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Decision Support Systems for Managing and Applying ITS Resarch

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Decision Support Systems for Managing and Applying ITS Research

Final Report

A Study Conducted under MOU 209

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Abstract

This study is presented in three related papers. The first develops a structure for making decisions regarding Caltrans/PATH research. It describes a research cycle in which real world needs and opportunities fed into a process by which research priorities are set, proposals invited, and projects are selected. These research projects ultimately provide information that can be used for further research or for implementation. Implementation changes society and technology and leads to new needs and opportunities, which in turn feed into the research process. The second paper develops and describes the process by which proposals are evaluated. The third paper describes how the products of research and implementation have been analyzed, summarized, and presented to researchers, potential implementers, and other decision makers via the Internet, thus supporting their decisions regarding further research and implementation and thereby moving research results into practice.

Key words: decision support, decision making, research, evaluation

Executive Summary

This report contains three related papers. The first concerns the process for making decisions regarding what research will be undertaken. The second describes a procedure for evaluating proposals. The last reports on a web site intended to bring the information gained from actual ITS implementation together so that potential ITS implementers can learn from the experience of others.

A Structure for Making Decisions Regarding Caltrans/PATH Research

A key determinant of PATH's success in helping Caltrans utilize advanced technology to improve the transportation system is the choice of which research to pursue. PATH research does not take place in a vacuum, but rather in the context of society's needs, technological capabilities, and research that has already been conducted. The choice of research to pursue can be thought of as being located in a cycle in which the real world influences research, which in turn influences the real world.

Making good decisions regarding PATH research requires identifying transportation goals, determining where there are opportunities to move closer to these goals, determining the state of research in advanced transportation systems, and assessing PATH's particular strengths. These inform the first decision, which is to set the research agenda. This agenda is communicated to potential research program participants via a Request for Proposals. The next decision is which of the proposed projects to include in the research program. This decision is based not only on research needs but on the quality of the proposals. The procedure for review and evaluation of proposals, PREATRP, is the subject of the second paper in this report.

The study found that the current process lacks clear linkage to the needs of the end users of research. The research agenda and proposals do not focus sufficiently on the benefits of the research to travelers, and lines of research are not prioritized in terms of their ultimate benefits.

We recommend that the research program development:

- begin with explicit consideration of the goals of the transportation system and how PATH research can support those goals,
- give more attention to Caltrans' needs and priorities,
- pay more attention to moving research into practice, and
- bring greater rigor to the research management process.

PREATRP: Procedure for Review and Evaluation of Advanced Transportation Research Proposals

Proposals should be evaluated not only in terms of the elegance of the concept and method of study, but also on the product of the research. Researchers

tend to focus on the former, while potential implementers, in this case Caltrans, focus on the latter. PREATRP was developed to address both of these criteria. It is designed for use by PATH peer reviewers and Caltrans staff. Proposals are evaluated in terms of seven criteria:

- Significance and relevance to PATH and Caltrans goals and mission
- Research methodology
- Quality of research plan
- Qualifications of research team
- Budget
- Utility of research outcome
- Feasibility of implementation of research outcome

Within these categories are subcategories for which reviewers provide a numeric score. Reviewers are also asked to provide a recommendation regarding funding and research priority. They are also strongly encouraged to provide comments, which are passed on to the author of the proposal.

Two or three academic experts and a similar number of practitioners review each proposal. Then PATH management and Caltrans New Technology and Research management separately make preliminary decisions regarding which proposals will be included in the research program for the following year. Together they make the final decision.

LEAP: Learning from Evaluation and Analysis of Performance

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

The web site currently contains information about Advanced Traffic Management Systems (ATMS)—traffic surveillance, incident detection, incident clearance, ramp metering, traffic management centers, and electronic toll collection. It also contains information about Advanced Traveler Information Systems (ATIS), including pre-trip information, en-route information, route guidance, and rideshare matching. It includes Commercial

Vehicle Operations Systems (CVO) and Advanced Public Transportation Systems (APTS), including automated vehicle location and advanced fare payment. It also includes longitudinal collision avoidance. Sections on variable message signs, probe vehicles, and highway-rail intersection management are currently under development and will be added soon.

Information is gathered from published sources: project evaluation reports, research reports, journals, and conference proceedings. Once published information on all ITS services has been posted to the site, unpublished information will be sought.

A set of analytical tools to help users determine which ITS services to implement and how to implement them is planned for the future. This portion of the project draws heavily on research and design undertaken in connection with PLANiTS, a computer assisted planning tool envisioned by PATH.

The web site has been visited over 8000 times during it first two years.

Acknowledgments

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Many people have helped develop the web site. Three visiting French students at PATH, Francois Granet, Ludovic Chabas, and Francois Durguety assisted in reviewing the literature and assembling material for the site, as have Justin Black, Lingo Leung, Wenbin Wei, Da-Jie Lin and Joe Wanat, graduate students at the University of California, Berkeley. The site owes its existence to the work of many people who conducted evaluations of and research into intelligent transportation systems and who published the results of their work. Please see the web site itself for a list of references to their work. The site also draws on the National ITS Architecture for its structure and on the PATH PLANiTS project for its inspiration

Table of Contents

A Structure for Making Decisions Regarding Caltrans/PATH Research

Joy Dahlgren and John Lathrop

Introduction

A key determinant of PATH's success in helping Caltrans utilize advanced technology to improve California's transportation system is the choice of what research to pursue. One of the deliverables for MOU 209 is a framework for making this choice and a white paper tying this framework to overall transportation goals. This paper provides both. It begins with a discussion of the environment in which research decisions are made. This includes the goals of the transportation system, the problems and opportunities that arise within the system, the state of ITS research, and PATH's particular strengths and interests. The second part of the paper is devoted to the process by which decisions regarding PATH's research program are made. First the current process is described, including changes that have resulted or are underway as a result of MOU 209. It concludes with recommendations for further improving the process, setting these in an overall decision-making framework.

The Research Cycle

PATH research does not take place in isolation. It is closely tied to the problems and opportunities that are constantly arising in the world of transportation and to the research being done by others. Figure 1 attempts to capture the place of PATH research in the larger world. Basic to everything else are the goals of the transportation system. Technology and society define these goals and create opportunities to move toward them, but they also create problems that move society further from the goals.

These problems and opportunities determine research priorities, which, along with the state of ITS research, PATH's particular strengths, and research being undertaken elsewhere, determine PATH's research agenda. This is the basis for PATH's Request for Proposal (RFP) to outside researchers and the proposal evaluation guidelines (described in the second paper in this report). The research agenda, along with the response to the RFP and the evaluations of proposals, determine PATH staff research and the overall PATH research

program. This program, in turn, guides decisions about PATH staff hiring, which adjusts PATH strengths.

The program produces research products. Those that have reached the point where they can be implemented may be put into practice, perhaps with the help of the Technology Transfer Program of the Institute of Transportation Studies. Once in practice, they should mitigate transportation problems, and subsequently alter research priorities. Some other research products form the basis for further research, which then competes for priority with other research ideas. Some research does not show promise and is not pursued further.

From Figure 1, it is clear that the key to the effective use of PATH resources is to set up a mechanism for clearly incorporating California transportation goals, problems and opportunities into research priorities. This calls for a more systematic structuring and analysis of those goals, problems and opportunities to use as a basis for setting PATH research priorities and agenda. Analytic tools exist for doing this, based on structured elicitation of opinions from expert panels. Such a process is described in detail in the recommendations at the end of this paper.

The Environment in Which Decisions are Made

This section describes the environment in which research decisions are made, represented by the boxes above the dark line in Figure 1.

Transportation Goals – Box 3 in Figure 1

The California Transportation Plan calls for:

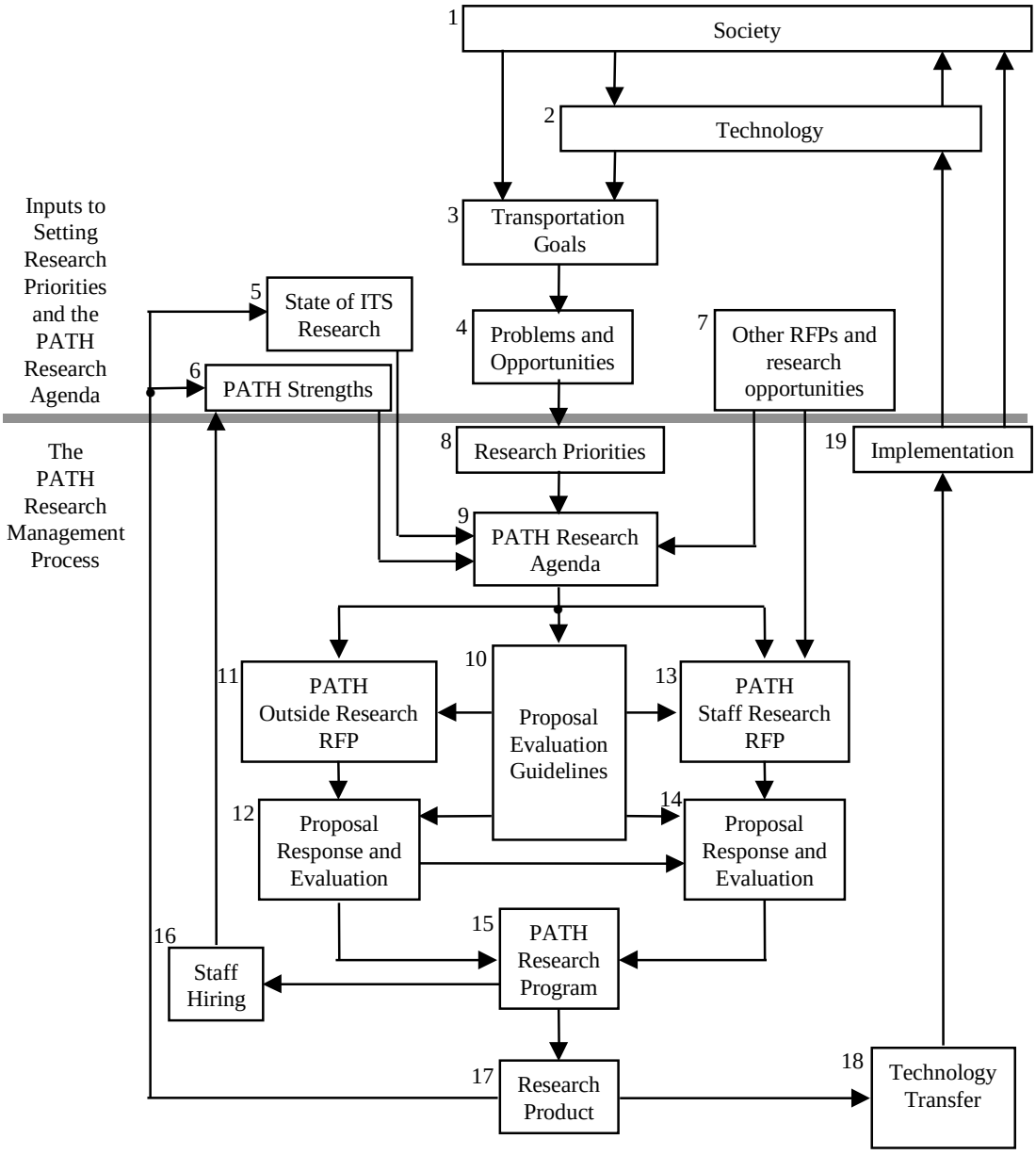
- Economic Vitality – Mobility with Choice
- A Safe, Convenient, Reliable Transportation System
- Environmental Protection with Mobility and Energy Efficiency

These goals spoke to the current concerns at the time the Plan was produced. The proposed goals for the 1998 additions to the Plan have a slightly different flavor, reflecting better economic times. However, underlying these goals is a more basic goal relating specifically to transportation, which will be described below.

The Overall Transportation System Goal

This goal is to maximize the overall societal net benefit of the transportation system. The societal net benefit is defined as the benefits to all of the parties, or stakeholders, affected by the system—individual travelers, commercial enterprises moving goods, the community as a whole, and private transportation service providers—less the costs to all of these parties. These are shown in Figure 2.

Figure 1 The Research Cycle



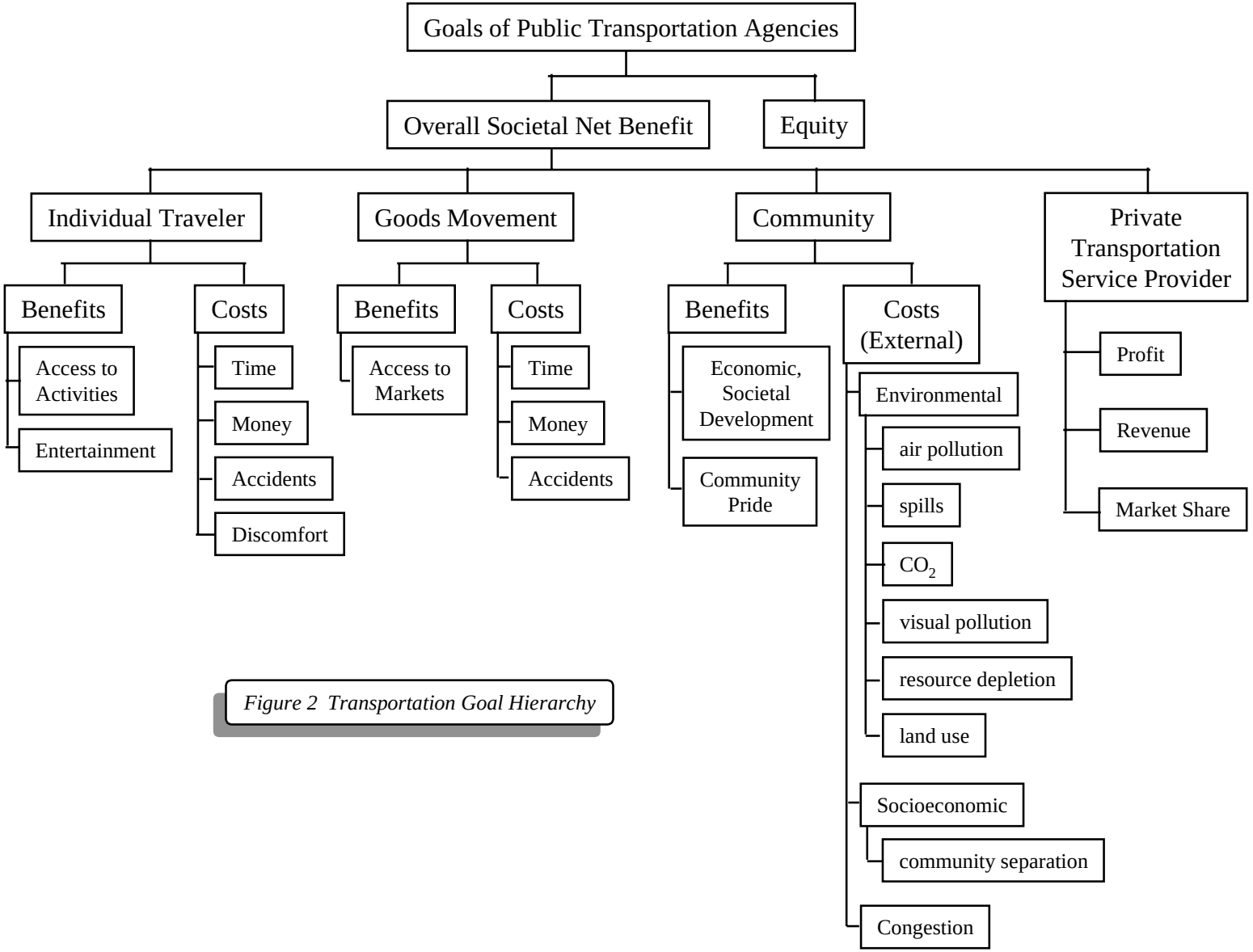


Figure 2 Transportation Goal Hierarchy

Equity – A Constraint

Equity is sometimes considered a goal. But equity is neither a benefit nor a cost. Rather, it is a measure of how benefits and costs are distributed. Here we consider it a constraint—both benefits and costs must be fairly distributed. This does not mean that improvements that damage some people can not be undertaken, only that benefits and damage should be fairly distributed across the population over the long run and that people should be directly compensated in cases where benefits and damage will not otherwise be fairly distributed. There are many long-standing policies that do this. Compensating people whose land is taken for transportation facilities is one example. Sound walls are an attempt to avoid imposing unfair noise burdens on people living adjacent to freeways. Measures taken to reduce noise near airports are designed to keep air travelers from imposing an unfair burden on nearby residents.

Goals of Individual Travelers[1]

Access to Activities

Most trips that people make are not made primarily for the fun of moving about, but in order to engage in some activity, such as work or visiting with friends. The primary goal for individual travelers is to gain access to activities they value[2].

Entertainment

However, sometimes people *do* travel just for fun. It is common to go out for walk or a bicycle ride solely for purposes of entertainment, and sometimes people go out for a drive, just for fun. People do not often go for pleasure drives during peak commute periods—it is more common on weekends.

Entertainment is often a component goal of a trip taken for another purpose. People want to get somewhere *and* be entertained along the way. They enjoy the solitude and comfort of their car after a busy day, the view from an airplane or automobile, the fun of a ferry ride, or the thrill of riding a

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[1] These goals also form the basis for the development of performance measures, which are described in the Final Report for MOU 267.

[2] It is sometimes argued that access should be increased by more compact development rather than by more travel and that this would result in a greater increase in utility. However, people and communities choose the level of compactness that they prefer—people do this by their choice of housing location, employment, and other activities. Communities do this through their general plans, zoning, and planning decisions. If people choose to live in communities, take jobs, and engage in other activities that require a certain level of travel over the long run, this must reflect a preference for this activity pattern over one that would require less travel. This would seem to indicate that for them, more travel provides greater utility than less travel. Of course, choices that require a high level of travel may impose higher costs on others than choices that require less travel.

motorcycle. This is why people buy high-performance cars and car stereos and why Caltrans plants trees and flowering shrubs along freeways and pays attention to the visual design of overpasses and sound walls.

Minimizing Travel Costs

People also want to minimize their cost when they travel. These costs are discussed below.

Time

Transportation takes time. There is not only the time spent actually traveling but also the time spent waiting to travel and arranging to travel, as well as the extra time allowed as a buffer in case of delay. Another time-related cost is schedule delay, that is, arriving earlier than desired in order to avoid travel delay.

Money

Travelers spend money to purchase, maintain, and operate vehicles (including the cost of insurance and garage space) and to purchase transportation services such as transit and air travel.

Accidents/Property Loss and Injury

Travelers sometimes have accidents or are robbed or assaulted by other people in the course of their travel. The result can be damage to their car or other vehicle, loss of possessions, and injury, sometimes fatal.

Discomfort

This is a class of costs that are hard to define and measure, but that are just as real as the other costs outlined above and may be just as significant. They include cognitive and psychic costs, such as the stress due to driving itself—which can be exacerbated by difficult driving conditions caused by weather, heavy traffic, mechanical problems, or other factors—as well as by worry about taking the wrong route, being late, missing the bus, having an accident, or having an unpleasant or dangerous encounter with another person. They include physical discomfort caused by being cold or wet, being exposed to loud noises, being pushed, having a bumpy ride, or being rudely treated.

Shippers' Goals

Access to Markets

Goods are shipped because they have more value in the destination location than in their original location. Transportation expands markets for goods. It allows producers to access more markets for raw materials, thus increasing the variety and complexity of products they can efficiently produce in a particular location. Transportation expands their market for finished goods, thus

expanding consumers' choice. In both cases this leads to a more efficient allocation of resources[3].

Minimizing Shipping Costs

These costs are what the shipper pays the carrier[4] to cover carrier costs and profit, as well as the inventory cost of the goods during shipment, which is proportional to the time elapsed during shipment.

Community Goals

Development

The goal of transportation system improvements is often to promote or enable development. In fact, even when the original goal is simply to reduce travel time, additional development often results. Over the long term, economic and social development has been the major benefit of transportation. Transportation has enabled spatial arrangements of activities that would not otherwise have been possible. When the only transportation was by foot, people's economic and social life was limited to the other people and the goods within walking distance. With transportation, larger numbers of people and a greater variety of goods can come together, enabling economies of scale and agglomeration, which make production more efficient. The resulting increased wealth makes more resources available for additional social and cultural activities. Today, because the goods necessary for life can be transported, large numbers of people can live in metropolitan areas, thus enabling development of a richer mix of economic and social activities. Furthermore, because of transportation they can come together for these activities without having to live in close proximity.

Of course, transportation only *enables* development, it does not by itself *cause* development. Here technology and population play the key role. Transportation facilities are built and services instituted because people see an opportunity for doing something new or something old in a different manner or in a different place.

The transportation improvements that open up new routes and modes of access, such as the railroads that linked California with the rest of the United States, have the greatest developmental effect, changing the direction and scale of development. These are followed by transportation improvements that expand access within the new area or add additional modes of access that

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[3] The provision of services is analogous to goods movement. Transportation of service providers, such as gardeners, plumbers, policemen, and teachers expands the area they can serve and benefits consumers by providing them with a wider range of services and a larger selection of service providers.

[4] The shipper and carrier are the same in cases where firms supply their own transportation.

enable new types of economic activity. Finally, there are improvements that are not designed to affect development, but rather to reduce costs, generally time. But of course, by reducing costs they can also influence development. In fact, each of these types of transportation improvements exerts its effects through reducing transportation costs—it is only the degree of cost reduction that differs. At this time in California, there are few opportunities for improvements of the first type. Most areas with development potential have been opened up and the only new mode on the horizon is the automated vehicle, which is still some years in the future. A few transportation improvements are of the second type, allowing expansion of development. However, many of the economic and social benefits of location and the spatial organization of activities have already been achieved. Most transportation improvements that will be made in California in the future are of the third type, designed to reduce the cost of transportation or to allow increased use without increased cost.

Other Community Goals

Transportation improvements are sometimes made because of other perceived benefits, such as community pride or learning about new technologies. A city may feel that its prestige is enhanced by a light-rail system. Or the goal may be to test or demonstrate a new technology. In the latter case the primary goal would be to provide information regarding the effects of the technology in order to inform decisions regarding future development of the technology and the circumstances in which it could be effectively implemented. If the technology proves useful or shows promise of being useful, this increases the likelihood that it will be used elsewhere. If not, additional ineffective experimentation can be avoided. In this case, the community served might be national or even world-wide.

Minimizing the External Costs of Transportation

Transportation often imposes costs on people other than the individual traveler or freight carrier. It can damage the environment, delay other travelers, or facilitate development that damages the environment or community character. Reducing these costs has been an important goal of transportation policy ever since environmental concerns gained attention and highway construction slowed in the early 1970s.

Environmental Costs

The use of transportation vehicles imposes environmental costs on travelers and non-travelers alike. These costs vary with location and mode. For example, the effects of emissions of pollutants and particulate matter are likely to be minimal in a sparsely populated or windy area. But in a heavily populated area or where the topography and climate favor the formation of ozone, effects can be significant. The effects of spilled fuel or oil leaks depend on how street runoff is treated. If runoff from a heavily used road or gas station drains directly into a small creek, the effects can be devastating,

but if it drains into a sewer system where it is treated, the effects will be less serious. However, in all locations, carbon dioxide emissions from the burning of carbon-containing fuel contribute to greenhouse gases in the upper atmosphere.

Worn out or obsolete transportation vehicles and infrastructure, such as old tires, wrecked cars, rotting piers, and abandoned railroad tracks can degrade the environment by becoming eyesores or adding to the solid waste burden. The extent to which these are removed from public view and their materials are recycled, determines the extent of degradation.

Other environmental costs include depletion of natural resources and damage to the land and water resources that are caused by the extraction, production and shipment of fuels, manufacture of vehicles, and construction of the infrastructure. These costs depend on the resources consumed, which in turn, depend on the fuel efficiency of vehicles and the design and quantity and types of materials used for vehicles and infrastructure. Social costs, such as the splitting of a neighborhood by a freeway or railroad, can also be considered environmental costs.

The development enabled by transportation can consume open space and agricultural land and lead to suburban sprawl. But suburban sprawl is not necessarily a net cost. Although it is almost universally condemned, suburban living has been the choice of the majority of Californians, so apparently they believe that the benefits are greater than the costs.

This definition of environmental costs encompasses the concept of sustainability—that is, meeting the needs of the present without compromising the ability of future generations to meet their own needs. The primary ways in which the current transportation system might compromise this ability are by contributing to global warming or depleting resources, including land available for transportation infrastructure and other uses.

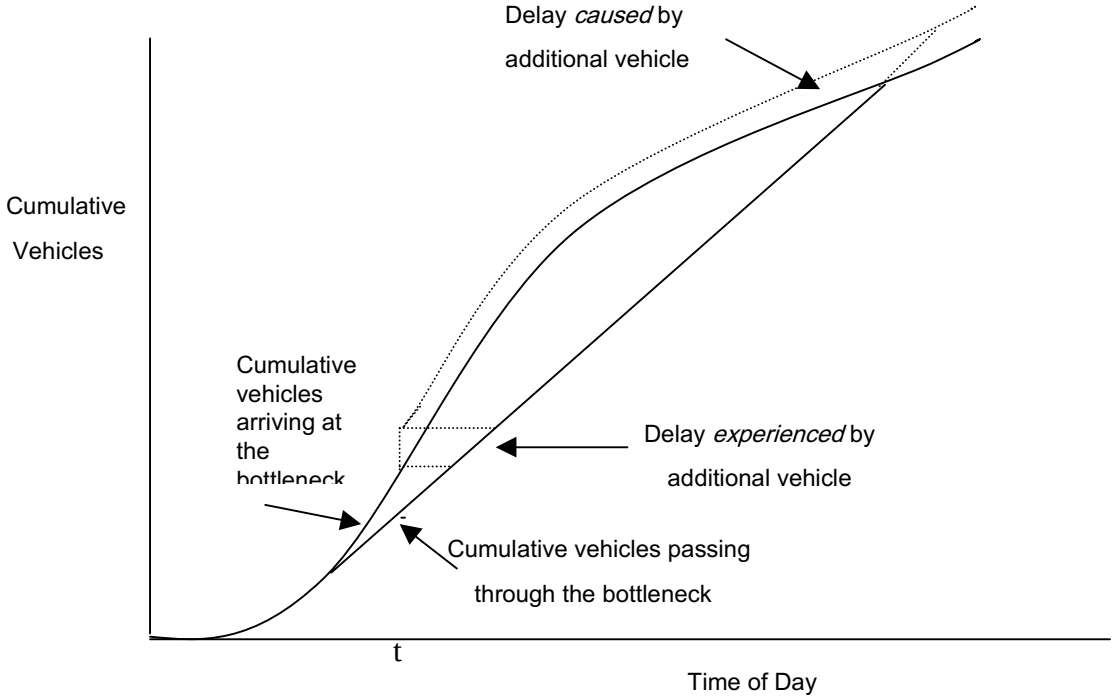
Costs Imposed on Other Travelers—Congestion

An equally important type of external cost is the additional delay each user of a crowded road imposes on the other users. The more crowded the road, the greater the cost. The nature of this cost can be seen in Figure 3. The vertical axis shows the cumulative number of trips during the peak period on a particular transportation link. The horizontal axis shows the time of day. The curved line represents the number of people wanting to pass through the link[5]. At first the demand exceeds capacity, so a queue develops. Then demand decreases below capacity, and the queue lessens until it is completely dissipated. The horizontal distance between the two lines represents the delay for the person wanting to pass through the link at that particular time. The second, dashed curved line represents the cumulative number of trips if an

[5] Actually this would be a stepped line, one step for each vehicle. However, for simplicity, it is shown here as a smooth line.

additional traveler joins the queue at time, t. The delay to that traveler is the area labeled "Delay *experienced* by additional traveler", but the delay that traveler imposes on other travelers is the area between the two curves. Clearly, this delay is greater than the delay he experiences. This phenomenon leads to inefficient use of the transportation infrastructure—the delay experienced by the traveler is less than the delay imposed on others. This additional delay not only increases the time costs for other travelers, it increases vehicle-hours, thus increasing carbon monoxide and hydrocarbon emissions. But the trip does not necessarily lead to a net social cost, because the benefit of the trip may exceed the total time costs resulting from the trip. Similarly, a person who uses a crowded bus or train, imposes additional crowding on the other passengers. The more other passengers there are, the greater the total discomfort he imposes. As with the automobile traveler, his cost is always less that the total cost he imposes on others.

Figure 3 Effect of an Additional Vehicle on a Congested Road



From the graph, one can see that it the vehicles arrived at the road at the same rate they could travel through the bottleneck there would be no delay—the problem is not too many travelers, but too many trying to travel at the same time. If there were some kind of reservation system or pricing system, the number of cars arriving at the bottleneck could be made to match the capacity.

Goal of Private Transportation Service Providers

The goal of private service providers may vary at different stages of their development or in different situations. They are likely to focus on maximizing profits, or increasing market share or maximizing revenues in the short term in order to maximize long term profits.

Effects Not Considered to be Benefits

Transportation jobs and investment costs, although sometimes called economic benefits, are not benefits, but rather costs, because the people and other resources used in transportation would otherwise be providing other services to society. Society is giving up those services in order to have the transportation facilities. Even if the people would be otherwise unemployed, and the government is paying them to work in transportation, society is giving up the other services that the government might have paid them to provide. The true economic benefits, beyond the benefit of reduced costs, are the development benefits. The alleged benefits are actually costs that are included in the money costs of transportation that are borne by the providers of the transportation infrastructure and services and by travelers and shippers.

Goals of Public Transportation Agencies

Public agencies are charged with the goal of serving the public. As indicated in Figure 2, that means they are charged with maximizing the overall societal net benefit, balanced against equity. By focusing on maximizing net benefits, they resolve the dilemma of how to serve all of the above transportation goals, many of which are in conflict, such as providing access while minimizing vehicle emissions. Determining net benefits, weighing benefits against costs, provides a mechanism for prioritizing transportation investments and determining when progress toward a certain goal is worth the cost. These benefits and costs include not only those that can be given a monetary value, but also those that can not be monetized or even quantified.

Problems and Opportunities – Box 4 in Figure 1

Problems typically derive from the costs of transportation. For example, there is too much congestion, too many accidents, too much air pollution, too much driver stress, too much uncertainty regarding travel time, while on the other hand there is too little public money for increasing capacity. People do not perceive the lack of something that has not previously existed as a problem. Before the railroad was invented, people did not conceive of its lack as a problem. Similarly, people today do not see the lack of an automated highway system as a problem. But many people see it as a means to utilize the opportunities presented by vastly improved technologies for sensing, computing, and communicating to move the transportation system to a much-improved state. These are problems and opportunities in the broadest sense. They inform the overall research mission. But associated with each larger

problem or opportunity are a host of smaller problems and opportunities, the solution to or utilization of which incrementally advances research or improves system operation. For example, an automated highway will need some type of emergency vehicle access. How can this be provided without building an emergency lane and defeating the purpose of reducing highway capacity needs? This is a small problem that must be solved before the larger opportunities can be realized. With already implemented technologies, there can be refinements in use, such as more useful messages on changeable message signs, or refinements in technology, such as more robust and accurate traffic surveillance devices. Each step forward in research and implementation brings new problems and opportunities.

State of ITS Research – Box 5 in Figure 1

Although PATH has been in the forefront in ITS research, particularly with respect to automated highways, many other universities are doing ITS research. Private industry, particularly the defense and automotive sectors, is developing ITS products. Engineering and management consulting firms are conducting research and developing expertise in implementing ITS systems. Federal demonstration programs and field tests are being evaluated. PATH must be aware of this research, utilize it, and exploit opportunities for fruitful collaboration. PATH must determine where redundant research is needed in order to expand, confirm or refute earlier findings and where it would be wasteful because earlier research is conclusive.

PATH Strengths – Box 6 in Figure 1

Reflecting its strong linkage with academic research, PATH has tended to concentrate on developing theory, models, and tools; evaluation of implemented ITS projects; economic analysis; and designs for implementation and evaluation. However, in the Advanced Vehicle Control and Safety Systems (AVCSS) program these research skills have been combined with those of development engineers and technicians, who were able to put the research products into vehicles.

PATH draws research proposals from campuses throughout the state, so it is well suited to undertake projects that are interdisciplinary in nature and broad in scope, such as the AVCSS effort.

Other Research Opportunities – Box 7 in Figure 1

Although Caltrans is the primary sponsor of PATH research, PATH has been involved in several federal research efforts including evaluation of field operational tests such as TravInfo, the National Automated Highway System Consortium, and the National ITS Architecture development process. There are also opportunities to work with state and local government agencies as well as private industry.

The Current Research Program Decision Process

This section contains a description and critique of the current process by which research priorities and the PATH research agenda are set (Boxes 8 and 9 in Figure 1). The primary goal of the process is to provide Caltrans and other research sponsors with the most useful products possible given the resources available. Secondary goals are to add to the general body of knowledge and foster the professional development of researchers.

Decisions to be Made

Caltrans New Technology and Research Program (NTRP) decides:

1. what budget to seek
2. how much to allocate to Intelligent Transportation Systems research and to PATH and how much to allocate to other research and other organizations
3. what types of research to request from PATH
4. which proposals to recommended and the funding for each

PATH decides:

5. what type of research to seek through the PATH Request for Proposals (RFP)
6. which proposals to recommend and the funding for each
7. what Caltrans NTRP-sponsored research to pursue with PATH staff
8. whether and how to respond to Requests for Proposals from other agencies and which other opportunities for government or private research funding to pursue
9. PATH staff level and makeup

Caltrans and PATH jointly decide:

10. which proposals to fund and the funding for each

This paper will not deal with decisions 1 and 2, because they are outside the realm of Caltrans/PATH relations.

Deciding on the PATH Research Agenda

Decisions 3 and 5 above determine the research agenda. The process by which these decisions are currently made is fairly informal. Individuals in Caltrans and PATH informally discuss their research needs and ideas in the course of other work throughout the year. This year an e-mail was sent to researchers soliciting their ideas for the RFP. Three meetings to discuss the research agenda are

generally held in connection with the PATH Annual Research Conference in early October. One is a meeting of the Advanced Traffic Management and Information Systems (ATMIS) Coordinating Council. Council members are faculty who have been associated with PATH; senior Caltrans staff from headquarters, the districts and NTRP; and staff from regional and local transportation agencies. A summary report on the state of current research is sent to members before the meeting to provide them with background for the discussion. However, the usefulness of the meeting is limited because most attendees are PATH and Caltrans staff members who have already shared ideas, and there is not adequate time to explore issues or engage in a thoughtful discussion of problems, opportunities, or priorities. The other two meetings are research focus group meetings, one for ATMIS and one for AVCSS, held at the end of the conference to discuss research for the coming year. Unfortunately, many meeting participants leave before the research focus meetings start. Some who attend are tired and eager to go home. Many useful ideas surface at these meetings, but there is generally not sufficient time to come to consensus on what is most important.

This year three other meetings at PATH also included discussion of the research agenda. At a PATH retreat in September, PATH managers presented research initiatives for the coming year. These and other ideas were discussed by PATH managers, academic partners, and Caltrans staff. This was quite a fruitful discussion. The research ideas were well prepared, there was a broad range of academic and Caltrans participants, and there was adequate time for discussion. After this meeting and the PATH Research Meeting, ATMIS and AVCSS staffs met separately to discuss the ideas generated at all of these meetings and to add new ideas, prioritize, and state individual research preferences. All of these ideas were molded into the PATH RFP, which was circulated to Caltrans managers and PATH researchers, who made suggestions that were incorporated into the final RFP.

Heretofore, ATMIS research at PATH has been fairly broad and diffuse. This is a good approach for a new field. However, now that ATMIS has matured somewhat, we know better which aspects will produce the greatest benefit and we want to concentrate effort on research that can be implemented in the near term. Therefore, this year we selected two themes: decision support for ATMIS implementation and the model TMC. At Caltrans request, a third theme, ITS Applications in Intermodal Services and Public/Private Partnerships was added. In order to get proposers to focus on the most beneficial aspects of ATMIS and on implementation, the RFP specified three special features, the inclusion of which would result in special consideration for projects. The first was to include potential implementers as part of the research team, either as active participants or advisors. The second was to include as part of the work program an assessment of the benefits of the expected deployed research product. The third was to include a plan for transferring the research to practice. In this way the proposers were encouraged to focus on the goals of the research and to become participants in determining what was beneficial and implementable. As this

paper is being written, the proposals to be funded have just been selected based on PATH and Caltrans reviews. We plan to examine the proposals to determine the extent to which these features were included and how inclusion affected reviewers' judgements of the merits of the proposals. Based on this examination, this approach will be continued, expanded, or curtailed. The ATMIS portion of the RFP is shown in the Appendix at the end of this paper.

Deciding on the PATH Research Program

Project Selection Criteria

These criteria are outlined in the form that is used in evaluating proposals (Exhibit 1 in the second paper in this report). Although there are several categories and sub-categories, in essence they all deal with three things: the quality of the research, the likelihood that it can achieve its objectives, and the usefulness of those objectives—in other words, the expected value of the research.

Responses to the RFP

The decision process for selecting proposals is quite formalized. Proposals are sent to reviewers who use the proposal evaluation process described in the second paper in this report. The current process was developed by Mohamed AlKadri of Caltrans NTRP. It was revised in 1996. After the 1996 selection process, reviewers met to discuss the form and the process. The comments were generally positive and provided good ideas for improvements to the form. It was revised again before the 1997 proposal review. No further revisions are planned.

The tracking of the proposals and reviews is computerized at both Caltrans and PATH. The possibility of handling the entire review process electronically was investigated in 1997. There were 32 proposals with 6 reviewers each. It was found that an electronic process would make it difficult for the person responsible for managing the distribution and tracking of proposals to share the work with other people. It was decided that, given the current state of file sharing and incompatible electronic formats, the significant programming effort required to set up such a system would not be worthwhile for a process that occurs only once a year.

Proposals are reviewed by both Caltrans and PATH/academic reviewers. Caltrans reviews tend to focus on the subject matter of the proposal, while PATH reviews tend to focus on proposal methodology and concept. Worthwhile proposals should pass both tests. The annual RFP Schedule is shown in Table 1.

PATH Staff Research

The selection of staff research is less formal and more flexible than the selection of faculty research. PATH staff members typically conduct the

federal research and other non-Caltrans sponsored research. They may be asked to fill in the gaps in research that is desired by Caltrans but not pursued by academic proposers. Conversely, they may have their own research ideas or opinions regarding what research would be most useful, for which they try to gain Caltrans support. It is an entrepreneurial process—they try to "sell" their ideas to Caltrans, Caltrans tries to "buy" the research it needs, and PATH management serves a brokering function. Sometimes a Caltrans staff member may take a research proposal directly to a trusted staff or faculty researcher.

Table 1 PATH Research Program Schedule

PATH issues RFP	Early December
Deadline for proposal postmark date	Mid-February
Proposals received by Caltrans NTRP	End of February
Proposals sent to PATH reviewers	End of February
Reviews due at PATH	End of March
PATH recommends proposals and budget	Late April
Caltrans NTRP/PATH proposal review and budget meeting	Late May
PATH submits new MOUs to Caltrans for funding	Mid- June
Caltrans NTRP approves MOUs	Early July

In recent years ATMIS staff have proposed tentative projects in January. These have been discussed within the ATMIS group and then with people from Caltrans NTRP. They are molded and shaped by Caltrans, PATH researchers, and PATH management until they are mutually acceptable to all. This is usually a rather long process, typically extending beyond the time when proposals made in response to the RFP are selected.

Responses to Other Research Opportunities

From time to time, RFPs are issued for ITS-related work. PATH can respond to these independently, team with others, or subcontract to another organization. In each case, the effort needed to respond must be weighed against the likelihood and benefit of being awarded the work. The benefits depend on how the work fits with PATH's mission and expertise, how it fits with other work being done, how it might influence future research opportunities, and the overall benefits of the research.

Summary Findings

The basic finding that emerges from this examination of the current PATH research management process is that it lacks a clear and demonstrable linkage

to the interests of the end users, either directly or via the Caltrans operating divisions. The current, largely bottom-up, "entrepreneurial" research management process, with its open and frank competition for funds, is laudable for its competitive efficiency, but it is only weakly influenced by the needs of end users. If the current program was subjected to scrutiny and the question was asked: "How is this process user-driven, or needs-driven?" the program would be hard-pressed to come up with a good answer.

This does not mean that the PATH and Caltrans staff involved in setting the research agenda do not consider end users. Many people give the process a great deal of thought and time and attempt to make it as responsive to needs as possible. The problem with the current decision-making structure is that in its early stages it is not closely tied to the overall goal of the transportation system—increasing the net benefit of the system—or to the ultimate role of the research products in addressing this goal. Because the benefits of the research products are not adequately addressed, research can not be prioritized in a sensible way. Caltrans' needs, which should also be related to increasing the net benefit of the transportation system, are not expressed in these terms—the linkage between this goal and the proposed line of research is not made.

There are actually two steps to that linkage: First, Caltrans needs, and the goals, problems and opportunities of California's transportation system, must to be articulated clearly and explicitly. Second, the expected benefits of each research program must be stated in terms of those goals, problems and opportunities. The expected benefits of the research are a function of the annual benefits to be expected from the ultimate product, the role of the research in producing that product, the likelihood that the product benefits will actually be realized, and the time when such benefits would begin to be realized.

Even with five meetings this year at PATH to discuss the research agenda, two things were missing in the process: 1) a thorough discussion of transportation and research problems and opportunities for research, and 2) a discussion of priorities. The RFP reflected the best judgment of PATH managers regarding these as well as the priorities of individual Caltrans NTRP managers. This is not necessarily bad, because PATH managers may have given more thought to these issues and may be best equipped to make such decisions, and presumably Caltrans managers' responsibilities reflect Caltrans needs and research priorities. Nonetheless, the process could probably have been improved by a more thorough discussion of needs, opportunities, and priorities.

A Recommended Structure for Research Decisions

The basic recommendation is to enhance the research management process in the direction of more clearly and demonstrably linking the funded research portfolio to the interests of the end users. The recommendation has four elements:

1. **Begin With Explicit Consideration of the Goal of the Transportation System and how PATH Research Can Support that Goal.**
2. **Give More Attention to Caltrans Needs and Priorities.**
3. **Pay More Attention to Moving Research into Practice.**
4. **Bring Greater Rigor to the Research Management Process**

Element 1: Begin With Explicit Consideration of the Goal of the Transportation System and How PATH Research Can Support that Goal

This would involve systematically eliciting from the participants at the earliest joint Caltrans-PATH research planning meetings opinions regarding Caltrans and California transportation goals, problems and opportunities, and a prioritization of them. This includes explicitly writing out each goal, problem and opportunity, and defining each of them in a clear enough way that it can be "scaled." That is, so that a scale (perhaps a subjective, verbal scale[6], but a scale nonetheless) can be defined clearly enough for each goal, problem and opportunity so that each research program can be assessed in terms of how well it addresses each goal, problem or opportunity. Any given research program may only address one or two goals, problems or opportunities, but that system of scaling will allow each research program to be evaluated in user-driven, needs-driven terms consistent across the range of programs being considered. There are established tools from a field called decision analysis that can be used to define and scale the goals, problems and opportunities as called for here.

Once that foundation is laid, subsequent research planning meetings can be built around four types of questions:

1. "Which goals, problems and/or opportunities does the proposed research project address, and how well does it address each of them?"
2. "What constituencies would be interested in that project? That is, who would want to implement it, at the public sector and/or the private sector level, and why? If it were possible to fully inform citizens regarding the proposed research[7], what degree and breadth of political support would be behind this project?"
   Alternatively, "What worthwhile on-going or new projects would this research enable?"

[6] Such a scale for goals might be "must be met", "very important", "less important".

[7] Our assumption is that it is *not* possible to keep citizens fully informed about every decision that is made by public agencies, because these decisions are too numerous and citizens to not have time to attend to them all.

3. ”Of any two projects, both addressing similar goals/problems/opportunities, which addresses them more effectively, per taxpayer dollar and/or per consumer dollar?”

After the projects being considered are matched with corresponding goals/problems/opportunities:

4. “How well does this portfolio of research projects address the whole range of highest-priority goals/problems/opportunities? Are there goals/problems/opportunities being neglected while others have several projects stacked up under them? How can we re-select and/or reallocate the portfolio to address the range of goals/problems/opportunities in a more complete and/or more balanced way?”

Those questions can be addressed at any level of analysis. They can be addressed on a purely non-quantitative, prose basis, or with subjective verbal scales, or with subjective numerical scales, or with more quantitative verbal or numerical scales. At each of those levels, there are established tools from decision analysis that can support the process and provide methodological defensibility. This process explicitly provides for high-risk, speculative projects that have a potential payoff commensurate with their risk.

Element 2: Give More Attention to Caltrans Needs and Priorities

Early Discussions with Caltrans Regarding Problems and Priorities

Before the RFP is prepared and staff proposals are made each year, discussions should be held with Caltrans NTRP, Operations, District, and other staff regarding Caltrans needs and priorities, including specific problems that could be addressed by ITS and priorities for solving those problems. Then PATH staff could present ideas and research opportunities. Those discussions should be centered on the elicitation from the participants of Caltrans and California transportation goals, problems and opportunities, and a prioritization of them, as described under Element 1 above. Effort should be made to assign priorities to all research needs identified by Caltrans. It is understood that different organizational units within Caltrans and even NTRP may have different priorities, but this exercise should make differences explicit and lead to enhanced understanding within Caltrans and between Caltrans and PATH. It is critically important that the ultimate users of the research, Caltrans District staff and local agencies, be involved in these discussions.

Research Outreach

Since this paper was drafted, PATH and Caltrans have completed another RFP cycle and selected a 1998/99 research program. This experience and the comments of reviewers of the draft of this paper suggest that a more flexible, broad, and continuous means of eliciting research ideas is needed. The

reviewers suggested that people tend not to "volunteer" ideas and that there should be a staff person each from PATH and New Technology and Research to actively contact senior staff at Caltrans Districts and relevant Departments throughout the year to discuss research needs and ideas. We recommend that this approach be implemented on a trial basis as soon as possible. It would provide raw material for the discussions described above. The effectiveness of this approach should be weighed against the staff time required when the 1999/2000 RFP process is completed.

Research Needs Web Site

Although there is a need to solicit opinions from key Caltrans staff, there is also a need for a more inclusive and broad-based discussion of transportation and research problems, opportunities and priorities. To satisfy this need, PATH's ATMIS group developed a web site on which Caltrans and PATH staff and others can post and comment on research needs, research ideas, and research opportunities. The "Research Discussion Bulletin Board" was established at the end of January 1998. Interested Caltrans and PATH staff seeded it with discussions intended to pique visitors' interests and motivate them to keep watching and to contribute. Caltrans New Technology and Research staff and PATH staff were invited to visit and contribute. The site functions much like a newsgroup except that the postings are not automatically sent to all subscribers. The advantage of this method of soliciting ideas over meetings of managers is that it can be much more extensive, both in terms of the people involved and time available for discussion. Ideas can be considered in more depth from more points of view. Our hope is that it can also be a means of encouraging potential implementers to become research partners and possibly for matching them with appropriate researchers. Ultimately, people in regional and local agencies and the general public might also be included.

Our initial idea was to use tools from Decision Analysis, so that the site provided a structured, clear elicitation and presentation of problems, needs and opportunities. We also intended to involve PATH staff, Caltrans district staff at many levels, headquarters staff, and NTRP staff in the design of the site. But in our haste to get something implemented, we bypassed these steps. Our failure to take these steps may in part explain the fact that it has received only two postings. Clearly we need to find out if the lack of postings indicates a flawed idea, flawed execution of the idea, or simply insufficient awareness of its existence and lack of sufficient development of interesting threads of discussion. We will attempt to find the answer through our discussions with individuals and through group discussions and to modify the site, if necessary, to make it more effective.

Element 3: Pay More Attention to Moving Research into Practice

The 1998-99 RFP is encouraging more implementable research by giving special attention to proposals that include partnerships with implementers and provide for technology transfer. Similar encouragement should be given to

PATH staff research. Implementability has a bearing on the ultimate benefit of the research product. For example, if there are two projects with equal annual benefits once implemented, the lifetime benefits of the first to be implemented are clearly greater. Efforts should be made to include people from both the Institute of Transportation Studies Technology Transfer and the Caltrans NTRP Technology Transfer Programs in research program planning.

Element 4: Bring Greater Rigor to the Decision-making Process Regarding Caltrans/PATH Research

The use of decision analysis tools to facilitate the recommendations made here has already been noted, in particular the elicitation and structured-question steps of Element 1, and the structuring of the web site of Element 2. The following other decision analysis tools might also prove useful:

1. Scenario Trees: These trees would be useful for laying out systematically how the future could unfold, including the relative likelihoods of different research outcomes. The trees would be populated by objective probabilities where available, but most likely all of the important probabilities would be subjective, elicited using expert elicitation of expert panels.
2. Decision Trees: These trees are simply scenario trees with downstream decision nodes. These trees form the basis for developing R&D management strategies, including "midcourse corrections" as the results of uncertain research, technological trends and markets gradually become known.
3. Triage Analysis. As grim as this sounds, it would be a very effective analytic step, combining the results of the above three tools to identify which research programs would really make a difference. That is, research on technologies that are going to be developed and implemented with or without PATH research would be de-emphasized, as would be research on technologies that are apt to fail to be developed and implemented with or without PATH research. What remains is a PATH research portfolio that maximizes the effectiveness of PATH resources.
4. Value of Information Analysis: This analysis is a more quantitative version of triage analysis. It quantitatively parses out the incremental value of a given research program by evaluating the ultimate expected value of the R&D decision tree first with then without the program being assessed.
5. Adaptive Management: This process systematically manipulates the R&D decision tree to maximize the advantages of adaptive management. That is, it identifies those actions that maximize the

reduction in uncertainty and minimize commitment of resources and puts those actions early, relative to actions where the reverse is true.

PATH and Caltrans should consider investing in outside decision analysis expertise to help implement the other elements of the recommendation. The cost would be on the order of $25,000.

A Plan for Making Decisions Regarding Caltrans/PATH Research

The four elements of the structure recommended above fit into the following plan, presented in chronological order.

1. **Research Agenda Web Site –** Caltrans and PATH staff, and perhaps others, continuously post and discuss problems, research needs, research opportunities and research ideas. The web site is structured in a way that encourages the explicit development of Caltrans and California transportation goals, problems and opportunities, and their prioritization, as called for in Element 1 above.
2. **Outreach Team** – A team is formed consisting of a PATH staff person and a Caltrans New Technology and Research staff person. They actively contact senior staff at Caltrans Districts and relevant Departments throughout the year to discuss research needs and ideas. This provides input to discussions on the web site and larger meetings.
3. **Caltrans NTRP and other staff meet –** They discuss what has been posted on the web site and what has come up in meetings with the Outreach Team, add other ideas, and then prioritize research areas, keeping in mind the ultimate expected benefits of the research. The meeting discussion forms the basis for a statement of Caltrans research needs and priorities. Again, this discussion is structured in a way that encourages the explicit development of Caltrans and California transportation goals, problems and opportunities, and their prioritization, as called for in Element 1 above.
4. **PATH staff meet** – They do the same, except that a statement of PATH, rather than Caltrans, research priorities is prepared.
5. **Caltrans and PATH staff meet at the PATH Annual Meeting** – Taking advantage of being together at the same venue, their joint meetings are focused around combining the results of the preceding three steps.
6. **PATH/Caltrans retreat –** This should include Caltrans staff and staff from the Technology Transfer Program of the Institute of Transportation Studies. It might also include people from regional and local agencies. In preparation for the retreat,

PATH prepares a report on the state of current PATH research, mapping it into the system of goals, problems and opportunities and their prioritization that has been developed in the preceding four steps. This and the combined results developed in Step 4, including both the Caltrans and PATH research priorities, are sent to participants before the retreat. The retreat begins with presentations laying out the results developed in Step 5, including Caltrans and PATH research needs and priorities. These are discussed in terms of their expected benefits, and systematically subjected to the four types of questions described in Element 1 above. Consensus is reached regarding the PATH research agenda. This is made possible by proper preparation, well-organized presentations, and adequate time for deliberation. The 1997 PATH Retreat is a good model. The retreat should inform both the allocation of funds to PATH and the PATH RFP.

7. **PATH RFP –** This is based on the outcome of the retreat. Features designed to enhance the ultimate benefits of the proposed research are included. These would include the features from the 1998-99 RFP that proved effective and new features that showed promise in improving the quality or usefulness of the proposals.

8. **Proposal review –** No changes in this process are recommended, except that it be centered on the four types of questions described in Element 1 above.

9. **Staff research** – Some projects, because of their nature, can only be done by PATH staff and should be targeted directly at staff rather than faculty. An example is preparing the vehicles for the Automated Highway System demonstration. Except for such projects, staff research proposals should respond to the RFP, in particular filling critical gaps where there are no good faculty proposals. The mix of staff projects should be selected on the basis of the same four questions used to evaluate outside proposals.

10. **Caltrans proposal approval –** This process would include a systematic review of the proposal using the four types of questions. Ideally, this would take place before mid-August, so that researchers would be able to compete for the most qualified student researchers. When approval is delayed, the best qualified students are often hired for other projects and are not available for new PATH research.

Schedule

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Caltrans staff meeting	-----	-----									
PATH staff meeting	-----	-----									
Joint meeting of PATH/Caltrans staff at PATH Annual Meeting		-----									
PATH/Caltrans retreat		-----	-----								
PATH RFP sent out				-----							
Faculty and other outside proposal review							-----	-----	-----		
PATH staff proposal review					-----	-----	-----	-----	-----		
Caltrans approval										-----	----

This year, PATH is introducing three themes and five special features into its research program. Proposals that are responsive to these themes or include these special features will be given special consideration.

Theme 1. Decision Support for Intelligent Transportation Systems (ITS) Investments

Potential ITS implementers and people involved in decisions regarding funding need tools to assist in deciding which ITS projects to implement or fund. To help meet this need, PATH has developed a scheme for classifying the effects—benefits, costs, and other effects—of ITS in terms of overall transportation goals. PATH is now developing a framework for assessing these effects. However, more and better information about ITS effects is needed to fully utilize this framework. Therefore, research is requested in the following areas:

A.1.1 Methods to estimate and value the effects of particular ITS services or combinations of services

Methods could take many forms, including simple analytical methods or extensions of existing simulation models. Especially useful will be methods or improved methods for estimating the effects of commonly implemented services for which good models do not yet exist. Methods are also needed for valuing information (even when it does not change travel choice), assessing the effects of ITS services related to inter-modal passenger or freight movement, and estimating environmental effects, especially changes in vehicle emissions. The validity of the methods should be tested with real data whenever possible.

A.1.2 Evaluation of implemented ITS projects[8]

Such evaluations provide the knowledge base on which the above methods can be built. Information is needed on the benefits, costs and other effects of ITS projects, along with the factors that influenced them, such as the implementation environment, design and management. Evaluations involving public/private partnerships, personalized public transit, and comparisons of the relative effectiveness of various information or control strategies are especially needed. All significant effects should be included, even those that can not be monetized or quantified.

[8] Proposals should be made only for ITS projects that do not already have an evaluation component. For example, an evaluation program has already been established for the Southern California Showcase projects.

A.1.3 Decision Tools in Support of ITS Development and Deployment

Identify existing decision support tools, or develop new tools, for developing, deploying, and operating ITS systems in cost-effective ways.

Theme 2. The Model Transportation Management Center (TMC)

Special attention will be given to proposals that describe the role their potential product(s) would play in a model TMC. These might include but are not limited to the following.

A.2.1 Design of components of a TMC-operated system for measuring, processing, storing, and disseminating information on transportation system performance for use by TMC operators, planners, researchers, and the general public

Research could deal with the entire system or with one component. If the latter, interactions with other components should be noted and accommodated

A.2.2 Methods for monitoring loop detector accuracy and adjusting for error

Loop detectors are the primary traffic surveillance method currently in use. Therefore methods are needed to automatically monitor the accuracy of current loop detectors and adjust for error in real time.

A.2.3 Methods for optimizing incident management and other traffic management techniques

Many methods for incident detection are in use and under development. However, incident verification remains a problem. Overall cost-effectiveness in reducing delay could be enhanced by developing new verification methods and by better integrating detection, verification and response strategies. Metering strategies, both onto freeways and between freeways, can also be optimized and integrated into incident response strategies.

A.2.4 Origin-Destination estimation and prediction methods

More accurate origin-destination estimates are needed for modeling and real time traffic management.

A.2.5 The role of TMCs in inter-modal freight operations

How can TMCs utilize ITS to improve commercial vehicle operations in and around ports, airports, and rail terminals? Are special commercial vehicle strategies needed or justified?

Theme 3. ITS Applications in Inter-modal Services and Public/Private Partnerships

A.3.1 Benefits of ITS in Inter-modal Passenger Service

Research is needed to identify and measure the benefits of ITS applications in inter-modal passenger service. Possible benefits include increased accessibility; reduced travel time, energy consumption, and air pollution (as a result of synchronized operations); smoother traffic flow; increased use of high occupancy vehicles (shuttles, buses, etc.); and somewhat decreased reliance on private automobiles. Evaluation Tools, forecasting models, and simulation model, as well as case studies may be used. Case studies to evaluation the benefit of existing system with inter-modal services may also be used.

A.3.2 Market Demand for ITS Applications in Inter-modal Operations

Research is needed to identify opportunities to use ITS services in inter-modal passenger and freight transport and to evaluate market demand for ITS services.

A.3.3 Public/Private Partnerships To Utilize ITS in Inter-Modal Freight Operations

In order to appropriately utilize ITS in inter-modal freight operations, public agencies need more information on opportunities for and constraints on public/private cooperation in implementing ITS in inter-modal operations. Issues to be investigated include: strong agency and/or industry biases toward certain modes; varying perspectives on the performance, benefits, and justifiable costs of inter-modal services; diversity of organizational objectives and expectations for inter-modal services; use of multiple standard operating procedures by operating agencies; concerns about having to share proprietary information on goods, movements; concerns about security and safe handling of goods during transfer; concerns about private sector responsibilities and potential liabilities; and difficulties in initiating and sustaining inter-modal, inter-agency and public/private partnerships.

A.3.4 Public/Private Partnerships in ITS Implementation

Evaluate different ways of forming and executing public/private partnerships to implement ITS. Study past and present experiences and propose approaches to better undertake and ensure the success of public/private endeavors in the research, development, and implementation of ITS.

Special Features

Feature 1. Partnerships with research users or implementers

Proposals that include in their research plan a partnership between researchers and users or implementers of the research will be given special consideration. Users or implementers could be part of the research team or they could serve on an advisory panel for the project. PATH hopes that such partnerships will encourage research that is responsive to users' and implementers' needs and that results in products that are more apt to be implemented. Proposers are encouraged to form their own partnerships, but PATH may be able to assist in identifying appropriate partners. Call Robert Tam at 510-231-5656 or e-mail rtam@uclink.berkeley.edu

Feature 2. Benefit Assessment

Special attention will also be given to proposals that include in their research plan a task to estimate the benefits of the deployed product(s) of the research. That does not mean that the research must result in the deployed product. But it does mean that the benefits of the research are to be estimated based on the deployed product(s) that are apt to result from that research. Estimates based on empirical data will be given more weight than estimates that are not. Special consideration will be given to benefit estimates that take into account the uncertainty in whether or not each possible product will be deployed, when it will be deployed, and its performance once deployed. PATH is not asking that an inappropriately large fraction of the budget be allocated to benefit assessment, but simply that such benefits be considered.

Feature 3. California ATMS Testbed

This facility at UC Irvine now receives real-time data from loop detectors and video cameras operated by Caltrans District 12 in Orange County. Similar data will soon be available from the cities of Anaheim and Irvine. The testbed also contains traffic simulation capabilities and allows researchers to actually implement and test some control strategies. Additional capabilities are under development. A description of the planned infrastructure components is found in the Appendix[9]. UC Irvine staff are available to assist researchers in using the facility or to arrange for researchers to capture data for their research. Call Professor Wilfred Recker, Institute of Transportation Studies, University of California, Irvine at (714) 824-5642 or Der-Horng Lee at (714) 824-1876 (email: dhlee@translab.its.uci.edu) for more information. Proposals that utilize the capabilities of this facility will be given special consideration.

[9] This refers to the appendix to the RFP, which is not included in this paper.

Feature 4. Caltrans-UCSB Testbed Center For Inter-operability (TCFI)

Research proposals are sought to utilize the resources and capabilities (software, hardware, simulation models, communications networks, and support staff) available at the *University of California at Santa Barbara (UCSB) Testbed Center for Inter-operability (TCFI).* This center has been established by Caltrans and UCSB to pioneer efforts in the development, testing, demonstration, and deployment of distributed systems, ITS standards, standards dependencies, inter-operability and system integration. One of the Center's objectives is to help establish a statewide integrated transportation high speed networking and advanced wireless communications network linking Caltrans districts, TMCs, UC campuses, and other partners from local and state agencies and private industry The testbed provides facilities for research in the following areas:

Distributed Systems

- Software reuse (CORBA Component Model, COM/CORBA inter-working, object oriented s/w cost models, testing, verification, configuration management, sustainability and maintainability)
- Security in distributed object environment
- Data interchange and mobile agents
- Real-time and fault tolerant CORBA specifications and implementation issues (specifically WAN related issues)
- ORB portability and ORB interoperability
- CORBA specifications in the special interest groups; electronics commerce domain, telecommunications domain, and transportation domain

Transportation Information and Control (Communication Systems)

- Integrated communications/sensors
- Interoperability of high speed networks (special interest to multimedia, interactive real-time virtual simulation application and parallel systems over ATM MAN/WAN)
- Deregulation impact on communications network technology, services, and economics
- Emerging wireless technology and services (DSRC spectrum IMT 2000)

Standards and Interoperability and Integration:

- Experimental design, protocol testing and demonstration of ITS standards (CORBA, ITS DATUM and location referencing, DSRC and NTCIP), dependencies and interoperability. Special interest in

end-to-end integration issue (from application to wireless and wireline media).

Feature 5. Technology Transfer

Special attention will be given to research projects that include a plan to transfer useable results of the project to professional practice. The plan should be appropriate for the intended audience and could involve, for example, designing training workshops or materials, facilitation of research/practice forums (to identify next steps), or writing a non-technical version of research results. The plan should be developed in consultation with the Technology Transfer Program of the Institute of Transportation Studies, which can provide expert advice in how best to bring the research into practice. For more information, call Linda Howe, Manager of Technology Transfer (510) 231-5678 or e-mail lhowe@its.berkeley.edu). For research that will be implemented by Caltrans, researchers should consult Michael Essex, who heads the Caltrans New Technology and Research Program's Technology Transfer Program, at (916) 654-9961.

PREATRP: Procedure for Review and Evaluation of Advanced Transportation Research Proposals

Mohamed AlKadri

Introduction

Research proposals are supposed to describe three research components: input, process, and output. Research input encompasses defining the problem, searching the literature, proposing a concept or a hypothesis, and establishing the need for the research. The research process encompasses how the research will be conducted, the proposed research methodology, selection of variables, analysis of data, and so on. The research output is the product of research. It takes the form of a concept, theory (proven/disproved hypothesis), set of observations and/or conclusions, set of recommendations (regarding a policy, procedures, or standards), system design, simulation model, computer algorithm, and so forth.

Need for Integrated Research Evaluation

The tendency in peer review of research proposals is to focus on research "input" and "process." Evaluation of the "input" and the "process" is normally done based on the proposal contents. Critiques can be supported with proper references to literature and established research practices. However, assessing the value of the research "outcome" is much more difficult. It requires beginning with the end in mind and often "guessing" the value of the research outcome for the real world. This is sometimes overestimated, underestimated, or overlooked altogether by reviewers.

Caltrans New Technology and Research Program (NT&RP) as well as PATH face this challenge in evaluating research proposals. PATH (mainly peer) reviewers are interested in new concepts, advancement to the state-of-knowledge, theory and hypothesis, and methodology of proposed research. Caltrans reviewers, on the other hand, are more interested in the research outcome, ease of technology transfer, technical and economic feasibility of implementation, extent of real-world problem solving, and measurable benefits of research in the short and long runs.

By way of solving this problem, Caltrans NT&RP and PATH researchers have worked together on this research project (PATH MOU-209) to establish a standardized procedure to evaluate research proposals. The procedure had to be scientific, applicable to all areas of ITS, and able to evaluate technical merit as well as implementation potential. It had to use one commonly agreed upon value system with specific measures of merits. It had to encompass all possible questions formatted in a proper language. One great challenge in creating this "standardized" procedure was how to examine the significance and value of proposed research while still encouraging creativity, originality, and new concepts (with less than certain outcome) and not restricting researchers on how to conduct their research.

PREATRP Research Evaluation Procedure

PREATRP, Procedure for Review and Evaluation of Advanced Transportation Research Proposals, has been designed to help reviewers make a balanced judgment by taking into account all three components simultaneously. A literature review on the state of practice in research evaluation was performed [1-6]. Among many sources, the previous PATH evaluation form, the San Diego Association of Governments (SANDAG) Proposal Scoring System and Evaluation Sheet [4], the Lawrence Livermore National Laboratory (LLNL) standard research evaluation process [5], and the Transportation Northwest (TransNow) research evaluation procedure [6], were all consulted to develop PREATRP evaluation categories. In addition, the goals and mission of Caltrans New Technology and Research Program (NT&RP) were used to determine the value system by which research proposals were to be evaluated. The NT&RP Strategic Plan was used to define research priorities. The NT&RP Program Plan was used to determine weighting scores.

A draft of the first version of PREATRP was circulated to obtain reviews from practitioner and academic points of view. The feedback was generally positive (see Exhibit 2). Many suggested specific improvements, and all feasible improvements have been made in the final version currently in use. Figure 1 shows the various consulting sources and contributors to the development of PREATRP.

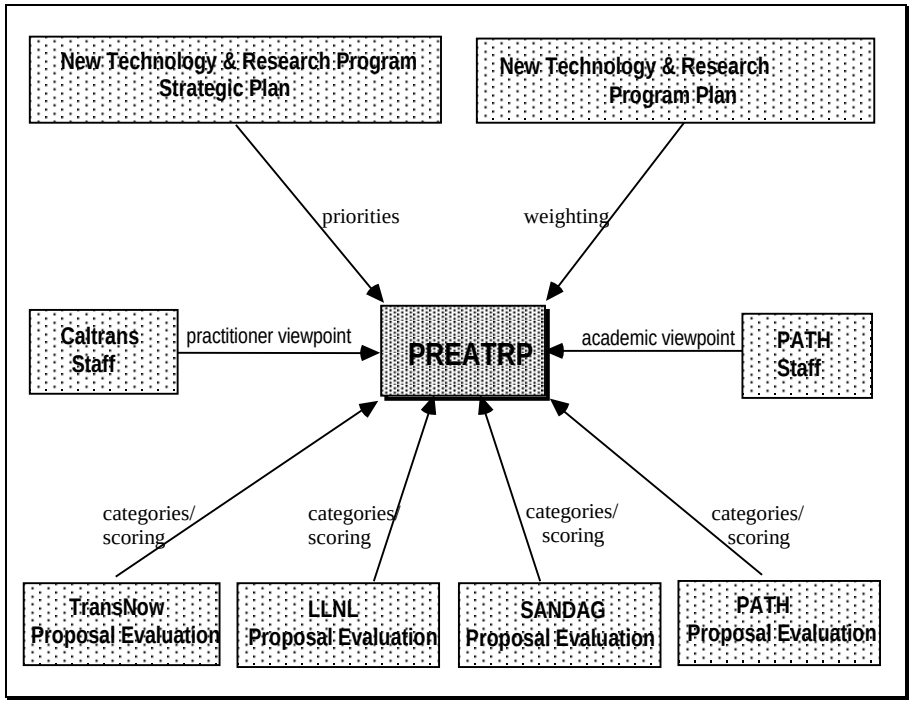


Figure 1. Input to PREATRP Development

Description of PREATRP

PREATRP is a procedure that has been designed to help Caltrans and PATH review ATS and ITS proposals from PATH partner campuses and other sources. It was first developed in 1995 and tested by few PATH and Caltrans reviewers to evaluate 1995-1996 proposals. It was further modified under MOU-209 and formally adopted by Caltrans and PATH as the standard evaluation procedure (and form) beginning with proposals for the 1996-1997 academic year.

This procedure has greatly improved the evaluation process at Caltrans and PATH. PREATRP asks critical questions and allows reviewers to score answers according to well-established evaluation criteria. The criteria are based primarily on Caltrans New Technology and Research Program mission, philosophy, stated goals, and research priorities.

PREATRP contains seven categories for evaluating proposals, including technical merit, implementability, and potential return on investment. Consideration of some of these issues might sometimes be underestimated, overestimated, or completely overlooked by reviewers. The seven categories are:

Significance and relevance to PATH goals & mission

Research methodology

Quality of research plan

Qualifications of research team

Budget

Utility of research outcome

Feasibility of implementation of research outcome

Each category has a set of questions intended to evaluate specific aspectsof the proposal at a microscopic level. Each question gives the proposal a score between 1 and 5 according to the following: 1= Poor, 2= Fair, 3= average, 4= Good, 4= Excellent. Scores are left blank if 'not applicable' or 'cannot judge' is checked. Scores are tallied for each category and divided by the number of applicable questions giving it one total average score.

Consistency among multiple reviews for each proposal is established by applying one standardized, not multiple evaluation criteria. With its clearly defined measures of merits, PREATRP encourages reviews to be concise and objective. At the same time, PREATRP is not restrictive in that it allows reviewers to use intuitive assessment. Reviewers are encouraged to provide written "qualitative" comments to discuss proposal aspects not captured in the quantitative section. Reviewers, if necessary, can make funding recommendations regardless of the final quantitative score so long as

recommendations are supported with proper arguments and convincing evidence.

The PREATRP form fits on a two-sided sheet and has been formatted to be easy to read, understand, and use (see Exhibit 1). Reviewers have the choice of using either a simple paper scoring sheet, or an electronic spreadsheet. PREATRP tables were developed using Microsoft Excel. Raw scores can be entered directly into the electronic version. Using the electronic version, all computations are done automatically and the reviewer is able to instantly view the resulting tabular calculations, evaluation summaries, and graphics, and print them on paper.

PATH Annual Proposal Evaluation and Selection Process Using PREATRP

Every year, PATH develops a Request For Proposals (RFP) to solicit research in Intelligent Transportation System (ITS) areas. RFP topics are based on what research has been done in each area and on existing research gaps. The draft RFP is circulated for review by implementing agencies such as Caltrans and by university researchers. Implementers have the opportunity to update their research information needs and the researchers have the opportunity to express new research interests. Subsequently, PATH synthesizes the input from researchers and implementers to identify a revised set of research priorities.

Based on the new set of research priorities, the RFP is finalized with help from Caltrans-PATH Research Coordinating Councils, and PREATRP is revised as necessary to reflect any changes to the value system by which proposals are judged. The RFP is then sent to PATH research partners and research institutions around the State. Figure 2 shows a flowchart of the process.

Researchers submit their proposals in response to the RFP. Proposals are then evaluated using PREATRP. Each proposal goes through a dual evaluation process: a) by practitioners mostly from Caltrans but sometimes from other public and private agencies and b) by academic reviewers from PATH and university campuses (i.e., peer reviews). Caltrans and PATH reviewers evaluate each proposal in its entirety. Each proposal is reviewed by at least 2-3 practitioners and 2-3 academic experts. Normally, Caltrans reviews focus on proposal objectives, budget, deliverables, real-world benefits, and implementability of outcome. PATH and university reviewers focus more on the research approach, research methodology, and technical merit. Coordinators from Caltrans and PATH assemble and reconcile multiple reviews of each proposal and submit consolidated recommendations to their management.

NT&RP management, on one hand, discuss practitioners' reviews and coordinators' recommendations and make preliminary funding decisions, taking into account overall NT&R Program needs. PATH management, on the other hand, discuss peer reviews and coordinators' recommendations and

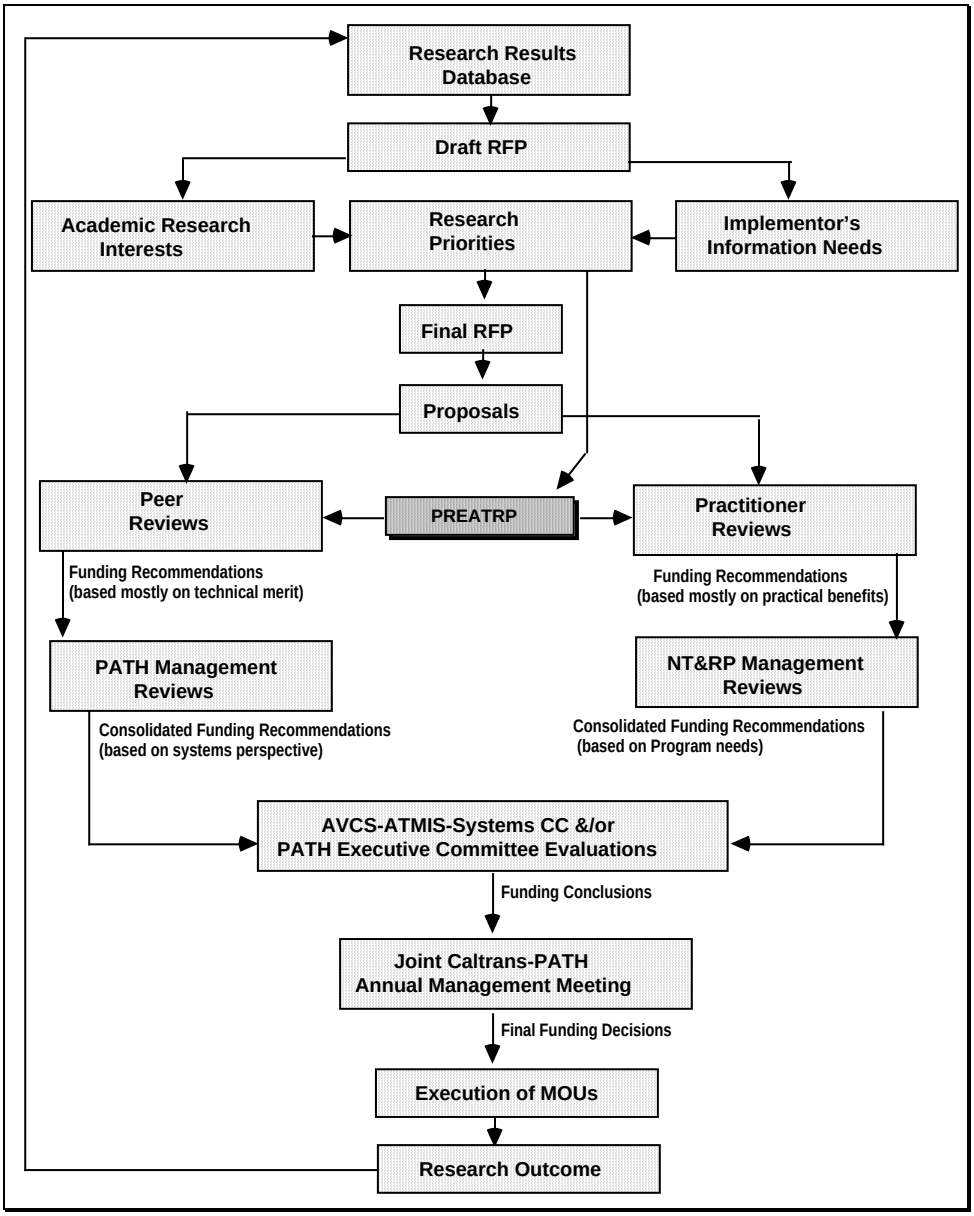


Figure 2. PATH Annual Proposal Evaluation and Selection Process

make preliminary funding decisions, taking into account an overall systems perspective. Preliminary funding decisions are discussed with the PATH Executive Committee and/or the AVCS, ATMIS, and Systems Coordinating Councils whose members come from academic institutions and implementing organizations. Evaluations are documented and presented to the Joint Caltrans-PATH Management.

Recommended proposals undergo a further down-selection process based on relative ranking and availability of funds. Joint Caltrans-PATH management discusses technical reviews, funding recommendations, Coordinating Council evaluations, and make final funding decisions. These decisions consider combined practitioner and academic perspectives as well as macro issues such as overall program goals, needs, research gaps, priorities, budget uncertainties, partnerships, short and long term research impacts, research management and implementation strategies. Policy direction, legislative mandates, and federal and state funding potentials are also considered.

Each selected proposal is processed into a Memorandum of Understanding (MOU) to execute the research. Each MOU is supposed to produce a set of deliverables, which constitute the ultimate output of the research. This output is added to the database of research results and is expected to advance and enhance the state of knowledge in ITS.

Exhibit 1: PATH PREATRP Proposal Evaluation Form

Proposal Title & No.: _____

Author(s) / Campus: «pi» «campus»

Reviewer's Name: _____ **Affiliation:** _____

Please enter a numerical score: 1=Poor, 2=Fair, 3=Average, 4=Good, 5=Excellent, or leave blank if 'not applicable' or 'cannot judge.. ***Please provide written comments on the reverse side.***

Significance and relevance to PATH goals & mission	
Clarity and focus of problem statement	
Concise definition of project objectives	
Likelihood of achieving stated objectives	
Originality and uniqueness of proposed research (any duplication of work?)	
Tie-in with past and ongoing ITS research within and outside PATH	
Advancement of ITS concepts and state-of-knowledge	
Research methodology	
Soundness of assumptions or hypotheses	
Appropriateness of research methodology	
Availability and reliability of proposed analytical tools, models, and techniques	
Availability of required research data	
Method of validating conclusions (model verification, sensitivity analysis, field testing, etc.)	
Quality of research plan	
Identification of tasks, milestones, and contingencies	
Adequacy of project timing, phasing, and duration	
Division of tasks within research team	
Likelihood of timely and successful project completion	
Qualifications of research team	
Academic qualifications and credentials	
Real-world expertise in area of proposed research	
Prior PATH research and project performance (if applicable)	
Budget	
Reasonableness of budget (labor, capital, equipment, facilities, subcontracts, travel, etc.)	
External cost sharing (if any)	
Overall cost-effectiveness of project -is the research worth the investment?	

Utility of research outcome	
Degree to which deliverables support timely, cost-effective deployment of ITS	
Contribution to solving significant California transportation problems	
Range of end users expected to benefit from implementation	
Feasibility of implementation of research outcome	
Identification of potential implementing parties	
Technical feasibility of implementation and ease of technology transfer to implementers	
Institutional feasibility of implementation	
Economic feasibility of implementation (cost of implementation to implementers)	

Reviewer's Funding Recommendation (circle one)

1 Fund as submitted

2 Fund with modifications (explain on reverse)

3 Do not fund

Research Priority (circle one)

H Urgently needed research

M Medium urgency research

L Low, do if extra funds are available

Reviewer's Signature:_____ **Date Evaluated:**_____

Proposal Title & No.: «pt» «pn»

Author(s) / Campus: «pi» «campus»

Reviewer number:

(PATH use only)

Please not that this page will be provided to the author(s)

Reviewer's Comments

Please return completed reviews by **April 4, 1997** to: Robert Tam
California PATH Program
Richmond Field Station
1357 S. 46th Street, Bldg-452

Richmond, CA 94804

Thank You!

Fax: (510) 231-9565

Exhibit 2: Selected Comments on PREATRP

A draft of the first version of PREATRP was circulated to obtain reviews from practitioner and academic perspectives. The feedback was overwhelmingly positive. Many suggested specific improvements, and all feasible improvements have been made to the final version currently in use. Below are sample feedback from Caltrans and PATH staff.

"Generally, I think your new PATH evaluation procedure is very well done. ... For your 'Procedure Objectives', you identify the heart of the matter: the research should be consistent with the New Technology Program goals and priorities...You have delineated the evaluation criteria to more discreetly definable chunks...I think your delineation and the relative weighting is quite good, and PATH may just have to learn to live with it." Joe Palen, NT&RP.

"The proposed procedure has the problem well-defined, and it is a serious problem...The premise of your solution [PREATRP] is well thought out, timely, and desperately needed. ... There are many excellent questions included that need to be asked, but there are too many. ... We need to start with all the good pieces of this document and then SIMPLIFY the evaluation and scoring process." Randy Woolley, NT&RP.

"We need to evaluate [while reviewing proposals] how the proposed research would [would not] constitute a 'building block' in the implementation of ITS... May this [PREATRP evaluation] be [preferably] done electronically by reviewers?" George Smith, NT&RP.

"Your proposed evaluation [PREATRP] is very good. ... In applying the proposed procedure, the process is rather lengthy. Unless this is done electronically, it many not be practical especially with the number of proposals and the available reviewers. However, all the criteria are important, and need to be included." Ramez Gerges, NT&RP.

"Very nice work. ... Someone will be using the deliverables as a means of managing the contract/ project. I suggest adding a fourth item 'deliverables' and giving it a weight of 5. [identification of] Clear, concise, and unambiguous deliverables make for less misunderstanding later in the project." Pete Zaniewski, NT&RP.

"The nature of benefits can include time savings, increased safety, dollar savings, preservation of environment, etc." Roy Rounds, NT&RP.

"The procedure is great and we need it as a tool. There is good presentation of the areas, topics, and evaluation criteria... We need to focus on milestones, consistency with ATS Program Plan and the NT&R Strategic Plan." Keith Christensen, NT&RP.

"We must focus on the ultimate product of the research... We need to look for who would be the beneficiaries of the research outcome, i.e., tax payers??... Must ask what is the relevance to our Strategic Plan... PREATRP is a good

tool and should be adopted for proposal evaluation by NT&R as well as [after calibration] UC Davis Automated Highway Maintenance & Construction Technology (AHMCT) Research Program." Tom West, NT&RP.

"Your procedure is a marked improvement over the existing [PATH] evaluation procedure." Jay Riley, NT&RP.

"Under 'Technology Transfer,' modify the wording to emphasize feasibility and ease of technology transfer to implementors." Hamed Benouar, NT&RP.

"[The procedure] is well structured... and should do what it is intended to do - help produce good reviews and proposal evaluations." Dr. Don Dean, NT&RP..

"[the procedure] is very good. Two problems need to be addressed: intermodal applications and our vision [which] promotes business and private industry..., not in place of public benefit, but in parallel." Bob Ratcliff, NT&RP.

"The procedure identifies excellent questions to be asked of proposals, but reviewers may not have sufficient information (e.g., a well-defined list of NT&R priorities, what has been completed in each area of research so far, what remains to be done, how much has been spent, how much more we can spend, etc.) to answer such questions in an educated way." "We have limited knowledge about PATH mission and goals, and therefore, those should be identified." "An assumption [obviously wrong assumption] was made that every reviewer had already received a copy of the PATH RFP. I recommend that a copy of the RFP be sent to every reviewer." Craig Anderson, NT&RP.

"As a reviewer, from outside PATH, I do not know how to evaluate the past performance of the PI's [Performance refers to technical, administrative, and contractual performance which some reviewers may not be familiar with]." "Most reviewers, especially Caltrans reviewers from outside New Technology, are not familiar with the state of research at PATH, the PATH Database, or the Project Tracker. Therefore, it was difficult for them to answer this question." Don Ochoa and Dr. Kazem Attran, Caltrans Transportation Planning Program.

"A proposed research outcome may be valuable and easy to transfer to implementors. However, the likelihood of adopting and implementing the outcome may not be highly likely for a variety of reasons. PREATRP should address this question." Jim McCrank, Caltrans District 4.

"...it is very fitting that someone try to revise the way in which PATH proposals are evaluated. For this reason, it is very refreshing to see a little more structure put on the evaluation process as you have done. If nothing else, the structure you are advocating allows us to identify the critical criteria that we should use in evaluating proposals. This in itself is a very valuable contribution." Mark Hickman, California PATH.

"Although some proposal objectives may be worthwhile as stated, deliverables, as described may not support the accomplishment of such objectives. PREATRP should as the question: To what degree do the deliverables support the accomplishment of the objectives?" Hong Lo, California PATH.

"PREATRP enumerates questions some reviewers may forget, but should ask of every proposal." Jim Misener, California PATH.

"It would have been nice to have separate questions for AVCS and ATMIS proposals, but PREATRP questions can still be applied to both areas." Godbole Datta, California PATH.

"This is the most comprehensive and thoughtful evaluation framework I have ever seen. It could be used for any project evaluation by [any] agency... there seems to be a need to consolidate [sub-categories] somewhat ... [but] all the items you have identified are important." Jacob Tsao, California PATH.

"I have always had discomfort with the current PATH Proposal Evaluation Form. I am glad that an effort is initiated to improve on the process. I still think that 'written' feedback is just as important." Scott Baysinger, California PATH.

"... I can see you have spent a lot of time thinking about it and coming up with a comprehensive and thorough evaluation procedure. This is very nice. I think the topics you chose are good. ... this will be a useful improvement compared to the current proposal evaluation [from]. ... I think of the sub-categories [of PREATRP] as triggers to the imagination of the reviewer, giving him ideas for what to look for and also a means to justify his final assessment. ... It is not human process to rank by statistics, but to rank by more fluid and impulsive mechanisms [what PREATRP is supposed to minimize]. ...In order to draw out this opinion in a rational manner we use [PREATRP] sub-categories. But I do not like the idea of assigning scores and computing rankings. The most useful information in a review is a paragraph written on the back... Where is the paragraph in your form?" Mireille Broucke, California PATH.

"With the following changes, we should begin using PREATRP as a standard tool for evaluating PATH proposals. Delete 'Availability of funding for implementation' since this changes constantly and is not a reliable measure of merit. Stress that reviewers provide written comments to supplement their quantitative evaluations." Dr. Pravin Varaiya, California PATH.

On the first version of PREATRP: "While this process [procedure] may be applicable for Caltrans internal research, I find it too mechanical for PATH evaluations. The criteria and the weighting factors shown here would promote the most mundane proposals and would work against the most innovative ones, those which have really advanced our knowledge and the state of the art. This is not well matched to high quality university research, I believe." On

the last version: "PREATRP looks good to me, an improved one from last year." Dr. Steve Shladover, California PATH.

On the first version of PREATRP: "I felt that you were pre-empting a management function of PATH (and personally of mine) by developing a tool for project evaluation that should reflect some kind of consensus set of values, but had never solicited mine... Caltrans frequently criticizes PATH for not delivering the right product, and, while I know you meant well, here I found a Caltrans initiative that I saw as getting in the way of our doing the efficient job that they are demanding... I should also repeat that because I find technical problems with PREATRP, the "organizational" problems described above are compounded... And, I should point out, this is a subject I feel quite expert about, and I am not inclined to claim that about lots of topics." On the last version: "I am now satisfied with PREATRP and feel confident recommending it be used by Caltrans and PATH reviewers." Dr. Stein Weissenberger, California PATH.

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Decision Support for ITS Implementers – On the Web

Joy Dahlgren

Motivation

In 1995, researchers with the PATH program at the University of California at Berkeley became concerned that what was being learned about intelligent transportation systems (ITS) was not easily accessible to potential implementers. As a result, implementation might not occur where appropriate and might be undertaken where not appropriate. PATH decided to design an information source that would describe ITS services, summarize what is known regarding their benefits and costs, identify deficiencies in existing research, and provide references to further research.

Fortunately, the desire to create such a resource coincided with the emergence of the world wide web. It is an ideal medium to distribute ITS information to a wide audience, and the contents can be readily updated and modified as ITS develops. The site is named LEAP, Learning from the Evaluation and Analysis of Performance, and is located at http://www.path.berkeley.edu/~leap. The primary audience is potential implementers—local planners, public works staff, consultants, and policy makers at all levels, but the site is also designed to be assist people involved in ITS research.

This paper describes the web site—its structure, sources of information, and current contents—and concludes with a discussion of planned improvements and responses of site visitors.

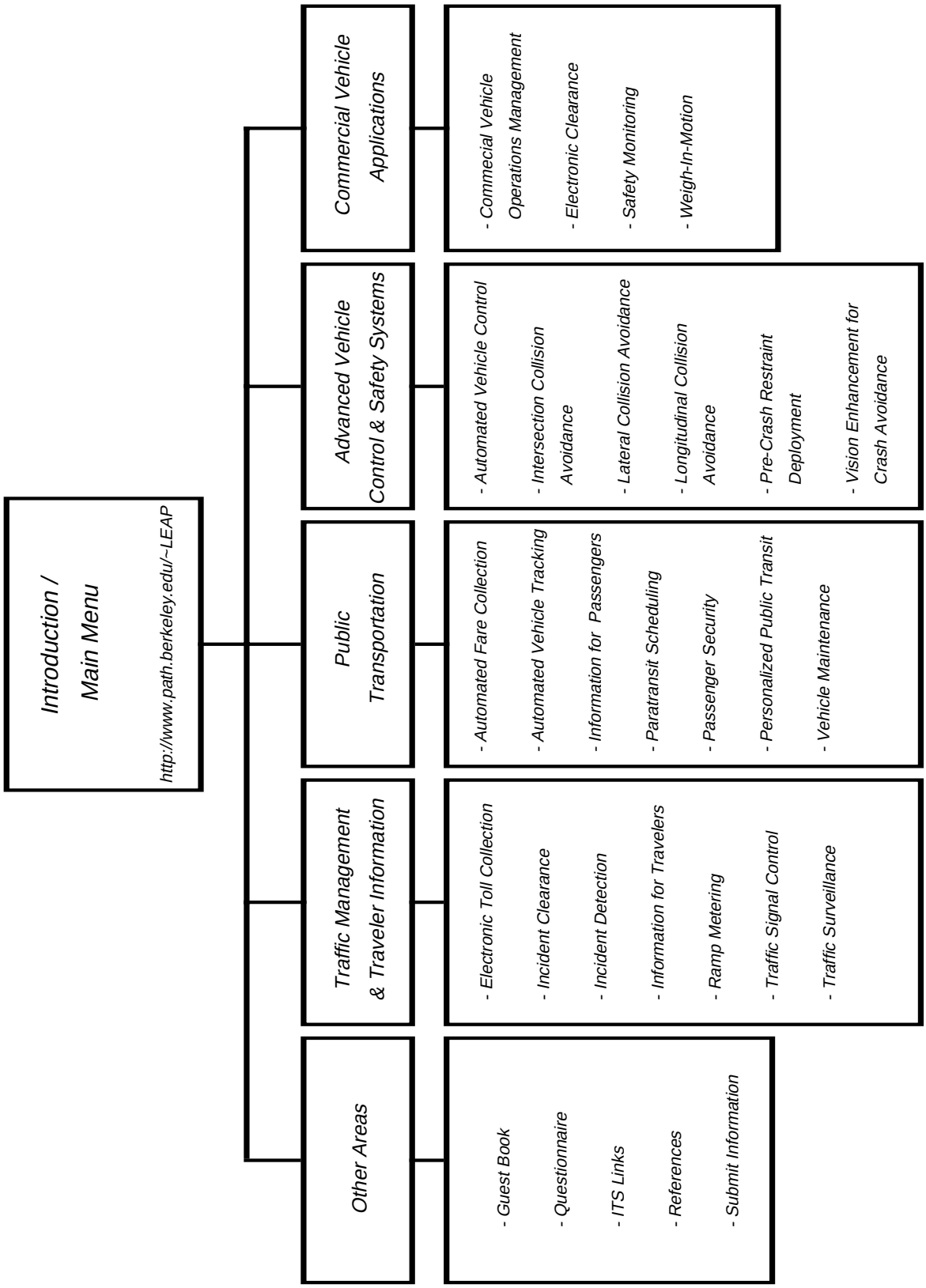
How LEAP Works

Structure

ITS Information

As shown in Figure 1, the site is organized according to the user services described in the Executive Summary of the National ITS Architecture: Travel and Transportation Management, Public Transportation Operations, Electronic Payment, Commercial Vehicle Operations, Emergency Management, and Advanced Vehicle Control and Safety Systems. The site is intended for people with different objectives; thus information is provided on a variety of levels.

Figure 1. Web Site Structure



The policy maker may prefer to look only at the highest level: summaries of the system or technology performance. The researcher may dig to the deepest level: evaluation methodologies and assumptions, test conditions, or research findings. Information about each ITS service includes summaries of findings as well as detailed tables and graphs that list case-by-case information.

The particular information that is provided for each ITS service varies, depending on what is available and, more importantly, the state of the practice. Performance measures are more readily available for mature systems, such as electronic toll collection, than for technologies that are still being tested, such as automatic incident detection using video cameras. Ultimately, the site is expected to be useful for making technology deployment decisions and research fund allocation decisions. Information about *measured* benefits and implementation costs is emphasized, because this is critical in making policy decisions. But because each ITS application is unique, additional information on the context of each application is also provided when available. For example, in discussing the performance of electronic toll collection systems, data describing the mix of modes and the traffic volumes at the toll plaza are presented.

To aid decisions regarding funding allocations for research, the site contains information on the different technologies being researched and their expected performance. To the extent possible, the performance of proposed technologies is compared to that of existing systems, to better understand what gains, if any, could be achieved with these technologies.

An important contribution of this site to ITS research is its assessments of the state of the practice. Gaps in the research are discussed. For implementers, barriers to implementation of a given service are noted whenever identified. The quality of evaluations is examined and sources of uncertainty in the data or methodologies are noted. Efforts are made to interpret the findings. For example, a review of the performance of incident clearance teams finds that most of their attributed benefits are savings in individual drivers' travel time. Although the total value of time saved at the system level is large, the time savings for each person are fairly small. Moreover, these benefits are calculated using a somewhat arbitrary value of time, usually assumed uniform over the population. Sensitivity analyses, testing assumptions about the distribution of the value of time over the population, about capacity reductions, or traffic levels, are rarely performed.

Web site users, reading the summary of research results, the evaluation of the research itself, and the costs and benefits (effects) of the particular ITS service in various settings, can better judge what the effects of applying the technology might be in their own situations. If a user wishes to learn more about the individual evaluations or studies, he or she can consult the references associated with each service.

The gathering of information from published sources is a continuous process. The site is updated as significant publications become available. In this

respect the web site provides a great advantage over published hard copy. It can be kept continually current, whereas hard copy can not be updated every time there is a small revision.

Cross Referencing

One of the advantages of the web is that information can be cross-referenced. For example, vehicle detection technologies used in electronic toll collection are similar to some of the technologies proposed for incident detection. The traffic surveillance technologies used for ramp metering can also be used for incident management and traveler information. In fact, the web site's organization highlights the importance of traffic surveillance as the foundation of several ITS services. Surveillance activities provide most of the information required by these services, and consequently their costs and effects are highly dependent on the current state of surveillance technology. By cross referencing information, the web site can help increase awareness that as surveillance technology advances, several ITS services may become less costly and more effective. In general, the web site's organization makes it easier to see the implications to one ITS service of advances or breakthroughs in related technologies.

Seeing the connections between ITS technologies gives web site users a better picture of how ITS works and what components are necessary to implement a given technology. Again, this means that in order to implement a motorist information system, first a good traffic surveillance program must be in place. The organization of the web site, as much as the information itself, can convey this message.

Links

To ensure that LEAP did not duplicate existing resources, other ITS-related sites were surveyed prior to site development. While these resources provided complementary information, none overlapped with the objectives of LEAP. A page within the site provides links to many ITS-related sites, some of which are described below:

ITS America - *http://www.itsa.org*

ITS America is a Congressionally-mandated organization established to coordinate the development and deployment of ITS in the United States. To aid in this goal, the site provides an activity calendar, employment opportunities, technology summaries,

ITS Deployment - *http://128.169.84.18*

An online database of the ITS infrastructure deployed in urban areas of the United States

ITS Online - *http://www.itsonline.com*

News, articles, and online forums related to ITS and transportation.

Rural ITS – *http://www.ruralits.org*

A site featuring rural applications of ITS.

PATH Data Base – *http://www.nas.edu.trb/about/path1.html*

An annotated data base of over 13,000 articles and books on ITS.

Transportation Resources - *http://dragon.princeton.edu/~dhb*

A comprehensive list of links to web-based transportation resources.

United States Department of Transportation - *http://www.dot.gov*

This site describes Federal participation in ITS research and deployment.

The Bureau of Transportation Statistics - *http://www.bts.gov/smart*

A digital library with transportation research papers available for download.

Feedback

In order to effectively develop the site for its target audience and to guide PATH research, a portion of the site is devoted to visitor feedback. Visitors can leave their name and email in a guest book, and contribute suggestions or information through online questionnaires. The feedback is summarized in greater detail later in the paper.

Sources of Information

To date, information for the web site has been gathered primarily from published sources: research and trade journals, conference proceedings, project evaluation reports, research reports, and other web sites. The excellent services and extensive collection of the Institute of Transportation Studies Library at the University of California, Berkeley has facilitated the compilation of information.

Most information currently on the web site comes from specialized research, trade, and public sector reports. The most complete and reliable information comes from evaluations of field tests and deployed systems. However, these are generally available only for mature services, such as freeway service patrols and electronic toll collection. For services and technologies that have not been widely deployed, such as advanced incident detection or vehicle guidance, much of the information is based on analytical studies, computer simulations, or limited-scope tests.

Through the literature review it has become clear that some systems are not evaluated, or that some evaluations are not published, particularly those of less successful applications. Such results should be made available, since important lessons could be learned from seemingly negative outcomes. Also, for some of the systems documented in the site, additional information would be helpful in understanding their effectiveness. One avenue to pursue is the web site's feedback page—one of the questionnaires is designed to solicit

information about evaluations not yet included in the web site. However, to date few people have volunteered such information.

Current Contents

The web site contains information about Advanced Traffic Management Systems (ATMS): traffic surveillance, incident detection, incident clearance, ramp metering, traffic management centers, and electronic toll collection. It also contains information about Advanced Traveler Information Systems (ATIS), including pre-trip information, en-route information, route, guidance, and rideshare matching. It includes Commercial Vehicle Operations Systems (CVO) and Advanced Public Transportation Systems (APTS), including automated vehicle location and advanced fare payment. It also includes longitudinal collision avoidance. Sections on variable message signs, probe vehicles, and highway-rail intersection management are currently under development and will be added soon.

Planned Improvements

Because there have been many recent additions to the web site, bringing it close to containing information on all ITS services, we plan to send an email to everyone who has signed the guest book, announcing the new additions. We will also send notices to ITS and other relevant newgroups.

LEAP already has a link to the ITS Architecture web site, which provides access to all architecture documents. The evaluation web site will not duplicate this information, but will include architecture information that enhances the usefulness of the evaluatory information. It will provide information on the physical, communications, and institutional requirements of each market package or service, and also identify other market packages that utilize the same components. It will also include standards, to the extent that they have been developed. Whenever possible, the web site will use terminology from the architecture. The web site is based on what has been done or at least carefully researched, while the National ITS Architecture is a framework for ITS future development. Therefore, the web site may not contain evaluatory information on all user services. However, this information will be added as additional ITS services are implemented.

Two major improvements are planned. The first is to add information about implementations for which there are no published evaluations. Managers and sponsors of these implementations will be contacted directly once the available published information has been gathered.

The second planned improvement is to provide advice about ITS service implementation[10]. As the web site now stands, the user can look around and delve as deep as he or she likes. But other than providing information in an

[10] These improvements were not part of MOU 209 and are not part of MOU 356, which funds continuation of the web site development.

organized and concise form, the web site provides no help to the user in deciding what to do or how to do it. The initial conception of the web site has been expanded to include not only information but also tools for deciding where and how to implement various ITS services. The tools for determining *where* to implement a particular ITS service may be hueristics, sketch planning methods, or models for estimating the effects of various ITS services in particular circumstances. Many people and organizations are trying to finds ways to model ITS benefits and costs; this is another effort in that direction.

Such an analysis might be approached in two ways; in either case ITS services and transportation system needs or problems would be linked. The web site visitor might begin with an ITS service and determine what benefits and costs might result in his or her particular setting. Alternatively, he or she might begin with a particular problem and determine which ITS services or conventional improvements would be most cost-effective in addressing the problem in his or her particular circumstances. The process would begin with the web site providing information and access to models to assess the current situation. Once the user had done this, the web site would present the user with a range of possible actions to address system problems. For those selected by the user, the web site would present hueristics, sketch planning methods, or models for selecting the most promising. The appropriate scale and limits of implementation would be developed in the process. Positive and negative interactions between ITS services would be identified and taken into account. This iterative process would ultimately provide a good match of actions to mitigate problems as well as solid analytical support for justifying the actions.

This may ultimately include the decision support framework currently being developed by PATH under MOU 357.

This portion of the project draws heavily on research and design undertaken in connection with PLANiTS, a computer assisted planning tool envisioned by PATH. PLANiTS was initially developed before the web came into widespread use and therefore was a few years ahead of its time.

For ITS actions that have been selected, advice on *how* to implement those actions would be provided. This advice would draw upon the literature and the experience of previous implementers. It could include implementation checklists or sample implementation plans.

In addition to providing analytical tools, PLANiTS also envisioned providing an interactive, multi-user planning environment. Once the other improvements to the web site have been completed, this might be an interesting avenue to pursue.

Response

Between July 1996 and July 1998, the site had over 8,000 visits. More than 100 signed the guest book or returned questionnaires. Visitors' affiliations are closely divided between academic institutions, the private sector, and

government organizations. (Figure 2) Respondent occupations ranged from emergency vehicle drivers and traffic signal technicians to university faculty and private-sector consultants. Visitors originate from Australia, Canada, China, Denmark, Finland, France, Korea, Japan, Mexico, the Netherlands, New Zealand, Portugal, Sweden, United Kingdom, and the United States. (Figure 3)

Overall feedback has been positive and constructive. Apart from suggestions concerning the site's layout, content, and organization, several visitors have volunteered information not reported on the site. Others have requested additional information and even asked for advice on ITS implementation.

Figure 2. Respondent Profession

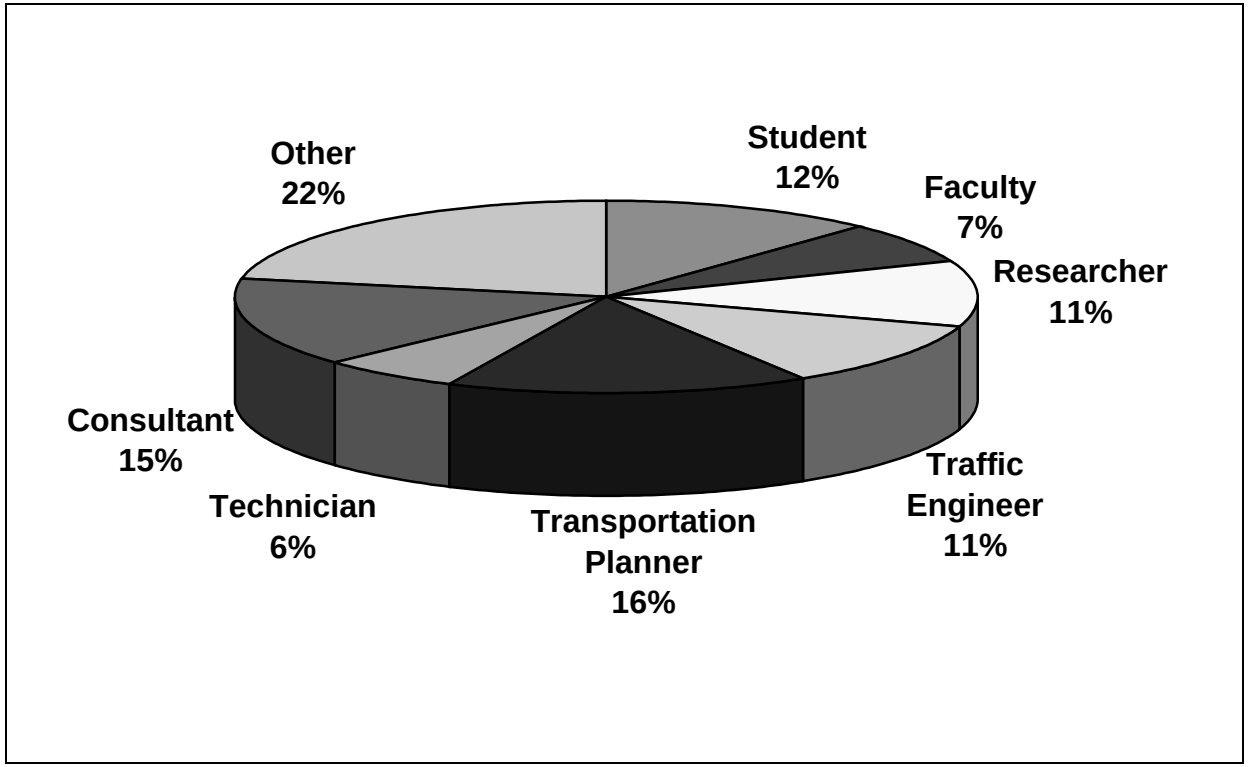


Figure 3. Respondent Affiliation