphasis is on applying new algorithms to inductive loop detector data to obtain vehicle “signatures.” By correlating the vehicle signature data from two sets of loop detectors, one “upstream” and one “downstream,” data can be obtained on the traffic characteristics of a section of the transportation network.

The research included development of a process for extracting vehicle feature vehicle pattern matching information from the inductive loop detector data so that information on traffic density and travel time data could be obtained. A video system was used to validate the inductive loop detector data and vehicle pattern matching accuracy.

Findings

The section-related data generated by the system developed for this research project provides a quantitative measure of traffic density, which can be used as a direct measure of traffic demand. Traffic density also gives a good idea of the “closeness” of vehicles, which can reveal the psychological comfort of drivers. For example, the stress level associated with free-flowing traffic is much less than that of “stop-and-go” traffic.

Title: Development and Testing of Field-Deployable Real-Time Laser-Based Non-Intrusive Detection System for Measurement of True Travel Time on the Highway

Author: Harry H. Cheng, et al, Integration Engineering Laboratory, Department of Mechanical and Aeronautical Engineering, UC Davis

TR-IEL-2000-101 (2000)

Problem

Reliable, real-time traffic speed information is invaluable for traffic planners. Current methods for measuring travel time do so by measuring speed at one or more points along a link and then extrapolating speed across the entire length of the link. Loops, radar, and video image processing all use extrapolation to deduct travel time. However, when traffic flow slows because of an accident, speed variations along any given link can be quite large. This is when accurate information for making routing decisions is most critical, and the uncertainties caused by extrapolation are magnified.

Vehicle-as-Probe (VAP) methods determine travel time by identifying vehicles at the start of the link and then re-identifying them at the end of the same link, giving true travel time as the time difference between the two. The cost of VAPs is quite high, however, requiring a large number of vehicle tags and tag readers to be effective.

It is possible to identify some distinguishing characteristic on a vehicle at the beginning of a link and then re-identify that same vehicle at the end of a link without the set-up costs of a VAP. If a characteristic can be found that separates cars into 100 possible classifications, a match between upstream and downstream vehicles can be made with high probability. Even more classifications would make the process even more accurate.

Method

This project developed a laser detection system that can directly and accurately determine origin and destination information for vehicles in the traffic stream non-intrusively and without violating privacy. It produces local vehicle speed, vehicle volume, and vehicle classifications, even under high flow conditions. Point-to-point travel time and incident detection can easily be determined.

This system can be mounted above the road, which allows it to be installed and maintained without tearing up the road or disrupting traffic. It operates on a simple “on/off” basis, requiring much less computation for vehicle detection than video methods. It also produces and senses its own signal, so it does not depend on time of day and weather conditions for accuracy (as do video detection systems). There are no moving parts, and power and bandwidth requirements are very low.

The system projects a laser onto the ground, and then collects the reflected light onto a photodiode array. A vehicle is detected when it passes under the beam, based on the absence of the reflected light. With two identical laser/sensor pairs placed close together,

it is possible to measure the speed of both the front and the rear of the vehicle as it triggers each sensor. The length of each vehicle is determined from the speed and the amount of time the vehicle spends under the detector.

Findings

We have built a field prototype detection system and tested it under real traffic conditions. Our test results verify that the principle of this system is technically sound and the software works in most cases. There are a few situations, such as stop-and-go traffic, where the detection of vehicle length does not work well.

We also found that the separating distance of the two laser-sensor detectors was too small in our test, which made the system detect different speeds for the front and the rear of vehicles. Also, the slowness of the analog signal contributed to the error. Both of these problems will be fixed in the next prototype, by putting the pairs farther apart and by using a faster digital signal.

Title: Dynamics in Behavioral Adaptation to a Transportation Innovation: A Case Study of Carlink—A Smart Carsharing System

Authors: Susan A. Shaheen

Date: December 1999

Description of the Research

Most trips in U.S. metropolitan regions are drive-alone car trips, an expensive and inefficient means of moving people. A more efficient system would allow drivers to share cars. Such a system is often less convenient for travelers, but convenience can be enhanced by deploying “smart” technologies in concert with shared-use vehicles and transit.

Using new survey research methods, this research examines CarLink, a smart carsharing service. The motivation for this research is to determine how the use of information and communication technologies can enhance flexibility and mobility—and what value travelers will place on these new transportation means.

Conclusion of the Research

This research is based on a longitudinal survey of responses to informational media conducted with San Francisco Bay Area residents in the summer of 1998. The survey results provide the attitudinal and belief data needed to evaluate dynamics in an individual’s learning and valuing response to an innovation. To assist in evaluation and interpretation, four focus groups were also conducted in October 1998.

This research concluded that willingness to use CarLink was influenced by the amount and type of exposure, as predicted by social marketing and learning theories. Informational media were used to teach targeted groups, and behavioral modeling (e.g., a video and drive clinic) was introduced to develop participant confidence in adopting new behaviors. For example, participants 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. The process by which individuals moved through definable stages in the behavioral adoption model, from precontemplation to contemplation, and in many cases into action, is documented in the report.

**Locator Number:
UCB-ITS-PRR-99-41**

**Title: Evaluation of the Anaheim Advanced Traffic Control System Field
Operational Test: Executive Summary**
Author: M.G. McNally, James E. Moore II, C. Arthur MacCarley, R. Jayakrishnan

UCB-ITS-PRR-99-18 (1999)

Problem

The city of Anaheim, California, experiences heavy traffic on a regular basis. Delays at intersections are a significant problem, and many special events create special traffic problems. The city has an advanced traffic control system, but wanted to test out several new technologies, so this field operational test was set up both to assess the technical performance of these methods and to analyze the institutional issues around their implementation and operation.

The three systems were: SCOOT (Split, Cycle, and Offset Optimizer Technique), a second generation technology for controlling systems of signals as opposed to isolated intersections, already in use in Europe; a 1.5 Generation Control system under development, whose purpose was to update baseline timing plans for the entire system; and a video traffic detection system presented as a low-cost alternative to loop detectors for critical areas.

Method

The evaluation was broken down into three main parts: a performance assessment of the technologies, an assessment of the institutional issues, and a separate evaluation of the video traffic detection system.

For the performance assessment, we looked first at how well SCOOT “sees” traffic and then at how well it performs to control traffic.

Findings

SCOOT is designed to rely on information from loop detectors placed farther away from the intersections than the mid-block locations of the loops already in place in Anaheim. We needed to know whether these loops could provide adequate information to the system, so we compared SCOOT’s estimates of queue length and clearance time to real time video at certain intersections, and identified large inconsistencies. Nevertheless, SCOOT successfully models traffic conditions, in general, but can be improved either by changing the location of loop detectors or by adjusting global control settings to compensate for the actual location of detectors.

To assess SCOOT’s performance, we used teams both at intersections to measure delay and in cars to measure travel time, before and after implementation. We discovered that SCOOT performed better than the existing system during off-peak hours, and very well at certain intersections during special events. However, our findings are inconclusive as to whether SCOOT is better than the system already in place.

To evaluate institutional issues, we used direct observation and interviews, all of which produced subjective information that was structured to provide many different points of view. We looked at implementation, operations, transferability, and maintainability of the system. There was an immediate problem with delaying implementation due to a vacancy in a key position (Principal Traffic Engineer), which led to a lack of experience and authority in the city's relations to the contractor (Siemens). We were not able to adequately evaluate operational issues because of the resulting delays, which led to late delivery, and limited staff training and experience prior to the evaluation. In terms of transferability of technology, we concluded that products that are not widely deployed are essentially still in the research and development process, subject to delays, changes, and cost overruns. This is especially true for the 1.5 GC system. Maintaining the new systems would involve significant costs, and much more training is needed to properly utilize it. Our overall conclusions in regard to institutional issues is that we have no specific recommendation, but costs would be likely to go up if SCOOT were to be expanded beyond its present limited deployment.

The last evaluation task, of the video system which is marketed as a low-cost alternative to loop detectors, found that its user interface is unsophisticated but effective. The system's performance results were good under ideal lighting and light traffic conditions, but not so good in low light, night, rain, or heavy traffic. (The manufacturer, Odetics, says it has since addressed and corrected these issues, but we have not evaluated the new system).

Title: Mobile Surveillance & Wireless Communication Systems Field Operation Test

- 1) Executive Summary (UCB-ITS-PRR-99-6)**
- 2) FOT Objectives, Organization, System Design, Results, Conclusions, and Recommendations (UCB-ITS-PRR-99-7)**
- 3) Appendices A-J Containing Evaluation Data Gathered During the Anaheim Special Event and I-5 Tests (UCB-ITS-PRR-99-8)**

Author: Lawrence A. Klein

Date: 1999

Problem

Traffic monitoring can be difficult in areas where permanent detectors, electrical power, and communications systems are not available. This research sought to evaluate the performance of wireless traffic detection and communications systems.

Method

The researchers designed and built six surveillance and three ramp meter trailers, a video and data retransmission (or relay) site, and video and data reception facilities at the Caltrans District 12 and Anaheim Traffic Management Center (TMCs) and the University of California at Irvine Institute of Transportation Studies Laboratory. The system was evaluated in two different types of tests. The Anaheim Special Event Test assessed the surveillance trailers in an application that transmitted video imagery in support of arterial traffic control during a special event. The Interstate-5 (I-5) Test examined the use of the mobile surveillance and ramp meter trailers to transmit video imagery and data in support of freeway ramp metering.

Findings

Several difficulties were encountered with the trailers. These include:

- **Frequent discharge of electrical systems.** This was remedied with a complete redesign of the generator, battery, charging, and power architecture systems.
- **Difficult logistics and setup with the use of the trailers.** Several weeks and multiple personnel were required to select sites, perform signal strength testing, secure permits, and determine the best way to position the trailers. Moving a trailer a few kilometers and deploying it took about an hour. On construction sites, contractors need to be made aware of the surveillance trailers' use so that space can be allocated for them and thereby reduce the need for the trailers to be repositioned. Supplemental relay sites would also reduce logistics problems.
- **Strong winds occasionally moved antennae off mark.**

The video system used tended to over-report mainline volume. This is due in part to the maximum height at which the video detectors can be mounted on the portable trailers. In particular, tall vehicles tended to be counted as multiple vehicles; tall vehicles also tended to obscure smaller vehicles and cause them to be underreported. A method of compensating for vehicle overcount by the system studied is needed in order to report more accurate traffic volumes.

The ramp signals responded properly to vehicle demand an average of 85 percent of the time. This is not adequate for ramp-metering operation. Positioning the video camera closer to the ramp may reduce this error. Increasing the camera's field of view and using optical recognition logic may further reduce the error.

Fuel (LPG) consumption of a surveillance trailer was estimated at 0.46 gallons/hour. With an LPG cost of \$1.75/gallon, fuel for continuous surveillance trailer operation is estimated at \$0.80/hr.

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

Problem Addressed by Research:

An over-saturated freeway exit ramp that causes congestion in the exit lane also causes slow-down in the adjacent lanes, and can create a serious bottleneck on all lanes of the freeway.

Method:

We observed the La Paz Road off ramp from Interstate 5 in Orange County using videotapes, a probe vehicle, and loop detectors (which worked intermittently).

Findings:

In this particular case, the bottleneck did not seem to be caused by drivers squeezing into the exit lane at the last opportunity; this happened at a very low rate and rarely affected through-moving traffic. Non-exiting drivers simply seemed unwilling to drive fast while next to stop-and-go-traffic in the exit lane, which slowed all the lanes until they reached the off ramp.

When the traffic signal downstream of the off ramp provided right-of-way to exiting vehicles, no queue formed in the off ramp and no bottleneck arose; the traffic on the entire freeway had a very high flow. This particular traffic signal has a queue elimination strategy, triggered by a particular loop detector on the exit ramp. Such a strategy is very valuable, since it can prevent a bottleneck which might affect all lanes of the freeway. Where complete elimination of exit queues may not be feasible, these observations suggest that at least some improvement in freeway conditions can be realized by keeping these queues as small as possible.

Title: V²SAT Final Report: Video Based Vehicle Signature Analysis and Tracking System Phase 2: Algorithm Development and Preliminary Testing

**Authors: Transportation Electronics Library, Department of Electrical Engineering
California Polytechnic State University, San Luis Obispo.
Loragen Corporation, Advanced Technology Group, San Luis Obispo.**

UCB-ITS-PRR-97-6

Problem and Findings

This report describes the field tests of the V²SAT video based vehicle signature analysis and tracking system. This system employs video cameras positioned over roadways to obtain images of passing vehicles. The video data is then processed by a digital image analysis to develop a “Video Signature Vector,” or VSV. The VSV consists of information such as color of the vehicle, size of the vehicle, and other characteristics like general body shape information.

Using multiple arrays of video cameras placed at various points along a freeway connected to a central computer via a wireless network, VSVs can be compared from the video cameras enabling individual vehicles to be tracked through the instrumented region of freeway. The data can be used to validate traffic flow, generate origin-destination data, validate local modal emission models, and possibly be implemented for law enforcement purposes.

Phase 1 of this research focused on validating the operational concept of the proposed V²SAT method. This included testing the viability of the VSV concept.

The primary focus of this part of the research (Phase 2) was to develop and debug the platform for the field implementation of V²SAT. This platform included software for real-time image processing and storage, refinement of the image analysis algorithms, and the required hardware. The system was then field tested under actual freeway conditions. The test site was a pair of freeway over-crossings 0.34 miles apart. The system was connected using a wireless network.

It was determined that the system had the ability to correctly re-identify vehicles at successive sites was 93.6%. Difficulty was encountered with motorcycles and tandem trucks in particular.

Title: Videobased Vehicle Signature Analysis and Tracking Phase 1: Verification of Concept and Preliminary Testing

Author: C. Arthur MacCarley, California Polytechnic State University, San Luis Obispo

UCB-ITS-PWP-98-10 (1998)

Problem

There is currently no way to automatically identify and track vehicles traveling on California freeways. With such a system, the California Department of Transportation could obtain data on vehicle flow patterns on California's freeways and arterial roadways to better manage traffic.

In order to meet this interest, a detection system must provide:

- 1) reliable detection and re-identification of a wide variety of vehicles under all possible traffic flow, environmental, and light conditions;
- 2) operate at very low power consumption to permit autonomous battery-only or photovoltaic (solar-powered) operation; and
- 3) be of low to moderate cost.

This report discusses Phase 1 of the research to address this problem. Phase 1 involves preliminary work to test the accuracy, reliability, and robustness of the basic technologies (a combination of video sensing, software processing of the video signal, and wireless transmission of data to other detection modules for a network of connected detection modules) upon which the detection method is based. Together, the technologies are termed Video-based Vehicle Signature Analysis and Tracking (V²SAT).

Phase 2 involves the development of experimental hardware and software for automated detection.

Phase 3 involves the design, development, and testing of a production prototype module. Based on the prototype, several such modules will be built, deployed, and tested.

Phase 4 involves the development of the wireless network components for telemetry between individual modules and local site transponders and the hardware and software components for telephone/modem communication between overcrossing transponders and a central correlation computer.

The proposed system is comprised of:

1. a detection module located on a physical structure (such as a freeway overpass) directly above each traffic lane; multiple modules make up a "site"
2. a local transponder/repeater, one per site, which receives data from up to ten modules and retransmits data via modem and telephone line to a network hub

3. a network hub, which receives the data stream from all detector modules and correlates the data to track vehicles through the monitored area

Method

The sensor is a simple video camera. The image is processed using filters and an efficient detection algorithm to develop a Vehicle Signature Vector (VSV), which is comprised of various measurements of the vehicle dimensions.

For Phase 1, two time-synchronized video systems were deployed at consecutive overcrossings spaced 0.5 to 0.6 miles apart on US Highway 101 in three different locations in the California Central Coast area. Data was collected on three different dates to cover four different illumination conditions.

Videotaped images from the field were then analyzed manually in the laboratory to test the accuracy and repeatability of the optical signature vector as a means for classifying and re-detecting vehicles. The analysis also sought to assess the general usability of the vector as a means for classifying a range of vehicles by dimensional measurements.

Findings

Under daylight conditions (midday and afternoon), an average of 98 percent of all vehicles were detected at the second site, for a sequence of 200 vehicles. For this data set and conditions, the method incorrectly matched the vehicle with the incorrect vehicle 0.87 percent of the time. Under daylight conditions, when a “reasonable time of arrival” window was used to admit only vehicles that could have traveled between sites at speed between 30 and 80 mph, the incorrect match percentage falls significantly, approaching 0 percent for the conditions of this test.

Under dusk illumination, but otherwise identical test conditions, correct matches occurred for 95.15 percent of all vehicles; false matches occurred for 2.02 percent of all vehicles in a sequence of 103 vehicles.

Under conditions of inadequate illumination (night) but otherwise identical test conditions, correct matches occurred for 75.49 percent of all vehicles while false matches occurred for 27.095 percent of all vehicles in a sequence of 102 vehicles.

It was found that supplemental illumination or use of specialized camera technologies will be required for sufficient nighttime vehicle detection and tracking.

On the basis of the results, the V²SAT method has the potential to serve as a reliable basis for non-intrusively tracking the progress of individual vehicles along an appropriately detectorized freeway network under daylight conditions.

Title: Video Based Vehicle Signature Analysis and Tracking System
Phase 2: Algorithm Development and Preliminary Testing
Authors: C. Arthur MacCarley, California Polytechnic State University, San Luis Obispo.

UCB-ITS-PWP-2001-10 (2001)
Problem

This report describes the field tests of the V2SAT video based vehicle signature analysis and tracking system. This system employs video cameras positioned over roadways to obtain images of passing vehicles. The video data is then processed by a digital image analysis to develop a "Video Signature Vector," or VSV. The VSV consists of information such as color of the vehicle, size of the vehicle, and other characteristics like general body shape information.

Using multiple arrays of video cameras placed at various points along a freeway connected to a central computer via a wireless network, VSVs can be compared from the video cameras enabling individual vehicles to be tracked through the instrumented region of freeway. The data can be used to validate traffic flow, generate origin-destination data, validate local modal emission models, and possibly be implemented for law enforcement purposes.

Phase 1 of this research focused on validating the operational concept of the proposed V2SAT method. This included testing the viability of the VSV concept.

The primary focus of this part of the research (Phase 2) was to develop and debug the platform for the field implementation of V2SAT. This platform included software for real-time image processing and storage, refinement of the image analysis algorithms, and the required hardware. The system was then field tested under actual freeway conditions. The test site was a pair of freeway overcrossings .34 miles apart. The system was connected using a wireless network.

Findings

It was determined that the system had the ability to correctly re-identify vehicles at successive sites was 93.6%. Difficulty was encountered with motorcycles and tandem trucks.