

UC Berkeley

Research Reports

Title

Integrating ITS Alternatives into Investment Decisions in California

Permalink

<https://escholarship.org/uc/item/8kr6h7kj>

Authors

Dahlgren, Joy
Lee, Jr., Douglass B.

Publication Date

2004-10-01

CALIFORNIA PATH PROGRAM
INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

Integrating ITS Alternatives into Investment Decisions in California

Joy Dahlgren, Douglass B. Lee, Jr.

**California PATH Research Report
UCB-ITS-PRR-2004-40**

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

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

Final Report for Task Order 4150

October 2004

ISSN 1055-1425

June 2004

Integrating ITS Alternatives into Investment Decisions in California

Prepared for the California Department of Transportation

**Authors: Joy Dahlgren and Douglass B. Lee, Jr.
Project Manager: Ashkan Sarafsaleh**

California Center for Innovative Transportation
Institute of Transportation Studies
University of California at Berkeley

FINAL REPORT

Acknowledgements

This study was performed for Caltrans Division of Research and Innovation by the California Center for Innovative Transportation at the Institute of Transportation Studies at the University of California at Berkeley.

The authors would like to acknowledge the assistance of Dr. Mohamed AlKadri, Systems Engineering and ITS Decision Support Branch Chief, Caltrans Division of Research and Innovation, and Katie Benouar of Caltrans Division of Planning, as well as the study's advisory committee members:

Mahmoud Mahdavi	Caltrans Division of Planning
Bill Tournay	Caltrans Division of Planning
Gordon Arruda	Caltrans Division of Mass Transit
Fred Dial	Caltrans Division of Traffic Operations
Pete Zaniewski	Caltrans Division of Research and Innovation
Tori Kanzler	Caltrans Division of Research and Innovation
Eric Alm	Caltrans District 4 Planning
Lisa Klein	Metropolitan Transportation Commission
Dean Munn	Association of Monterey Bay Area Governments

Many other people provided information regarding the planning process, the role of ITS, and specific project information:

Steve Hague	Caltrans Division of Planning
David Lively	Caltrans Division of Research and Innovation
Blanche DeLeon	Caltrans District 4 Planning
Christina Atienza	Metropolitan Transportation Commission
Ross McKeown	Metropolitan Transportation Commission
Jeff Georgevich	Metropolitan Transportation Commission
Bob Huddy	Southern California Association of Governments
Jon Elson	Santa Clara County
Anne Tsang	ITS America
E. B. Lee	Institute of Transportation Studies, UC Berkeley
Cyrus Minoofar	Alameda County Congestion Management Agency
Frank Quon	Caltrans District 7
Linda Turnquist	Caltrans Division of Planning
Ashkan Sharafsaleh	Institute of Transportation Studies, UC Berkeley
Kurt Scherzinger	California Transportation Commission
Hamed Benouar	Institute of Transportation Studies, UC Berkeley
Lily Lim-Tsao	Santa Clara County
Scott Eades	Caltrans District 5
Luis Mendez	Santa Cruz County Regional Planning Commission
Pranav Shah	Caltrans District 4

While the authors are grateful for the time and energy expended on the part of those who helped us, the authors take sole responsibility for interpretation, as well as any errors and omissions.

Abstract

The purpose of the study was to document the process by which decisions are made in California about implementing intelligent transportation systems (ITS) projects, and to consider ways for “mainstreaming” ITS in the sense of evaluating ITS projects alongside non-ITS projects. The transportation planning and decision process is reviewed and described as a base for judging the efficacy of decisions with respect to the adoption of (ITS) projects. The decision process is complex and varied, involving government agencies at federal, State, regional, and local levels, but the process seems to be workable and suitable. In practice, however, critical information for making decisions does not appear to be available to decisionmakers at the points in the process when they need it. In particular, information on the impacts of ITS projects and the expected benefits appears to be missing from planning and project information documents such as Project Study Reports. Although generic claims for benefits in the form of delay savings, accident reductions, and other user or environmental benefits are sometimes provided, they are not quantified and are not specific to the particular project. Costs, on the other hand, are usually very specific, because they represent a budgetary commitment. Good decisions, however, call for better information on what benefits the specific costs will generate.

Providing better information on benefits does not need to take major effort, and precise answers are not essential; any estimates would be better than what is provided currently, and the processes and methods for generating the information can be improved with experience and streamlined at the same time. A few examples of the type of analysis that would be helpful are presented in the context of two California ITS projects.

Some recommendations are offered for moving toward improved information for making decisions about ITS projects, allowing them to be compared with other transportation investment on an equal footing.

Executive Summary

Public investment in transportation projects is the result of decision processes that depend upon information. The processes are unique in some ways for every municipality, region, and state, but they typically involve many people and organizations. The information utilized to make decisions may be formal or informal, explicit or intuitive, and relevant or tangential.

To at least some degree, California's problems with highway congestion, transit services, safety, and vehicle emissions could be mitigated by ITS, but a review of currently programmed transportation projects in California found only a few projects that could be classified as ITS, representing a very small fraction of funding. Relatively few state and federal funding programs have funding specifically available for ITS. ITS components can, however, be included in standard projects such as highway expansion or rehabilitation. Should more ITS projects be implemented? Are there biases or deficiencies in the decision processes that favor or disfavor ITS? How easy is it to assess the merits of ITS projects?

Use of ITS in California

This study seeks ways to encourage the inclusion of ITS alternatives in situations where ITS treatments offer benefits relative to costs that are comparable to other types of transportation improvements. The study investigates what can be done to insure that the following questions are addressed during the planning process:

Study Purpose

- Are there ITS services that can help solve the community's problems?
- Are there data and methods that can be used to estimate ITS benefits relative to costs that permit direct comparisons between ITS and other possible improvements?

Potential implementers of ITS are concerned about how well it will work and what impacts it will in the local context. This study looks at both the process by which ITS and other transportation improvement decisions are made in California, and the ways in which useful substantive information can be incorporated into those decisions. The study attempts to reconcile several perspectives, taking a top-down look at planning and decisionmaking as well as a project-specific look through two case studies.

Transportation planning is a complicated process with many sources of funds, each with different criteria and requirements. All projects that are programmed in the State Transportation Improvement Plan must be supported by a completed project study report (PSR) or other Project Information Document (PID). California Transportation Commission policy requires that projects or groups of projects be evaluated in terms of their costs and benefits.¹ Caltrans policy requires value analysis of any projects

Transportation Planning and Project Evaluation in California

¹. See See "Appendix A: The CTC Policy on PSRs" on page 75.

that will cost over a million dollars; this analysis identifies alternatives to the proposed project, evaluates them, and identifies the alternative that provides the required functions with the lowest overall costs.²

A number of analytic tools are being offered for assistance in project evaluation in general and ITS in particular. Caltrans has developed Cal-B/C, a model that estimates the benefits and costs of new highways, highway expansion, ramp meters and HOV lane connectors.³ Caltrans also supports a website providing guidance on selecting ITS treatments and another offering general guidance on benefit-cost analysis (BCA).⁴ These are two among many such planning and analysis aids that are available, each of which has its strengths and weaknesses for the purposes of evaluating ITS projects.⁵

Stovepipes

To help make the decisions both systematic and easier, the decision processes categorize the choices into those of similar type. Transportation is a broad category, highways and transit are smaller categories, safety and pavement are even narrower categories. Colloquially, these categories are sometimes called “stovepipes,” meaning that once decisions are categorized, the choices are made within each category and independent of other categories. Expenditures on transit are determined by the funds allocated to the transit stovepipe, and highway expenditures are determined separately.

For purposes of generating alternatives—either alternative ways of solving the same transportation problem (for which only one alternative will be selected), or alternative proposals for programming (of which as many projects as can be funded may be selected)—stovepiping may be necessary and productive. The best ITS projects can be evaluated against each other, while the same occurs for capacity-increasing projects. Ultimately, however, projects serving a wide range of transportation purposes using a variety of treatment (e.g., ITS and physical improvements) must be prioritized for implementation.

While stovepipes may reduce the number and range of choices, and thereby reduce the burdens on the decision process, the categorization prevents or obstructs tradeoffs that may be important. If the same problem could be treated with either a safety improvement, or a pavement improvement, or a combination, the separation of these categories becomes an obstacle rather than an aid.

Findings

On paper, the current planning process looks good. But three factors limit its effectiveness, particularly with regard to ITS. The first is the availability of data. Despite the thousands of traffic monitoring devices installed around the state, for a number of reasons good data for a particular section of road are not likely to be immediately

². See section “4.3.6 Value Analysis (VA)” on page 23.

³. Refer to section “4.4.1 Cal-B/C” on page 24 for further details.

⁴. See section “4.4 Economic Analysis Tools” on page 24.

⁵. See section “4.3 Analytic Tools” on page 21.

available. Second, because ITS is relatively new, there is a scarcity of information about its effectiveness in various situations. Third, although there are policy recommendations urging the use of benefit-cost analysis, and considerable technical assistance, it is rarely accomplished or attempted and expected impacts are seldom quantified.

ITS has often been oversold by its enthusiasts, which has led to skepticism about ITS in some quarters. Overly ambitious projects have tended to encounter problems that result in delay in implementation or incomplete deployment, making people reluctant to undertake ITS projects. PSRs and strategic plans present ITS treatments with vague promises of efficacy, usually divorced from the actual setting and supported at best by generalized claims (e.g., coordinated signal and surveillance systems decrease travel time by 8-20%). Followup studies have typically been inconclusive.⁶

For ITS, the problems can be summarized by the following:

- Information for helping to choose among ITS alternatives, or among other transportation improvements, is currently inadequate for making good decisions.
- Practices for introducing relevant information at suitable points in the decision process are especially weak with respect to evaluation (benefits and costs).

These problems can be addressed in several ways.

(1) Make ITS investment decisions in comparison with other types of transportation investment, i.e., integrate ITS planning into the established planning process.

Recommendations

Decisions regarding ITS probably should not be stovepiped, i.e., separated from other decisions about transportation investment; ITS should be “mainstreamed.”⁷ While ITS project alternatives can be designed and developed in conjunction with other ITS projects, selection of projects for prioritizing or programming should take place in a context of all suitable alternatives for solving a given problem or enhancing transportation system performance.

Some proponents feel that ITS is still in an “incubator” stage and needs to be given earmarked funds. We are of the opinion that ITS needs to make its case on objective grounds in competition with other types of projects, and will gain more rapidly if it does so than from being protected.

⁶ See, for example, SAIC (September 2003) and Rakha et al. (May 1999).

⁷ This suggests that matching ratios or other funding constraints should be the same for relevant alternatives; while desirable from the standpoint of making choices neutral with respect to costs and benefits, the bias can be offset at least in part by a decision process that considers all applicable alternatives.

- (2) **Promote more aggressively the use of benefit-cost analysis for evaluation of project alternatives, whether ITS or non-ITS, and for selection of projects for programming.**

Currently, decisionmakers do not have information on project impacts or benefits, and are left having to generate the information from other sources as best they can.

- (3) **Conduct BCA both before-the-fact, while projects are in the planning stage, and after-the-fact to acquire information about what makes for successful projects and to improve forecasting and analysis methods.**

Impacts on traffic, accidents, etc., should be estimated and the key parameters identified that will result in a successful deployment. Both prospective evaluations and retrospective evaluations are needed. Not every project needs a retrospective, but every programmed project (as well as those that don't make the cut) should have a prospective BCA. Shift the retrospective evaluation paradigm from "before-and-after" to "with-versus-without" to obtain results that are useful for planning.

- (4) **Initiate formal evaluation for a project early in the planning process, and deepen it as the project becomes a candidate for programming.**

Thinking about impacts and potential benefits helps to clarify purposes and aids in designing the project to maximize benefits.

- (5) **Analytic methods and data need to be developed in response to actual problems, as opposed to generating all-purpose analytic tools.**

Analysis tools should be considered successful only if they are actually used in project design and evaluation. "Back-of-the-envelope" methods are often more useful for planning and evaluation purposes than refined models that require substantial effort and data to run. The availability of data and performance measures that are suitable for estimating the prospective benefits of a project needs to be increased.

- (6) **If separate ITS plans are prepared as a means for generating ITS project proposals, the plans should estimate the benefits of each project in solving the transportation problems identified in the specific context in which the projects will be deployed.**

- (7) **Establish an organizational unit for "Economic Analysis" to conduct project-level evaluations and provide technical assistance as needed.**

Economic evaluations would be included in all planning information documents (PIDs) such as project study reports (PSRs). Professional staff familiar with data sources, benefit-cost analysis, spreadsheet delay and safety models could follow projects from conception to programming, offering suggestions or conducting analyses as needed.

Contents

Executive Summary	v
Use of ITS in California	v
Study Purpose	v
Transportation Planning and Project Evaluation in California	v
Stovepipes	vi
Findings	vi
Recommendations	vii
1 Study Purpose and Approach	1
1.1 Purpose for this Study	1
1.2 The Planning Process and Project Decisions	1
1.3 Study Strategy	3
1.4 Problem Solving in Transportation	4
1.5 Example Case Studies	5
1.6 Organization of this Report	6
2 Transportation Planning and Decisionmaking in California	7
2.1 Transportation Planning in California	7
2.2 Current California Investment Programs	9
2.2.1 State Highway Operation and Protection Program (SHOPP)	9
2.2.2 State Transportation Improvement Program (STIP)	10
2.2.3 Regional Transportation Improvement Program (RTIP)	10
2.2.4 Interregional Transportation Improvement Program (ITIP)	10
2.3 Programs Outside the STIP/SHOPP Process	11
2.3.1 Congestion Management and Air Quality Program (CMAQ)	11
2.3.2 Regional Surface Transportation Program (RSTP)	11
2.3.3 Transportation Enhancement Activities (TEA)	11
2.3.4 Local Transportation Sales Tax Programs	11
2.3.5 Transportation Fund for Clean Air (TFCA)	11
2.3.6 Federal and State Special Projects	12
2.4 How ITS Fits into the Current Planning Process	12
2.4.1 Currently Programmed ITS Projects	12
2.4.2 California Transportation Commission Policy	13
2.4.3 CMAQ Guidelines	13
2.4.4 Corridor Planning	14
2.4.5 Federal Guidance	14
3 Diagnosing Transportation Problems	15
3.1 Current Transportation System Problems and Needs	15
3.2 How Could ITS Mitigate these Problems?	16
3.2.1 Congestion	16
3.2.2 Transit	17
3.2.3 Safety	17

3.2.4 Emissions	17
3.2.5 Traveler Information	17
3.2.6 Traffic Surveillance	18
4 Planning Tools and Resources	19
4.1 Planning Documents	19
4.1.1 Transportation Plans	19
4.1.2 Project Study Reports	19
4.2 ITS Data Sources	20
4.2.1 PeMS Database	20
4.2.2 Other sources of Data	20
4.2.3 FHWA ITS Benefits Database	20
4.3 Analytic Tools	21
4.3.1 ITS Decision Website	21
4.3.2 Traffic Analysis Tools	21
4.3.3 ITS Deployment Analysis System (IDAS)	21
4.3.4 Intermodal Transportation Management System	22
4.3.5 California Air Resources Board Analytical Tools	23
4.3.6 Value Analysis (VA)	23
4.4 Economic Analysis Tools	24
4.4.1 Cal-B/C	24
4.4.2 Benefit/Cost Website	24
4.4.3 Economic Analysis Primer	24
4.4.4 MicroBENCOST	25
4.4.5 AASHTO Redbook	25
5 Earlier Studies of ITS Implementation	27
5.1 The Value of Incremental Development and Learning Networks	27
5.2 Mainstreaming ITS	27
5.3 Survey of ITE Members for ITS Decision Website	28
5.4 Lessons from Case Studies	29
5.5 Summary	30
6 ITS Example Project: Silicon Valley-ITS in Santa Clara County	33
6.1 Purpose of the Project	33
6.2 Planning Reports	35
6.3 Project Description	35
7 ITS Example Project: SR-17 in Santa Cruz County	41
7.1 Planning Reports	41
7.2 Problem Context	43
7.3 Alternative Treatments	44
7.4 Public Preferences	54
7.5 Long Term Planning	55
7.6 Improved Planning Information	55

8 Findings	57
8.1 On Paper the Current Process Looks Good	57
8.1.1 The Caltrans Recommended Steps	57
8.1.2 California Transportation Commission Policy on Project Evaluation	58
8.2 There are Few ITS Projects in the Current RTIPs	58
8.2.1 Overselling of ITS	58
8.2.2 Problems Encountered With Overly Ambitious ITS Projects	59
8.2.3 Architecture Requirements Can Inhibit Implementation	60
8.2.4 ITS Plans Are Not Always Problem Driven and May Inhibit Consideration of ITS in Developing Regional Transportation Plans	60
8.3 There is Little Estimation of the Benefits of ITS Projects at Any Stage of the Planning Process	61
8.3.1 Data on the Effects of ITS are Scarce	61
8.3.2 Data Regarding the Current Transportation System may be Difficult to Find	62
8.3.3 Evaluations Can Still Be Done, Even With Limited Data	62
8.3.4 There is Little Guidance Regarding How to Conduct Analyses	62
8.3.5 Interorganizational Gaps in Communication	63
8.4 Other Factors	64
8.4.1 ITS Projects May Have Unforeseen Uses	64
8.4.2 Highway Operations Are Not Given Much Importance	64
8.4.3 Caltrans Decentralization Can Retard Progress	64
9 Recommendations	65
9.1 Integrate ITS Planning into the Planning Process	65
9.2 Encourage Benefit-Cost Analysis in the Planning Process	65
9.2.1 Make Basic Data More Readily Available	65
9.2.2 Encourage Retrospective Evaluations of Projects	67
9.2.3 Establish an Economic Analysis Group	67
9.3 Develop Realistic County and Regional ITS Plans	68
9.3.1 Create Near-term ITS Plans that are Problem Driven	69
9.3.2 Ease Conformance with the National ITS Architecture	69
9.3.3 Use ITS Plans for Information Exchange	70
9.4 Change the Emphasis of ITS to “Operations”	70
10 References	71
Appendix A: The CTC Policy on PSRs	75
Appendix B: BCA Evaluation of ITS Pilot Projects	79
A.1 Analytic Strategy	79
A.1.1 Methods and Models for Project Evaluation	80
A.1.2 Benefit-Cost Evaluation	80
A.2 Freeway-Arterial Diversion in the Silicon Valley	81
A.2.1 Line Haul Function	81
A.2.2 Users Make Choices	81
A.2.3 Supply and Demand	81
A.2.4 Recurring Delay and Incident Delay	82

A.2.5 Preconditions for Benefits 82

A.2.6 Traveler Information 82

A.2.7 Whether Diversion is Faster 84

A.2.8 Estimating Benefits of Arterial Diversion 84

A.2.9 Estimating Benefits of Carpool Lanes 87

A.3 SR-17 From Santa Cruz to Los Gatos 88

A.3.1 Incident Delay 88

A.3.2 Estimating Benefits from a HOV/HOT Lane 91

1 Study Purpose and Approach

1.1 Purpose for this Study

The objective of the study was to develop a framework for transportation investment decision-making that included intelligent transportation systems (ITS) as well as more traditional physical improvements. This orientation was in response to the perception that intelligent transportation systems were not being fully utilized by transportation agencies, and that the pace of implementation was slow because such systems were not considered during the planning process.

This naturally then led to the question of whether speedier or more widespread implementation of ITS was warranted on the basis of its effectiveness in solving local transportation problems. Encouraging the deployment of ITS in situations where it would not be as useful as alternative investments is counterproductive. Therefore, the study investigated not only whether ITS options were being considered, but whether there was sufficient evidence at the point of decision to make a sound determination on the merits of ITS.

1.2 The Planning Process and Project Decisions

Overall, the study sought to understand and describe the decisionmaking process for transportation capital funding, looking closely at the ways relevant information is or could be introduced into that process so as to make sound decisions. The subsequent objective was to determine how ITS alternatives could be included in the planning and selection process, so that ITS investment can be compared to other types of investment in a balanced way.

A diagram representing the aspects of the decision process that are of interest is shown in Figure 1. At the top, funds are raised at federal, state, and local levels of government, usually with some restricted range of designated purposes with respect to transportation. Transit and highways used to be completely separated from each other, from the federal level down to local, but ISTEA legislation in 1991 provided for much greater flexibility in using funds for either purpose, at local discretion. These categorical restrictions (labeled “stovepipes”) nonetheless still exist, and are created at all levels of government. When funds become available to state and local decisionmakers, they try to match the fund categories to problems they perceive.¹ The process for doing this is to prioritize projects that are proposed by state and local agencies, according to problem urgency and interjurisdictional fairness.

¹ The SCCRTC (2001) Plan contains a chapter with detailed explanation of sources of funds for Santa Cruz County projects, the extent and type of earmarking or dedication for each source, and a chart showing the shares of dedicated versus discretionary funds.

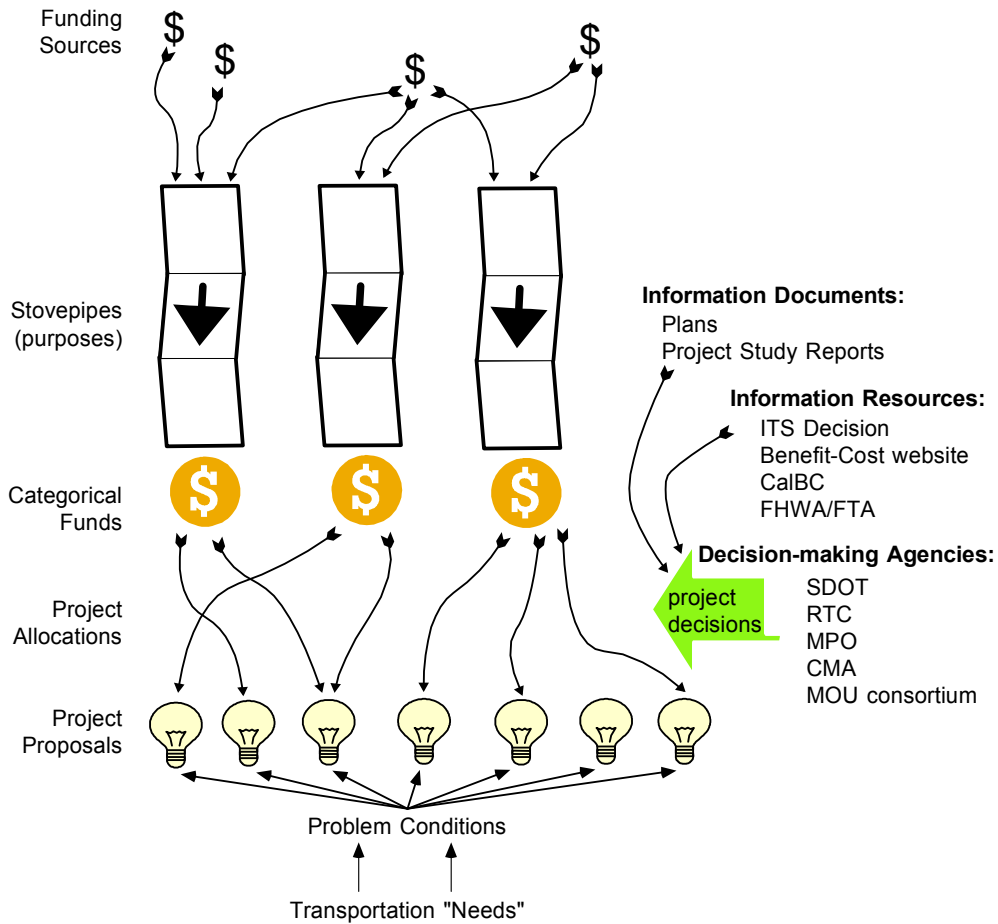


FIGURE 1. Structure of funding allocation process in California.

Decision-making agencies include state DOTs (Caltrans), Regional Transportation Commissions (e.g., Santa Cruz County Regional Transportation Commission), designated Metropolitan Planning Organizations (e.g., MTC in the Bay Area), Congestion Management Agencies (e.g., the CMA in Alameda County), and ad hoc groups of local agencies tied together through a Memorandum of Understanding (e.g., the Silicon Valley ITS group). Generally, one agency is responsible for a given project decision, but must reach agreement with other agencies. Each agency’s process is unique, but all must achieve a consensus before action can be taken, and decisions typically are made by a group of individuals rather than a single person. Decisionmakers are usually receptive to having good technical information available, although they may have preconceptions about the correct decision in any given instance.

Of primary concern here is the process and information used by the agencies to make choices among projects. The formal documents provided to (and by) these agencies include plans and project information documents (PIDs) such as project study reports

(PSRs). The plans may be state, regional, or lower level, and may include specific projects as well as policies. The PID/PSR is meant to be the information document for choosing projects and for programming funds, and each project should have its own PSR or equivalent. Regional and local agencies may not require any specific type of justification report, and may be more informal in what they expect in the way of documentation, but projects included in a transportation improvement program (TIP) should have some kind of suitable PID.

In addition to these relatively formal documents, other information resources are available to both professional staff and to decisionmakers. Several of these are web-based information sources that provide general guidance (e.g., how to conduct a benefit-cost analysis), background information (e.g., what kinds of ITS exist and serve which purposes), or specific data. (e.g., traffic volumes, accident statistics). This intersection of funding streams, local political decisionmaking, and information resources—indicated by the green arrow labeled “project decisions” in the diagram—is the most challenging facet of transportation infrastructure development; unwise decisions can generate negative consequences for the local economy and quality of life in the short run, and more so in the long run.

1.3 Study Strategy

To address these questions, the study simultaneously pursued a top-down strategy and a bottom-up analysis:

- (1) The macro view studied the planning methods and procedures promoted at the state and regional levels, and collected data on the nature of the decision processes through interviews with key participants in the planning and decisionmaking process. Resources describing the decision process in California and sources of methodology and data have been identified and evaluated.
- (2) The micro view worked from the perspective of two case study sites—the Silicon Valley arterial ITS deployment in Santa Clara County, and SR-17 from Santa Clara (Los Gatos) to Santa Cruz—and sought to determine how evaluation information was or could have been utilized in the decisions about specific improvements in those corridors. These projects were thought to provide good examples of ongoing projects with representative kinds of transportation problems and decision processes.

The study reviewed what was known about ITS implementation as well as the current transportation planning and programming process in California. Based on the findings of this review, recommendations were developed for improving the effectiveness of the existing planning process. A cross-section of people involved in transportation planning and ITS planning and implementation were interviewed to test and confirm these findings and to obtain feedback on recommendations and refine them.

1.4 Problem Solving in Transportation

Several aspects of the planning process seem to be not as productive in supporting good decisions as they might be. To provide a basis for discussion, we offer an “ideal” paradigm that is suited to describing the ways in which decisions actually get made:

- (1) Identify the problem and enumerate all of the aspects that create or constrain it; this can be done at the regional level for strategic planning purposes, but more commonly needs to be project- or facility-specific. By “problem” we mean a condition that negatively affects citizens, for example long delays on a particular road, lack of access to jobs for people without cars living in a certain area, or a high rate of accidents at a particular location. We do not mean “lack of regional ITS architecture” or “too many single occupant vehicles.” These may contribute to the problem, but they are not the problems that the people experience.
- (2) Generate a comprehensive list of alternatives that might be able to address at least some of the problem symptoms; the list should include traditional highway physical improvements, ITS applications, operations improvements, ridesharing initiatives including bus transit, parking programs, vehicle code enforcement, regulatory constraints, and new transit in its own right-of-way, as appropriate to the problem.
- (3) Explore the most plausible alternatives by making back-of-the-envelope calculations of costs and, most importantly, likely impacts; the most promising options can be explored further by making quantitative estimates of benefits, driven by potentially measurable assumptions. e.g., incident duration.
- (4) Provide the estimates of costs and benefits at key decision points in the planning process: when it is decided that the project or program is worthwhile and should be part of the short range transportation plan, when priorities are set for utilizing available funding, and when projects are programmed and funded. These estimates should be backed up with evidence from previous experience using the same treatments. The estimates should be refined at each step in the decision process.

This is a highly simplified outline of a preferred process for informing decisionmakers of what they need to know before making a decision, but it will serve to focus the discussion of integrating ITS decisions into the planning process in California.² We do not seek to revise the decision process but, rather, to support the existing process in the most efficient manner.

² The steps listed are also included in those recommended by Caltrans’ Division of Transportation Planning, described below in Section 8.1.1 “The Caltrans Recommended Steps” on page 57.

1.5 Example Case Studies

Two California ITS projects were selected by the Advisory Committee³ at its March meeting in 2003 as prototypes for an investigation of the evaluation of ITS projects. Both the decisionmaking process for selecting such projects and the technical analysis used to support decisions are encompassed by the study. In one of the case studies (Santa Clara/Caltrans District 4) the group of agencies only considered ITS applications within its scope of effort; at the other case study site (Santa Cruz/Caltrans District 5), planners turned to ITS only after physical improvements were found to be too costly. The two projects are:

- (1) Silicon Valley ITS (SV-ITS), an arterial management project in a freeway corridor.
- (2) SR-17 in Santa Cruz County, a major freeway with portions not built to expressway standards, and no arterial alternatives for diversion.

The broad questions of interest for these projects are:

- (1) How explicit were the expected impacts or benefits of the project before the project was implemented?
- (2) Did the goals of the project change during implementation?
- (3) Could prospective evaluation (i.e., a quantitative forecast of expected benefits, as opposed to retrospective evaluation of actual benefits) have provided better information about likely benefits?
- (4) How can technical information such as benefit forecasts be incorporated into the decision process for ITS decisionmaking?

Broadly, both projects involve arterial management, and require cooperation between many state and local governmental jurisdictions. The choices faced by the agencies are influenced by many factors, notably:

- (1) The level of trust and cooperation among jurisdictions.
- (2) The extent to which expenditure categories are “silos” or “stovepipes,” meaning that funds are allocated to categories by heuristic means, without knowing the costs or benefits of individual projects within the categories.

³ Advisory Committee for the PATH (Partners for Advanced Transit and Highways) study “A Framework for Integrating Investment Decision Analysis Across ITS and Other Caltrans Investments,” initially with Dr. Joy Dahlgren as Principal Investigator and subsequently with Mr. Ashkan Sharafsaleh after her retirement. The committee is composed of members representing transportation agencies in California appointed by Caltrans in January, 2003 (see “Acknowledgements” above), and chaired by Mohamed AlKadri.

- (3) The amounts of funds available from non-local sources (state and federal) that are “earmarked” in some way that constrains their use to limited purposes.
- (4) The likelihood that the project will produce results that will be perceived by the public as beneficial.

The two projects, although lying in two Caltrans districts, are oriented toward a single stretch of the same highway, namely, State Route 17 (SR-17, which becomes I-880 when it crosses I-280 near San Jose). The study area runs from Santa Cruz at the south end over to Santa Clara County and up to Milpitas at the north end. The location is thus at the south end of the San Francisco Bay Area. Both projects lie in a commuting corridor.

1.6 Organization of this Report

The report proceeds from a general description of the planning process to specific consideration of project alternatives, then draws some conclusions. Section 2 reviews current transportation planning in California, including transportation system needs, the potential role of ITS in addressing these needs, currently planned transportation investments, the planning process, and how ITS fits into the process. Section 3 contains findings regarding ITS and the planning process, including results of interviews with people involved in transportation planning and programming at various levels of government around the state. Section 4 describes a range of information resources available for transportation planning analysis. Section 5 summarizes previous studies of ITS implementation. Sections 6 and 7 describe the two case study examples. Section 8 summarizes study findings regarding the process for project selection, and Section 9 presents recommendations for integrating ITS into the planning process, both as a tool for improving transportation and as a means to provide information for improved transportation planning. Appendices explain CTC policy on project information and give examples of simple benefit-cost analyses.

2 Transportation Planning and Decisionmaking in California

Separate from efforts to deploy particular ITS treatments is the overall planning process that may or may not accommodate the inclusion of ITS projects in investment decisions.

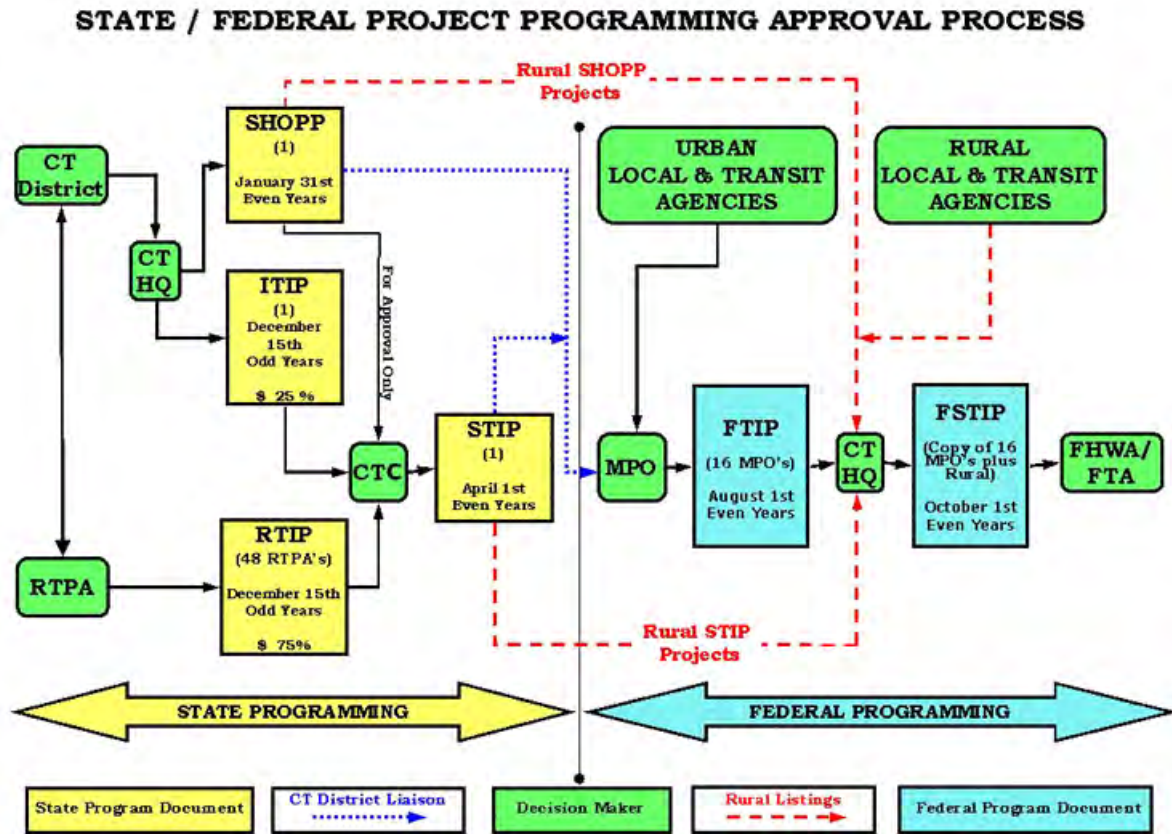
2.1 Transportation Planning in California

Transportation planning is a tedious and complicated process with many sources of funds and many different sets of criteria and requirements. There is a state programming process and a different, but related, federal programming process. The left side of Figure 2 shows the state process, which focuses on the STIP (described below in Section 2.2.2 “State Transportation Improvement Program (STIP)” on page 10) and the SHOPP (described below under 2.2.1 “State Highway Operation and Protection Program (SHOPP)” on page 9). County and transit district projects are carried forward by the regional transportation planning agencies (RTPAs) or by Caltrans in counties where there is no RTPA. The RTIP is developed from these projects. Caltrans develops the ITIP, a program of interregional transportation improvements. The RTIP and ITIP are submitted for approval to the California Transportation Commission (CTC) and upon approval become the STIP. Although the CTC has the final word on STIP funding, very few changes to the RTIPs or ITIP are made by the CTC.

The federal planning process focuses on the Federal Statewide Transportation Improvement Program (FSTIP), which includes all projects that are of regional significance or are federally funded. This process is shown in the right side of Figure 2. The FSTIP includes not only the STIP and SHOPP, but also projects in the CMAQ (described in Section 2.3.1 “Congestion Management and Air Quality Program (CMAQ)” on page 11), RSTP (Section 2.3.2 “Regional Surface Transportation Program (RSTP)” on page 11), and TEA (Section 2.3.3 “Transportation Enhancement Activities (TEA)” on page 11), as well as federal transit demonstration programs, and other state and locally funded programs of regional significance. It must include evidence that the projects can be completed by funds reasonably expected to be available and must be demonstrated to be in conformity with the air quality plan for the area. Submittal of the FSTIP is a condition for receipt of federal transportation funding.

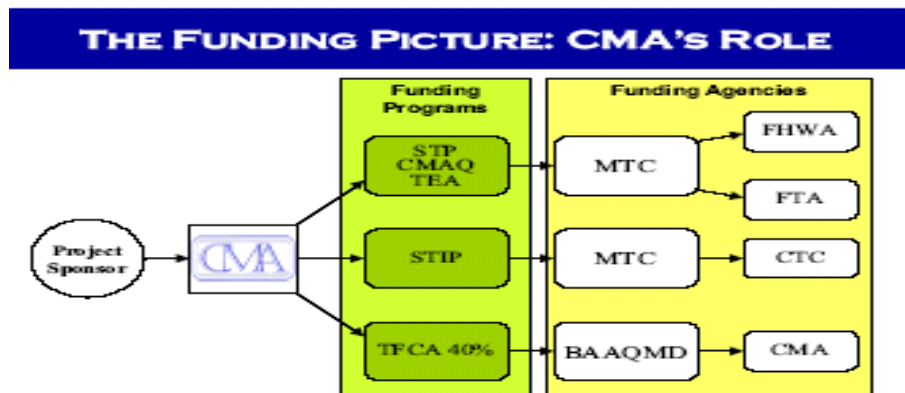
Figure 3 shows the process from the perspective of the county congestion management agency (CMA). The project sponsors are cities, the county, and transit agencies. Although CMAQ funds are not programmed by the State, California law apportions funds to areas that have not attained air quality standards on the basis of population weighted by the degree of non-attainment of air quality standards. Elements of the CMAQ are programmed directly by the regional agencies.

Federal law apportions Regional Surface Transportation Program (RSTP) funds by population to the 11 urbanized areas in California with populations of 200,000 or more and one additional region that includes the rest of the state. These funds are also programmed by the regional agencies except for the last case, in which they are programmed by Caltrans.



source: State/Federal Project Programming Approval Process, Department of Transportation, Division of Transportation Programming (<http://www.dot.ca.gov/hq/transprog/gifs/ProgProcess800.jpg>).

FIGURE 2. Programming Approval Process.



source: Alameda County Congestion Management Agency, Board Retreat, 2/7/04 Funding Summary (http://www.acma.ca.gov/pdf/board_retreat_2004_02.pdf).

FIGURE 3. Example funding process for a CMA (Alameda County).

The Transportation Enhancement Activities (TEA) funds are allocated to counties and Caltrans in the same manner as STIP funds and are programmed by the regional agencies and Caltrans. Each 2-year planning and funding cycle begins with Caltrans making an estimate of the funding that will be available from federal and state sources for the STIP and SHOPP in the next funding cycle. Most of the STIP funding is apportioned by formula: 75% to metropolitan planning organizations (MPOs) and counties and 25% to Caltrans for interregional projects. Of the MPO portion, 60% goes to Southern California and 40% to northern California. Two thirds of each allocation goes to counties based on the county population (75%) and state highway mileage (25%). Of Caltrans' share about half goes for the interregional road system outside urbanized areas, and a little less than 10% to intercity rail and grade separation. TFCA (Transportation Fund for Clean Air) funds in Alameda County are generated by a vehicle registration tax. These programs are described in greater detail in Section 2.2 “Current California Investment Programs” on page 9 and Section 2.3 “Programs Outside the STIP/SHOPP Process” on page 11.

The previous paragraphs deal with the top-down part of the planning process—the opportunities for funding, requirements and guidelines for each type of funding, and planning procedures (top of Figure 1). But the bottom-up part of the process is equally important. Projects originate in response to both opportunities and problems. The opportunities are typically funding for particular types of projects. This funding can come from a government agency, fees paid by developers, or other private sources. Another type of opportunity would be a rail right-of-way that is being abandoned by a railroad. A problem could be a congested road, an unsafe curve, or a lack of shelter for people waiting for buses. Projects arising out of these problems or opportunities find their way into city and county general plans, county congestion management plans, regional plans, and state plans. The county congestion management agencies (CMAs) work with their constituent cities to develop the county congestion management plans that provide input to MPOs or Caltrans, which in turn prioritize projects in order to develop their regional transportation improvement plans. Each Caltrans district is required to do advanced system planning based on traffic and economic projections. Bottlenecks or other problems are identified and measures to mitigate problems are developed and become the pool from which ITIP projects are selected.

2.2 Current California Investment Programs

Some of the stovepipes created at the state level seek to ensure that sufficient funds are available to address continuing needs such as system preservation.

2.2.1 State Highway Operation and Protection Program (SHOPP)

The State Highway Operation and Protection Program (SHOPP) is limited to capital improvements and operations costs related to maintenance, safety and rehabilitation of state highways and bridges that do not add a new traffic lane to the system. The 2002 SHOPP allocation for FY 2003/2004 totaled \$1.1 billion. Projects ranged in cost from \$121 thousand to replace planting on a Section of Route 99 in Fresno to \$56 million to

rehabilitate a Section of Interstate 80 near Auburn in Placer County. Out of 228 projects, 15—mostly roadway rehabilitation projects—cost more than \$10 million, and 17, many pedestrian or beautification projects, cost less than \$1 million. Road rehabilitation projects were the most numerous (60) and the most costly, accounting for about half the total SHOPP expenditures. Another large category of projects, accounting for almost \$200 million, was related to safety and collision reduction projects, such as realignments, median barrier and guard rail improvements, additional auxiliary and truck lanes, modified interchanges, and widening on and off ramp improvements. There were also bridge replacements and improvements, drainage and bank stabilizations, landscape and irrigation projects, bicycle and pedestrian projects, and beautification projects such as mural creation and restoration and installation of mission bells on highways.

2.2.2 State Transportation Improvement Program (STIP)

As a result of California Senate Bill 45, passed in 1997, the STIP is divided into two programs: the regional transportation improvement program (RTIP), which receives 75% of the STIP funds and the interregional program (ITIP), which receives 25%. Projects for the RTIP are initiated and programmed by the 16 metropolitan transportation organizations (MPOs) in the state and, with Caltrans assistance, by the 22 counties that are not part of an MPO. Projects in the ITIP are limited to interregional facilities and are planned by Caltrans.

2.2.3 Regional Transportation Improvement Program (RTIP)

The 2002 RTIP included 1,400 projects programmed from FY 2002/2003 to FY 2007/2008. The amount allocated for FY 2002/2003 was \$975 million. This covers a wide range of projects. For example, the biggest expenditures in Los Angeles County in FY 2002/2003 were \$57 and \$37 millions for high occupancy vehicle lanes on two sections of Route 405, \$18 and \$12 millions for HOV lanes on sections of I-5, \$15 million for light rail vehicles, \$15 million for light rail fare collection system, \$15 million to modify an interchange on Route 134, and \$14 million for grade separations on the Alameda rail corridor. There were many more small projects such as widening and channelizing an arterial in Monterey Park (\$29 thousand) and widening a bridge and adding bike lanes on Laurel Canyon Boulevard in Los Angeles (\$49 thousand).

Of the total RTIP expenditures, 60% were for improvements to state highways, 24% for local streets and roads, and 13% for transit. Counties with heavy transit use allocated most of their funding for transit: San Francisco 73% and Alameda 69%. Small counties situated on major highways allocated most of their funds for state highways, while small rural counties devoted most of their funds for local roads and streets.

2.2.4 Interregional Transportation Improvement Program (ITIP)

Allocations for 2003 were \$218 million. Most projects involved highway widening, including climbing lanes, auxiliary lanes, and managed lanes. A few were rail and grade

separation projects. Many were multi-year projects. None cost more than \$80 million, and many cost less than \$10 million.

2.3 Programs Outside the STIP/SHOPP Process

Programs outside the STIP/SHOPP process are primarily those that are funded by federal categorical programs or draw primarily from local revenue instruments.

2.3.1 Congestion Management and Air Quality Program (CMAQ)

This is a federal program intended to reduce vehicle emissions in areas that do not meet air quality standards. Many of the eligible types of projects are designed to reduce vehicle miles, but it also can be used for traffic flow improvements, which might include ITS projects. The FY 2003/04 distribution to California was \$327 million.

2.3.2 Regional Surface Transportation Program (RSTP)

The RSTP apportions \$320 million annually to California. Eligible projects are construction, reconstruction, rehabilitation, resurfacing, restoration, and operational improvements on highways and bridges; capital costs for transit projects; carpool projects; safety improvements and programs; capital and operating costs for traffic monitoring, management and control; and transportation enhancement activities. Many types of ITS projects could be funded under this program.

2.3.3 Transportation Enhancement Activities (TEA)

These federal funds are reserved for bicycle and pedestrian projects and projects designed to preserve or enhance transportation facilities. Examples of the latter include land acquisition to preserve views and historic rail station restoration.

2.3.4 Local Transportation Sales Tax Programs

Many counties in California, particularly those with significant congestion, have passed sales taxes to support specific transportation projects such as rail systems and extensions and freeway construction and expansion. The projects supported by these funds are not part of the STIP, but those that are of regional significance become part of the FSTIP (See Section 2.1 "Transportation Planning in California" on page 7).

2.3.5 Transportation Fund for Clean Air (TFCA)

The TFCA funds are generated by a \$4 fee on vehicles that are registered in Alameda County. They are used for projects to reduce air pollution. Funds are distributed to the cities/county based on population, with a minimum of \$10,000 to each jurisdiction

(70% City/County Guarantee Funds). The remaining 30% of the TFCA are distributed to transit related projects.

2.3.6 Federal and State Special Projects

Congress, the state legislature, or a voter initiative may make funds available for specific projects or types of projects. Often these funds must be matched by funds from other sources. An example of such funding from the federal government is the New Starts program for transit. An example at the state level is the previous Governor's Transportation Congestion Relief Program (TCRP) for 141 specific projects around the state, and approved by the legislature in 2000. Projects funded under these programs become part of the FSTIP.⁴

2.4 How ITS Fits into the Current Planning Process

ITS projects can be included in the normal plan-making process (as with SR-17 improvements, Section 7 "ITS Example Project: SR-17 in Santa Cruz County" on page 41) or advanced as separate projects (as with SV-ITS, Section 6 "ITS Example Project: Silicon Valley-ITS in Santa Clara County" on page 33).

2.4.1 Currently Programmed ITS Projects

ITS projects appear to account for a very small fraction of transportation investment. In the 2003 SHOPP, there were 6 projects that might be classified as intelligent transportation system projects, costing a total of \$18 million and accounting for 1.6% of all SHOPP funds in California. These projects included signal upgrades, surveillance systems, and a traffic management system.

The RTIP for Los Angeles County, which has the most developed ITS program in the state, included various components of the ATISAC signal control system, signal synchronization, and automated fare collection equipment. Together these projects accounted for 12% of Los Angeles RTIP projects and 6% of expenditures.

None of the ITIP projects could be characterized as ITS projects. There may, however, have been ITS elements in many of the road and interchange improvements in the ITIP, as well as in the SHOPP and RTIP. The CMAQ could include ITS projects to improve traffic flow and the RSTP can fund capital and operating costs for traffic monitoring and management.

In the letter of transmittal for California's Federal Statewide Transportation Improvement Program (FSTIP), which includes all federally funded projects and non-federally funded projects of regional significance, \$12 million was programmed for the Intelli-

⁴ Funding for the TCRP is currently uncertain as a consequence of the State of California's financial crisis.

gent Transportation System Program in FYs 2002/03, 2003/04, and 2004/05, 0.04% of the total FSTIP. This is in addition to projects in the SHOPP, STIP, and CMAQ.

2.4.2 California Transportation Commission Policy

In November 2003, the CTC sent a memo to the Caltrans Programming Manager outlining suggested updates to the 2004 STIP guidelines. The first item was to add the following:

“Innovative Technology Projects: One percent of STIP programming capacity will be reserved off the top in each programming cycle for projects incorporating innovative technologies that result in better future transportation systems and strategies.”

Existing CTC policy supports implementation and application of transportation management systems (TMS) improvements to address highway congestion and to manage transportation systems. It encourages the regions and Caltrans to work cooperatively together to plan, program, implement, operate and manage transportation facilities as an integrated system with the objective of maximizing available transportation resources and overall transportation systems performance. Therefore, it allows TMS improvements for state highways to be programmed in the SHOPP and in the RTIPS if timely programming through the SHOPP isn't possible. According to CTC policy,

“TMS improvements include the following types of projects:

- Transportation Management Centers (TMCs) including necessary computer software and hardware.
- TMC interconnect projects which allow a TMC to substitute for another TMC during an emergency
- TMC field elements such as, but not limited to, traffic sensors, message signs, cameras and ramp meters which upgrade the existing facilities and are necessary to facilitate the operation of the TMC.

“The application of TMS improvements should be coordinated with other operational improvements such as freeway ramp/local street access modifications and auxiliary lanes in order to maximize the TMS benefits. Prior to programming a new highway facility for construction, reconstruction or rehabilitation in the STIP or in the SHOPP, regions and Caltrans should fully consider transportation systems management plans and needs and include any necessary TMC field elements to support operation of existing or planned TMCs.”

See also “Appendix A: The CTC Policy on PSRs” on page 75.

2.4.3 CMAQ Guidelines

The CMAQ program also supports ITS. Its guidelines state:

“In addition to traffic signal modernization, coordination, or synchronization projects designed to improve traffic flow within a corridor or throughout an area like a central business district, Intelligent Transportation Systems (ITS), traffic management and traveler information systems can be effective in reducing traffic congestion, enhancing transit bus performance and improving air quality. The following have the greatest potential for improving air quality:

- regional multi-modal traveler information systems;
- traffic signal control systems;
- freeway management systems;
- transit management systems;
- incident management programs;
- electronic fare payment systems; and
- electronic toll collection systems.

While interconnected traffic signal control systems and freeway management systems have been recognized for their air quality improvement benefits, other user services like electronic fare and toll collection systems can be useful in reducing or eliminating air quality “hot spots.” Individually, these core infrastructure elements can reduce emissions and therefore qualify for CMAQ funding. When linked together in a system, however, their benefits are likely to be greater.

Operating expenses for traffic flow improvements are eligible for CMAQ funding where they can be shown to: 1) have air quality benefits, 2) the expenses are incurred from new or additional services, and 3) previous funding mechanisms, such as fares or fees for services, are not displaced.”

2.4.4 Corridor Planning

The Caltrans TMS (transportation management system) master plan priorities are based on corridor objectives. The MPOs are also interested in considering corridors. There are two ITS-based corridor projects in District 4, the Alameda/Contra Costa Corridor, managed by the CMAs of these counties, and the Silicon Valley Smart Corridor. MTC has identified 16 corridors in the Bay area. Caltrans has identified 24. The corridors tend to be based on Caltrans routes.

2.4.5 Federal Guidance

In 2001 the FHWA Office of Travel Management published Guidance on Including ITS Elements in Transportation Projects. The basic premise is that it is more economical to install ITS field elements when a highway is being constructed or expanded, rather than as a special project. The region's ITS plan or existing ITS infrastructure is considered when transportation projects are being planned to see what ITS elements should be considered in the project. For example bridge construction might also include laying fiber-optic cable, CCTV for observing traffic, and variable message signs.

3 Diagnosing Transportation Problems

The previous section outlines the flow of funds from funding sources (primarily higher levels of government) to the agencies making transportation expenditures. This section looks at how transportation problems are actually diagnosed and treated. Transportation problems arise from a number of macroscopic factors (economic and demographic trends) interacting with the specifics of a local situation.

3.1 Current Transportation System Problems and Needs

Most Californians live in or near large metropolitan areas with highly developed street and road networks and transit systems. A wide area with a vast array of activities can be reached by automobile in a relatively short time. In cities and denser suburbs, transit also provides access but to a narrower range of destinations, and except in congested areas, with longer travel times. The physical inputs and outputs of the state's economy are moved through large sea and air ports, via a transcontinental rail network, and via truck on the state's road and street network. As the transportation infrastructure has grown and improved and transportation vehicles have improved, travel times have dropped dramatically without a significant increase in accidents. But the system now suffers from its own success:

- (1) First, it is so extensive, and much of it so heavily used, that the resources needed to keep it in good shape have increased significantly. The existing California highway system has an estimated value of \$300 billion and took over 100 years to build. Much of the system was built in the 50's, 60's, and 70's, and over 50% of the state highway bridges are over 30 years old. An increasing number are reaching the age at which major rehabilitation or replacement will be required. About one third of the state highway pavement needs rehabilitation.

Use of the system is growing. Between 1992 and 2012 population is expected to increase by 39%, vehicles in use by 41%, and highway freight by 31%. Although state highways make up 9% of the highway mileage in California, they accommodate 54% of the vehicle miles traveled. The increased vehicle miles result in a faster rate of pavement deterioration and increased hours of traffic congestion. Where it is most heavily used, it must be repaired more often and must be repaired at night or on weekends, at much higher cost than during the daytime. This leaves fewer resources to address other transportation needs.

- (2) Second, heavy use of the system at certain places and times causes congestion that can increase travel times many-fold. With more traffic on the road, an incident that blocks a bottleneck or otherwise reduces capacity will further increase travel times. The more congested the road, the more variation in travel time results from these incidents and from normal variations in the number of vehicles trying to use the road.

The usual means of mitigating congestion has been the construction of new roads and the expansion of bottlenecks on existing roads. But this is difficult and expensive in built-up regions, and the funds devoted to this type of construction have not kept pace with the increase in travel. New or expanded transit systems do not generally attract enough people to significantly affect congestion.

- (3) Third, as an increasing percentage of Californians have acquired automobiles, use of the transit systems has declined in most places. Heavy capital and operating subsidies are required to provide basic mobility to people who do not have access to automobiles and to motivate people with automobile access to use transit.
- (4) Fourth, freeways and increasing automobile traffic on streets and roads have made pedestrian and bicycle travel more circuitous and dangerous in some locations.
- (5) Fifth, even though emissions from new automobiles are only a fraction of what they were 20 years ago, the increased use of light trucks, continued high emissions from other transport vehicles, and increased vehicle-miles traveled have prevented attainment of air quality standards in many areas. Furthermore, heavy road traffic, trains, and planes generate noise, which has negative impacts on the affected neighborhoods. Road runoff pollutes the water, and roads present a barrier and hazard to wildlife.
- (6) Finally, although most modes of transportation are safer than ever, accidents still affect a large number of people, and remain a serious problem.

3.2 How Could ITS Mitigate these Problems?

After problem symptoms have been described, alternative treatments—including ITS—can be considered. ITS applications tend to have small incremental impacts, and need to be carefully designed for the particular problem circumstances.⁵

3.2.1 Congestion

Many ITS services are intended to reduce congestion. Several improve road and street operations: electronic toll collection, freeway service patrols, traffic management centers and incident management, ramp metering, traffic signal control, and traveler information via changeable message signs, highway advisory radio, telephone systems and the internet. Some ITS services are designed to reduce congestion by reducing vehicle travel demand: electronic toll collection used to enable congestion pricing, technologies to enable car sharing in order to shift longer trips to transit, ridesharing technology to

⁵ Additional information on ITS treatments and potential impacts can be found at the Caltrans “ITS Decision” website (See 4.3.1 “ITS Decision Website” on page 21.)

encourage carpooling, transit technologies that make transit more convenient, telecommuting, and pre-trip information on congested routes that results in people traveling on less congested routes or at less congested times. In cities, parking systems that tell travelers where parking is available can reduce congestion arising from vehicles searching for parking places. Safety-enhancing ITS can reduce congestion by reducing accidents that cause delay.

3.2.2 Transit

A number of ITS technologies are designed to make transit more efficient and more attractive to potential users. Automated vehicle location systems allow better scheduling and operations of buses and real time arrival times for passengers. Electronic fare payment increases convenience for passengers, provides more flexibility in fare structures, and reduces cash handling costs. Closed circuit TV and alarm buttons are intended to reduce crime on transit vehicles and in waiting areas. Transit signal priority at intersections increases transit speeds, allowing better utilization of equipment and shorter trips for passengers.

3.2.3 Safety

Changeable or variable message signs and highway advisory radio warn travelers of dangerous conditions. There are speed and weight sensing systems that warn trucks when they are approaching a curve too fast. Ice and fog sensors trigger de-icing and warnings to travelers. Red light running monitors and cameras and intersection collision warning systems are designed to reduce accidents at intersections. Countdown signals and flashing lights on occupied crosswalks are intended to reduce pedestrian accidents. Work-zone signs and sensors are designed to protect workers and prevent rear-end collisions due to sudden stops. There are in-vehicle systems to increase safety, such as adaptive cruise control and collision warning systems.

3.2.4 Emissions

Most automobile emissions are produced by a small number of vehicles with faulty emissions systems. Remote emissions sensors can identify such vehicles, especially those that are driven a lot and contribute the most pollutants, sooner than they would be identified by periodic emissions systems inspections.

3.2.5 Traveler Information

Many types of traveler information can be provided via many channels. Information on traffic conditions, accidents, weather-related travel restrictions, and road construction can be provided via telephone information systems, the internet, TV, and radio. Live video of traffic conditions can be provided via TV and the internet. Route guidance for a particular trip based on shortest travel times or shortest mileage can be provided via the internet or via in-vehicle devices. Maps and driving directions are available via the internet. Roadside variable message signs and highway advisory radio can provide

information about conditions en-route. Transit information is available via the internet and telephone. At some transit stops, signs display the expected arrival time of the next bus or train.

The benefits of some of this information go beyond congestion reduction, safety, and demand management. It can help people plan their trips, reduce anxiety regarding the length of delay, and satisfy their curiosity.

3.2.6 Traffic Surveillance

Traffic information provided to travelers must be collected by some means. One is via video cameras installed at key locations. Many agencies use loop detectors to measure vehicle flows and densities. Various other types of detectors can be placed on the roadside or over the road to collect similar information. Travel times can be measured by vehicles acting as probes and reporting their locations via roadside readers or other wireless means.

4 Planning Tools and Resources

There is no substitute, of course, for specific knowledge about the project, both the existing situation and the nature of the possible alternative improvements, but many sources of information can be found on general policies and objectives, previous results, and analytic methods for evaluation. These resources are grouped into four broad categories, in no particular order: plans, data sources, analytic tools, and economic analysis resources. There are software packages that can provide results for single projects or for packages of projects, on the basis of input data that may be modest or large. No single software package addresses all types of problems; each has a particular purpose, which it may serve adequately or with limitations.

4.1 Planning Documents

These reports should contain information about problems being addressed, alternative treatments, impacts, and evaluation of costs and benefits, at regional, corridor, or project levels.

4.1.1 Transportation Plans

Plans include regional transportation plans, ITS plans, and STIPs. These frequently contain lists of specific projects, along with general discussions of problems and goals, but there is no analysis that provides justification—quantitative or heuristic—for any specific project. More information about the planning documents that pertain to the two case study sites is included in Section 6 “ITS Example Project: Silicon Valley-ITS in Santa Clara County” on page 33, and in Section 7 “ITS Example Project: SR-17 in Santa Cruz County” on page 41.

4.1.2 Project Study Reports

All projects that are included in the STIP must have a completed project study report (PSR) or, for a project that is not on a State highway, a PSR equivalent. The California Transportation Commission's policy on Project Study Reports is given in “Appendix A: The CTC Policy on PSRs” on page 75. It requires that each RTIP and the ITIP be evaluated for performance and cost-effectiveness at the system or project level, as appropriate. Large projects should be evaluated at the project level. Each RTIP or ITIP submission should be accompanied by a report on its performance and cost-effectiveness. Although each region is responsible for establishing the transportation goals, objectives and standards to be used in its evaluation of RTIP performance, the CTC urges that improvements to mobility, accessibility, reliability, sustainability, and safety be part of these goals. The evaluations should be on a life cycle bases. In order to facilitate statewide consistency between regions and Caltrans, the CTC suggests that regions use values of performance and benefits and evaluation methodologies that are commonly accepted, such as the values of time, safety, vehicle operation costs and discount rates that are developed by Caltrans for benefit cost analysis of transportation projects.

Furthermore, for larger projects value analysis should be used to develop alternatives to the project that meet the project goals, and to identify the alternative that meets the project's goals at the lowest overall cost.

The PSR policy also supports monitoring transportation systems and projects for performance and using the findings to refine performance forecasts in future RTIPs and ITIPs.

4.2 ITS Data Sources

Data sources can provide information specific to a given context, but they do not offer means for generating or comparing alternatives.

4.2.1 PeMS Database

The PeMS (Performance Measurement System) project at the University of California archives existing Caltrans loop detector and incident data. Data are currently available for the major urbanized areas in California. However, not all highways have loop detector, and in many locations either the loop data are not good or the communications links are faulty. Error checking can be done by the PeMS system so that the various districts can correct problems with the loops or communications systems.

4.2.2 Other sources of Data

Caltrans districts and headquarters, and local and regional agencies, also collect traffic data, as well as accident data. Regional air quality agencies collect data on air quality. Although there are vast amounts of such data, data relating to a particular facility location may not be available.

4.2.3 FHWA ITS Benefits Database

This web-based compendium assembles a wealth of reports and studies, many sponsored by the Joint FHWA/FTA Program Office but also including broad coverage of the literature (e.g., TRB papers) on ITS deployment examples, tests, and impacts. For many of the citations, the original document is not provided, only a summary of conclusions. The citations are referenced in multiple categories, so the same source may appear frequently, especially those that are broad and less specific. The quality of the analysis or the defensibility of the conclusions is not evaluated, and varies greatly. The term “benefits” is used very broadly, to include “evaluations” of whether the hardware and software functioned, and whether potential or actual users had good opinions about or experience with the deployment. Quantitative estimates of benefits are in generic form, unrelated to the specifics of the deployment context.⁶

⁶ <http://www.benefitcost.its.dot.gov/its/benecost.nsf/bylink/benefitshome>.

4.3 Analytic Tools

Analytic tools, whether methods, spreadsheets, or computer software, have the capability of generating alternatives and comparing them under “what-if” scenarios.

4.3.1 ITS Decision Website

The ITS Decision website⁷ developed by the Institute of Transportation Studies at the University of California for potential ITS implementers contains information on ITS services, their effectiveness, and where they have been implemented, and offers a tool to help users match ITS with the needs of their particular jurisdiction.⁸ Soon to be added to this website is a case-based reasoning system and associated case bases for evaluating employer transit pass programs, freeway service patrols, automated vehicle location, and other ITS services. Case-based reasoning (CBR) is useful when there is a substantial body of experience with a particular service, but not enough to develop general rules or models. CBR allows the user to find projects that have been implemented in areas with circumstances similar to those in his or her area and to infer from these projects how the service would perform in his or her area. This tool is especially helpful for the generation of ITS alternatives for a given problem.

4.3.2 Traffic Analysis Tools

Benefits of improvements include travel time savings, accident reductions, operating cost savings, agency cost savings, emissions, and consumer surplus from changes in traffic volumes that result from the improvement. Traffic analysis models deal primarily with speed and delay, and hence travel time savings. Emissions and vehicle operating cost models can be attached to the traffic models. One way of characterizing these models and their purposes is shown in Table 1.

The models can be simple or complex, and each one has limited purposes for which it is suited. For estimating likely impacts, a complex model is not necessary. If data have already been assembled for a traffic demand model (i.e., a traffic assignment model), it might be used for project evaluation if the diversion potential is particularly hard to guess. What is most important is to pick models—usually formulas that can be easily entered into a spreadsheet—that are applicable to the project context.

4.3.3 ITS Deployment Analysis System (IDAS)

IDAS was developed for the FHWA to help state, regional, and local agencies easily and consistently assess intelligent transportation systems (ITS) deployments. It is a sketch planning tool to be used with metropolitan transportation traffic analysis models that allows users to systematically evaluate the impacts, benefits, and costs for more than 60

⁷ <http://www.calccit.org/itsdecision>.

⁸ http://www.calccit.org/itsdecision/match_needs/main_page.htm

TABLE 1. Typology of Traffic Analysis Tools

Category of Analysis Tool	Typical Purpose	Example
Sketch-planning tools	rough order of magnitude in a corridor, for general planning purposes	
Travel demand models	4-step models used in forecasting traffic volumes and assignment to links	EMME2, Minutp, Tranplan, TransCad
Analytic/deterministic tools (HCM based)	application of algorithms in the Highway Capacity Manual for estimating speed, delay, queuing, capacity on single facilities	
Traffic optimization models	used for developing traffic signal plans in relatively isolated or single arterial conditions	Transyt
Macroscopic simulation models	used to estimate speed, flow, and density on individual highway sections, without explicitly considering variability or individual vehicles	FREQ
Mesosopic simulation models	a blend of macro and micro, using individual vehicles but governed by average relationships rather than individual behavior	
Microscopic simulation models	specialized treatment of intersections or toll plazas where volumes change over short time periods and variation in individual vehicle behavior is important	Paramics, Vis-sim, Aimsun
source: summarized from Alexiadis, et al. (2004); see Jeanotte, et al. (2002) for a guide to matching traffic analysis tools with problem type and data requirements.		

types of ITS investments deployed in isolation or in any combination. It draws generic impact rates from the FHWA “Benefits” database above (Section 4.2.3), and has significant data requirements.⁹ In California, Hayward and the Association of Monterey Bay Area Governments (AMBAG) are using IDAS.

4.3.4 Intermodal Transportation Management System

The ITMS is an Arcview GIS software application that can be run on a PC. It provides recent forecasts of passenger vehicle trip volumes that are assembled from all MPOs in the state and non-MPO regions, both current volumes and twenty-year forecasts. It also utilizes national freight commodity flow data to generate section-level forecasts of truck traffic by converting dollar volumes to tonnage volumes to truck movements, and allocating movements to sections. Commodity types are detailed for agriculture and other commodities critical to California’s economy. Rail, water, air, and highway modes are included, and freight is assigned (or shifted) to modes via a mode choice model. High-

⁹ Training and consulting services are available through <http://idas.camsys.com/>.

way traffic responds at some high level to a generalized price that includes time and money costs, and speeds are estimated using a BPR speed-volume function based on the volume-to-capacity ratio.

The intent of ITMS is to provide information for system-level planning of multimodal facilities, especially freight and intercity. It provides a limited amount of information that might be used at the project level if supplemented by specific local data. Users must provide or select input data, and they receive performance measures for the facility; by changing, say, the capacity, a set of comparable performance measures can be obtained. Thus the model has some ability to screen project alternatives or project locations for those projects that can be adequately described in ITMS terms. Constructed by Booz-Allen for Caltrans, it can be used by regional and local planners, and consultants, for identifying problems and for preliminary analysis of alternatives. It does not yet include ITS alternatives because data are lacking on their impacts.

4.3.5 California Air Resources Board Analytical Tools

The California Air Resources Board (CARB) has developed methods and examples as well as automated Access database programs for evaluating the cost-effectiveness of various projects in terms of air quality improvement: cleaner on- and off-road vehicle purchases and re-powers; cleaner street sweepers; new bus service operations; vanpool and shuttle service; traffic signal coordination; bicycle facilities; telecommunications; and ridesharing and pedestrian facilities.

4.3.6 Value Analysis (VA)

Also called value engineering or systems engineering, this process is used to identify alternatives to the proposed project and to optimize the proposed project. Caltrans' policy is to apply value analysis to any transportation projects that are estimated to cost over one million dollars. Each year it submits to the FHWA an annual State-wide VA Program containing all Caltrans VA studies and any other VA studies of state-wide significance.

VA is a function-oriented approach to solving problems and reducing life-cycle costs. It identifies the functions, uses creative thinking to generate alternatives to provide these functions, and then assesses the performance of various alternatives to determine the alternative that provides the required functions at the lowest overall costs.¹⁰

VA is intended to meet the following goals:

- Improve project quality
- Build consensus with transportation partners
- Develop solutions to difficult transportation issues

¹⁰Caltrans value analysis policies and procedures can be found at http://www.caltrans.ca.gov/hq/oppd/pdpm/chap_html/chapt19/chapt19.htm.

- Reduce project development time
- Reduce initial costs of projects
- Reduce life-cycle cost of projects

Value engineering typically considers alternative ways to construct a given facility, as opposed to, say, considering a transit alternative to a highway expansion.

4.4 Economic Analysis Tools

The number of economic analysis tools is relatively small, and they have not been widely used. Economic analysis, however, is essential in evaluating the costs and benefits of projects for funding decisions and inclusion in improvement programs.

4.4.1 Cal-B/C

Booz-Allen & Hamilton developed Cal-B/C for Caltrans, a spreadsheet for conducting life-cycle benefit-cost analysis of highway improvements. It is used primarily to prioritize highway projects, those with the highest benefits relative to their costs being the first to be programmed. Caltrans has recently added ramp metering, HOV lane connectors, and maintenance and rehabilitation to the types of improvements that can be evaluated. The CTC accepts CalB/C for transit and highway plans but does not require that it be used. One of the inputs to the model is speed, so the accuracy of the output depends on the accuracy of the speed estimates.¹¹

Cal-B/C is an easy-to-use Excel spreadsheet for benefit-cost analysis of highway and transit projects in a corridor that already contains a highway facility or a transit service. Highway projects may include HOV and passing lanes, interchange improvements, and bypass highways. Transit improvements may include enhanced bus services, light-rail, and passenger heavy-rail projects. Default data are given for California conditions.

4.4.2 Benefit/Cost Website

Caltrans has developed a site that outlines the basic principles of BCA, in a structured format with many hyperlinks, allowing the user to move back and forth between general principles and specific details.¹²

4.4.3 Economic Analysis Primer

FHWA's Office of Asset Management has produced a primer on using economic analysis in project selection, either in the form of life-cycle cost analysis (LCCA) or benefit-

¹¹http://www.dot.ca.gov/hq/tpp/planning_tools/tools.htm. For documentation, see Booz-Allen & Hamilton (1999) and Technical Supplement (1999).

¹²<http://www.pinchy.org/joy/>.

cost analysis (BCA). The presentation is very accessible, with a minimum of technical language and few formulas. Emphasis is given to practical ideas rather than cook-book methods.¹³

4.4.4 MicroBENCOST

Texas Transportation Institute (TTI) developed MicroBENCOST computer software to calculate benefits and costs of highway improvement projects. The package is actually two pieces of software: the Main Program is the software that performs economic analyses, and it is accompanied by the Update Program, which can be used to customize and update most of the default data set (including values like unit operating costs and maintenance costs) in the Main analysis program. The program compares the user costs for an existing situation to the motorist costs after an improvement is completed.¹⁴

The program grew out of a project to revise and update the 1977 AASHTO Manual on User Benefit Analysis of Highway and Bus-Transit Improvements (which has recently been revised) and has been distributed by McTrans since 1993.¹⁵

4.4.5 AASHTO Redbook

The 1977 AASHTO “Redbook” has been updated and revised by ECONorthwest under the sponsorship of the National Highway Cooperative Research Program, and published by AASHTO in 2004.¹⁶ A set of programs is included with the analytic algorithms contained in spreadsheets. The package allows for benefit-cost evaluation of a wide range of highway improvement projects, and provides suggested ranges of parameter values or default values.

¹³<http://www.fhwa.dot.gov/infrastructure/asstmgmt/primer.htm>.

¹⁴<http://tti.tamu.edu/product/ror/microbencost.stm>. For documentation, see McFarland et al. (1993) and User’s Manual (1993).

¹⁵<http://mctrans.ce.ufl.edu/index.htm>.

¹⁶<https://www.transportation.org/publications/bookstore.nsf/BestSellers?openform>.

5 Earlier Studies of ITS Implementation

Ever since the applications of information and communication technologies to transportation first came to be known as ITS in the early 1990s there has been interest in the factors that favor effective implementation or that are barriers to implementation. Four studies of ITS implementation are described below.

5.1 The Value of Incremental Development and Learning Networks

Based on the literature on innovation and experience with early ITS implementation, a study by Partners for Advanced Transit and Highways (PATH) at the University of California (Weissenberger 1998) found that successful ITS innovation occurs incrementally, relying on learning by doing and learning networks. It is easier to implement small, local projects than complex, inter-agency projects. With this process inter-agency coordination can result from other agencies following the example of the earliest implementers, such as occurred when Orange County followed the example of the Los Angeles advanced traffic signal control system (ATSAC). Trying to implement projects that are very complex, either technically or jurisdictionally, can result in delay and high implementation costs.

Learning networks are effective in transferring technology from person to person and jurisdiction to jurisdiction. These can take many forms: the relationships between a consultant and multiple clients, information networks in which knowledge about ITS is gathered and synthesized, professional society meetings and more informal relationships between people involved in implementing ITS, and formal training.¹⁷ Some things can only be learned by doing. Incremental implementation allows small successes and avoids large failures.

5.2 Mainstreaming ITS

A study by the University of California Transportation Center (Deakin et.al., 2003) found a wide range of opinion regarding ITS. The study included a detailed literature review; a survey of 228 transportation engineers, planners, and transit staff members, and interviews with 52 of these staff members; interviews with 51 California decision-makers, managerial staff, and opinion leaders; and interviews with 20 national leaders in ITS. California opinion leaders did not see a problem in fitting ITS projects into mainstream transportation planning processes, but complained of a lack of good information on ITS benefits and costs. About a third advocated earmarking funds for ITS. Significantly, very few of the staff members felt that a lack of analysis tools or a lack of information on the impacts of ITS projects were barriers. The study found the following barriers to implementation:

¹⁷For example see Section 4.3.1 “ITS Decision Website” and Section 4.4.2 “Benefit/Cost Website” on page 24).

- Low awareness of ITS on the part of local officials
- Perceived high costs of ITS
- Not enough information about ITS
- Misconceptions about ITS
- Low public awareness
- Not enough staff training
- Poor fit with existing planning processes
- Prior commitments crowd out ITS
- No earmarked funds
- Lack of resolution regarding who controls ITS projects
- ITS too focused on freeways and not enough on local needs
- ITS too focused on devices, not enough on demand
- Concern about impacts

Whether ITS would be embraced and implemented if these complaints were satisfied is difficult to determine, but certainly the lack of information on local suitability needs to be overcome.

5.3 Survey of ITE Members for ITS Decision Website

In order to determine what information and analytical tools potential ITS implementers would find useful on the “ITS Decision” website (Section 4.3.1 “ITS Decision Website” on page 21), a sample of members of the Institute of Transportation Engineers were surveyed in 2002. Of the 46 respondents, slightly over half were consultants and 36% worked for city, county, state and federal transportation agencies. Fifty-four percent were engaged in traffic engineering, 15% in planning, and 9% in traffic operations. Sixty percent had been involved in planning, implementing, or operating ITS, primarily traffic signal coordination and optimization, special event management, traffic surveillance, traveler information, ramp metering, and ITS plan or architecture development. Sixty-three percent said that they generally consider ITS when thinking of ways to address a particular problem. For those who did not, the most common reason was that their area was too rural or small to have the problems that ITS addresses. Other reasons were lack of ITS expertise, ITS costs, and a belief that road expansion was more effective and politically acceptable. When respondents were asked how important various factors would be determining if a particular ITS project should be undertaken they responded as shown in Table 2.

These responses imply that what motivates implementation of ITS is knowledge that a particular ITS application will work well, will be cost-effective, can be funded, and will be accepted by the public.

Asked what specific types of help they would find useful in implementing ITS, they responded:

TABLE 2. Responses of ITE members to question of ITS decision factors

	% considering the factor “very important”
How well it has worked	80%
Cost-effectiveness	63%
Funding sources	52%
Public acceptance	48%
Competition for funds with other projects	48%
Political feasibility	26%
Who else has tried it	24%

- Help in estimating the effects of particular ITS services in your situation (76%)
- Information about specific ITS services and where they are appropriate (63%)
- Help in determining which ITS projects are likely to be appropriate in your area (50%)
- Help in developing an ITS plan appropriate to your situation (48%)

Unlike the results of the mainstreaming study, these responses seem to indicate that help in analyzing the effects of ITS services and technologies would be useful.

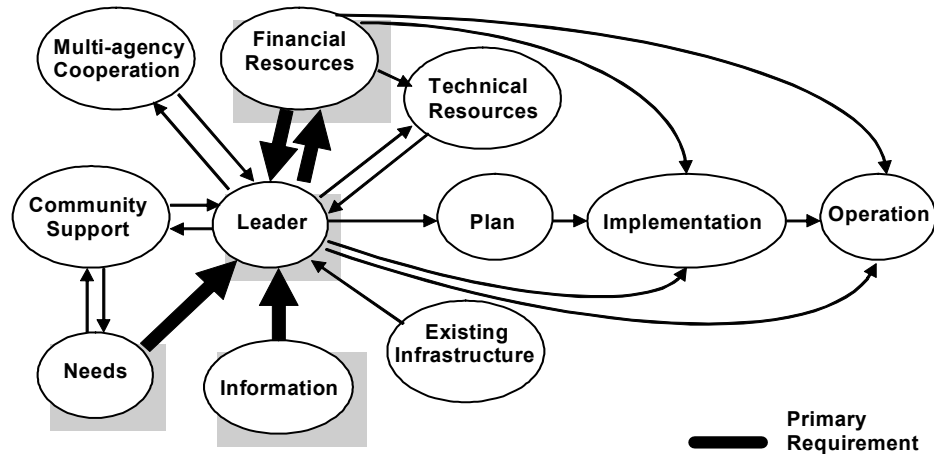
5.4 Lessons from Case Studies

A series of case studies of cities and Caltrans districts that had and had not implemented advanced traffic management systems conducted by PATH (Dahlgren 1996), found the following requirements for successful ITS implementation at that time:

- A need and desire to improve traffic conditions
- Information
- Strong professional staff leadership to:
 - Seek out funding
 - Develop community/political support
 - Acquire technical expertise
 - Fit a system to the existing infrastructure
 - Cooperate with other agencies
 - Develop a plan
 - Implement the plan

The process by which a particular project is implemented is shown in Figure 4. The diagram was originally developed to describe how intelligent transportation system projects were implemented, but the same process applies to all types of projects originating at any level of government. Some leader or leading group puts needs, information about how the project would work, and financial resources together and proposes

the project and makes it part of a plan. In this process it may be necessary to obtain community support, cooperation from another agency, or additional technical resources. Some projects, particularly those that are clearly needed and are not controversial, are lead by agency staff. More visible, larger, or more controversial projects are often lead by a local politician who can develop support for the project.



source: Dahlgren, et al (1997) (<http://www.path.berkeley.edu/PATH/Publications/PDF/PWP/96/PWP-96-09.pdf>).

FIGURE 4. Requirements for Successful Implementation.

The implementation pattern was:

- Areas with early implementation were characterized by surges of special event traffic.
- Their systems were extended beyond these special needs.
- Other jurisdictions followed their lead with, similar systems, the same consultant, or sometimes even the same personnel.
- Smaller jurisdictions cooperated with larger jurisdictions.
- Some jurisdictions did not implement ATMS because there was little need, it was not cost effective, or there was no desire to accommodate the traffic.

These findings suggest that ITS implementation occurs first where there is the greatest need, which tends to generate the greatest benefits and political and public support. As implementation becomes more widespread, the cost is likely to drop, making it cost-effective in more situations.

5.5 Summary

Where clear benefits in excess of the costs of implementing ITS can be seen, as in the case of electronic toll collection and traffic signal coordination, ITS implementation

occurs without special funding, and champions arise to see the implementation through. Where benefits are less clear, implementation is slow and often occurs only with outside funding. Although people profess knowledge of ITS and many claim that lack of analytic tools is not a barrier to implementation, they appear to find additional information regarding performance useful.

Incremental implementation is more effective and less costly than large scale, inter-jurisdictional programs supported by outside funding.

6 ITS Example Project: Silicon Valley-ITS in Santa Clara County

The northern of the two case study projects is called the “Silicon Valley ITS” project,¹⁸ and consists of a number of distinct ITS treatments that are associated with state route (SR) 17 by being in the same corridor, but the treatments are mostly applied to nearby facilities rather than to SR-17 itself. Treatments include freeway-to-arterial diversion, traffic signal timing, transit service coordination, and peak HOV lanes with variable message signs. The SV-ITS project as a whole is assembled from a variety of ITS applications in different locations that do not necessarily relate very closely to each other.

6.1 Purpose of the Project

Goals offered for the SV-ITS program include:¹⁹

- improve multi-jurisdictional traffic signal coordination, including the use of signal timings that provide superior response to or adapt to traffic conditions;
- improve ability to respond to traffic incidents;
- improve ability to manage traffic flows associated with incidents and congestion on area roadways;
- a better integrated transportation system that considers all travel modes (automobile, transit, bicycle and pedestrian);
- better and more reliable real-time traveler information;
- minimum intrusion of freeway traffic onto local streets due to freeway congestion and freeway incidents;
- improve coordination of activities and sharing of resources among agencies;
- keep all transportation facilities within the Highway 17/Interstate 880 corridor operating at maximum efficiency, even following a major disruptive incident.

A specific intent of the program is to adapt to incidents on SR-17 by “flushing” the traffic through parallel arterials and returning it to SR-17 as quickly as is practicable, and to smooth flow and ease congestion on arterials both by coordinating among local jurisdictions and by introducing a carpool lane on one of the arterials.

A map of the facilities included within the SV-ITS project is shown in Figure 5. At the north end of the SV-ITS area is an integration of highway and rail transit travel, with intermodal interfaces. On the west side, the San Tomas Expressway provides a peak-period HOV lane managed with VMS. The southern section of the SV-ITS area addresses the possibility of diversion of traffic from incidents on the freeway to adjacent arterials. The solid blue line shows the fibre-optic network that connects the transportation operations centers (TOCs, the numbered circles on the map) in the participating jurisdictions to each other.

¹⁸Formerly known as the “Silicon Valley Smart Corridor (SVSC)”

¹⁹Extracted from Caltrans et al. MOU (1997), IBM (2002), Rizzo (2001), and Kimley-Horn (2003).

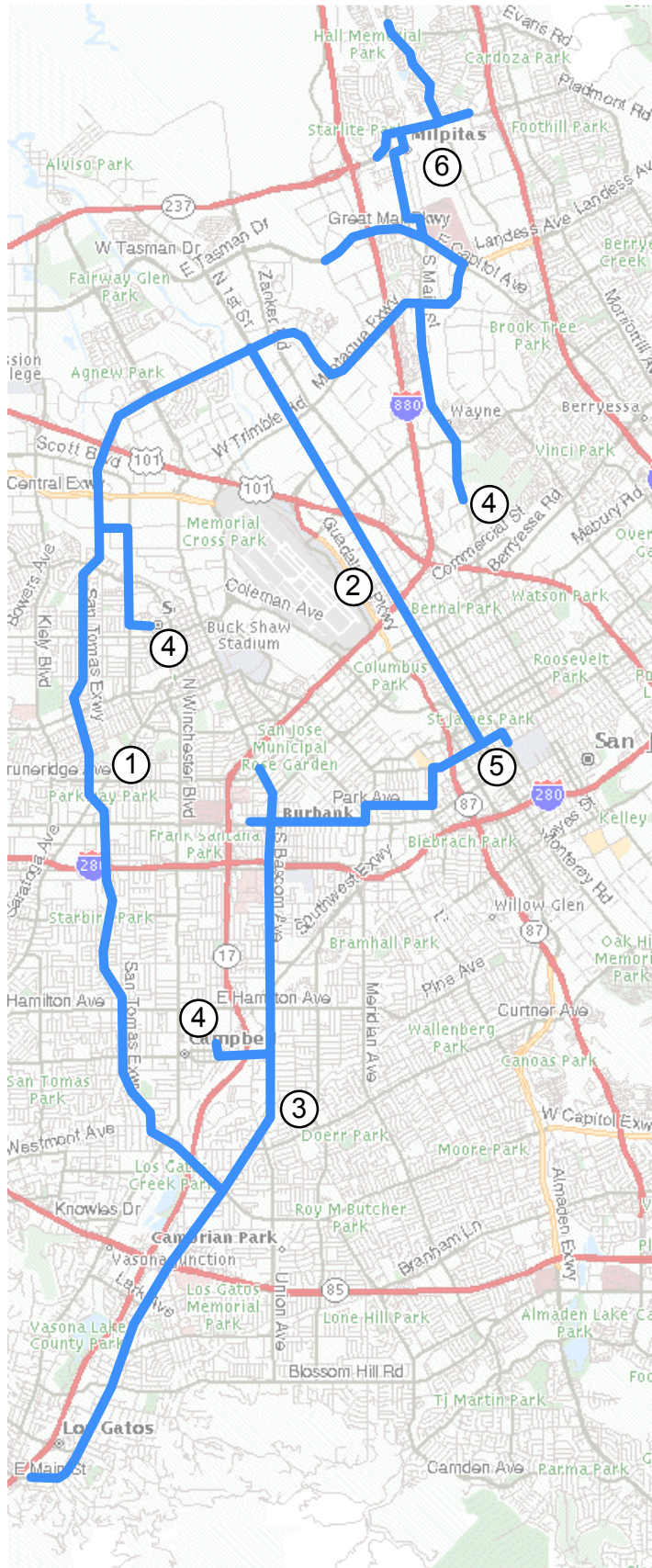


FIGURE 5. Map of Silicon Valley smart corridor (SV-ITS).

6.2 Planning Reports

The “TMS Arterial Signalization Business Plan” (IBM, 2002) describes in general terms several “smart corridor” plans, including the Silicon Valley Smart Corridor Project. A number of technical papers (e.g., Fehon and Elson, 2001; Fehon, Chong, and Black, 2003) describe the components of deployment, but do not attempt to evaluate any particular actions. The City of San Jose “2002 Transportation Report” devotes one page to the SV-ITS effort. The Memorandum of Understanding (MOU) names the participants (including Caltrans, the CHP, MTC, Santa Clara County, VTA, and seven municipalities in Santa Clara County) and ascribes responsibilities. The MOU refers to a 1994 feasibility study.²⁰ Although the Silicon Valley smart corridor program is included in several regional reports, the ITS program is mainly a local initiative.²¹

6.3 Project Description

The purposes and constraints have evolved since work began in 1997, but the main themes can be outlined:

- (1) Diversion takes place in response to congestion (i.e., a major incident) on SR-17, perhaps reinforced by extinguishable message signs (EMS) on the freeway that display a message to consult the highway advisory radio (HAR) at that location. An example is shown in Figure 6.
- (2) It is not the intent of the local jurisdictions to encourage diversion, only to accommodate it with the least disruption when it occurs. If diversion occurs, arterial signals will be adjusted to favor through at the expense of cross traffic. Return to the freeway is aided by special EMS (Figure 7). Only one of the two arrows (continue straight or turn left at the next intersection) will be displayed, depending upon whether the incident location has been bypassed.
- (3) The return-to-freeway signs are few in number (2 northbound) and not prominently visible, but presumably those who are seeking to bypass an incident already know about the signs and are looking for guidance. An example is shown in Figure 8.
- (4) Diversion onto local streets (as distinct from arterials) is actively discouraged.
- (5) The method for signal adaptation is “partially distributed,” but whether this means that strategic adjustments are made when diversion occurs or is expected, or that the decentralized control system detects the increased vol-

²⁰DKS (November 1994), which was not obtained for the present study.

²¹For example, Kimley-Horn (2003); this report describes hardware, communications, and basic functionality in general terms, but mentions little about impacts on travelers and provides no evaluation of expected benefits. See also http://www.ci.san-jose.ca.us/dot/traffic_its.htm.



(message display simulated)

FIGURE 6. EMS on freeway SR-17 northbound.

ume (diverted or not) and makes appropriate adjustments, has not been fully determined.

- (6) Diversion is based on having available capacity on parallel arterials that can substitute for the congested or blocked freeway capacity. The main parallel facility—Bascom Road—is a six-lane facility with widely spaced intersections having left and right turn lanes. Figure 9 shows a typical intersection. Parking is permitted between intersections, but terminated where left- or right-turn lanes begin.
- (7) Any improvement in traffic flow, arterial or other, will induce some additional traffic, both diverted and new. The treatments implemented by SV-ITS do not increase capacity nor reduce vehicle flow, but attempt to allocate available capacity in the most productive way. No “demand management” techniques (e.g., parking pricing or restrictions, peak period tolls, HOT lanes) are under consideration.
- (8) Thus congestion will be likely to worsen unless the same vehicle flow carries more person trips. This leads to a need for ridesharing in some form: carpools, vanpools, or transit service. Bus transit and light rail transit are not part of the SV-ITS scope. In an effort to promote carpooling, an HOV lane has been created on San Tomas expressway, a semi-circular roughly north-



(message display simulated)
FIGURE 7. EMS on Bascom Ave. at Camden Ave.



FIGURE 8. Bascom Ave. northbound at Hamilton Ave. with return-to-freeway EMS.

south signaled arterial west of SR-17. Fixed signs are posted (Figure 10) stating the rules. The lanes operate only in the peak period and in the peak direction, enforced by VMS (Figure 11) and diamond-lane markings.



FIGURE 9. Bascom Ave. northbound at Camden Ave.



FIGURE 10. Rules for HOV lane on San Tomas Expy.

- (9) Interjurisdictional coordination ensures that local improvements and actions taken in response to traffic patterns are consistent with policies in adjacent jurisdictions. This applies primarily to signal timing on the arterials spanning several jurisdictions.
- (10) “Corridor-level control” is emphasized.²² The initiative for the deployments is the result of a voluntary association among local jurisdictions operating under an MOU. Regional network coordination does not seem to be planned or perhaps required, other than coordination with Caltrans.



FIGURE 11. HOV lane on San Tomas Expressway.

- (11) Incident management will be improved through vehicle detection and monitoring, consisting of loop detectors and algorithms, and traffic operations centers (TOCs).
- (12) Traveler information is mentioned as within the SV-ITS scope; cable TV and internet are mentioned, but actions or plans are not evident.²³
- (13) Park and Ride facilities with substantial attractions and services are in planning.

Locations of cameras and signs in the Bascom Avenue corridor are shown in Figure 12.

²²Rizzo (2001).

²³Concern is directed at fibre-optic network reliability and transmissions of video images (Fehon and Elson, 2001), but how the information is to be used is not described.

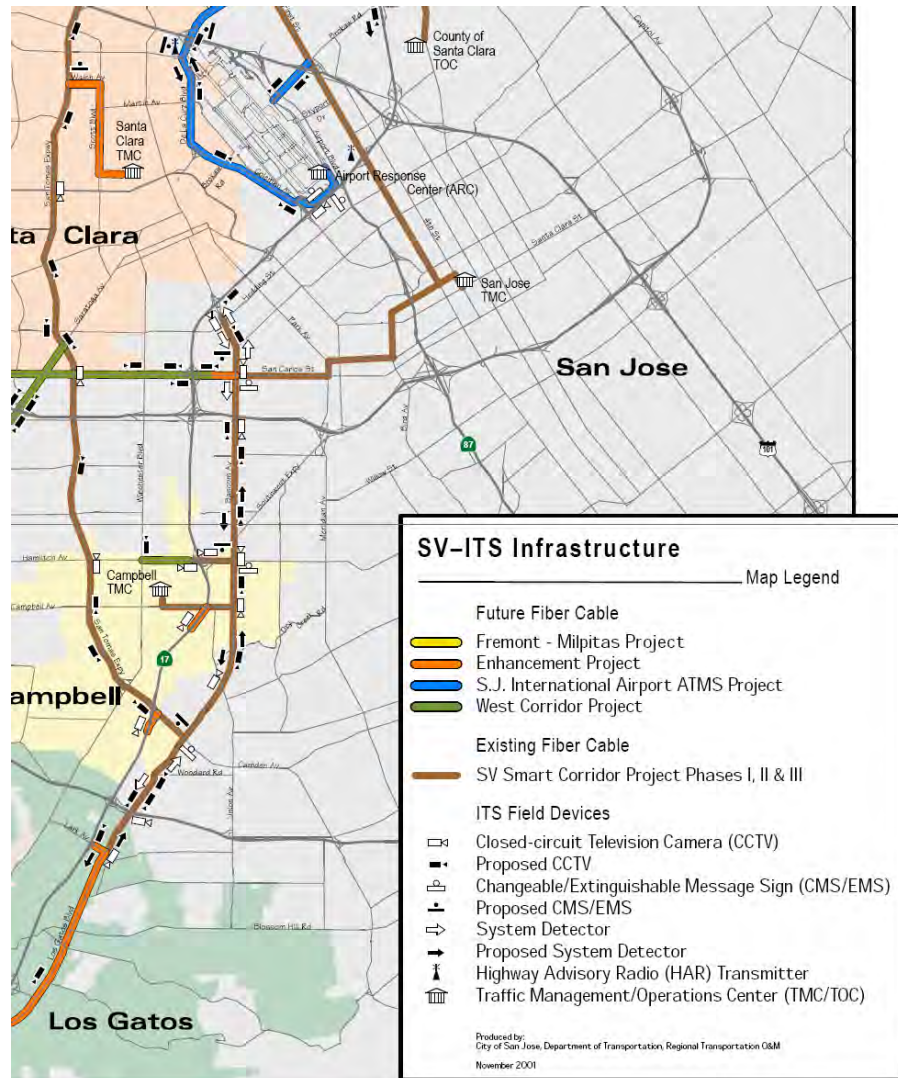


FIGURE 12. SV-ITS deployments on Bascom Ave.

7 ITS Example Project: SR-17 in Santa Cruz County

The southern of the two case study projects offers traveler information on a congested road for which there are few practical alternatives. This portion of SR-17 starts in Santa Cruz, runs up over the coastal mountain range, and drops down into the Santa Clara Valley. The ridge line along this portion of the coast range separates Santa Clara County—where the SV-ITS is located—from Santa Cruz, where SR-17 begins. Santa Cruz is in District 5 of Caltrans, which is headquartered in San Louis Obispo. A map of the route is shown in Figure 13.

7.1 Planning Reports

The 2001 Santa Cruz County Regional Transportation Plan contains an overview of County problems, both short and long range, and the forces behind them (Silicon Valley commuters, citizen desires for both expanded highways as well as expanded transit alternatives), a (brief) chapter on goals, a detailed explanation of the sources of funds and constraints on their use, and a complete list of projects and maps. Projects are grouped into six types, which are partly constrained by dedicated funds. There is no evaluation of projects; that is assumed to have been done outside and prior to the Plan.

The 2002 Regional Transportation Improvement Program contains cost estimates for each project by cost component, and a few words of project description. For 2002 projects, a one-page “nomination” form is filled out, with a few words on “transportation problem to be addressed” (e.g., repair pavement), but no benefit estimates.

The Central Coast ITS Strategic Plan (2000) covers a 5-county region that includes Santa Cruz County as the region’s northern end. The report is long and exhaustive in terms of listing a full range of ITS possibilities, a survey of what already exists, and descriptions of capabilities and costs for planning purposes. Applications in specific locations are described in general terms. A 100-page appendix describes each type of ITS application in a standard one-page format, outlining functionality but largely omitting benefits. One page in this appendix contains a table with example benefit estimates from a few categories such as “Freeway Management Systems (Ramp Metering),” showing “Freeway Travel Time” savings of 20-48%.

The PSR for ITS enhancements on SR-17 (2002) contains detailed information on costs and on the ITS components being deployed, but no estimates of impacts on traffic, accidents, traveler behavior, or other potential benefits. The report provides a succinct description of the problems and constraints (see below, “Problem Context”) and some heuristic evaluation about some alternatives (see below, “Alternative Treatments”), as well as three stages of deployment. The PSR also describes how the information gathered will be used to dispatch emergency vehicles and inform motorists. The expected benefits are enumerated and impacts implied, including trip diversion, reduced secondary accidents, and improved data for “assessment of improvement options.” Accidents are reported to be higher than State average in the southbound direction and less than

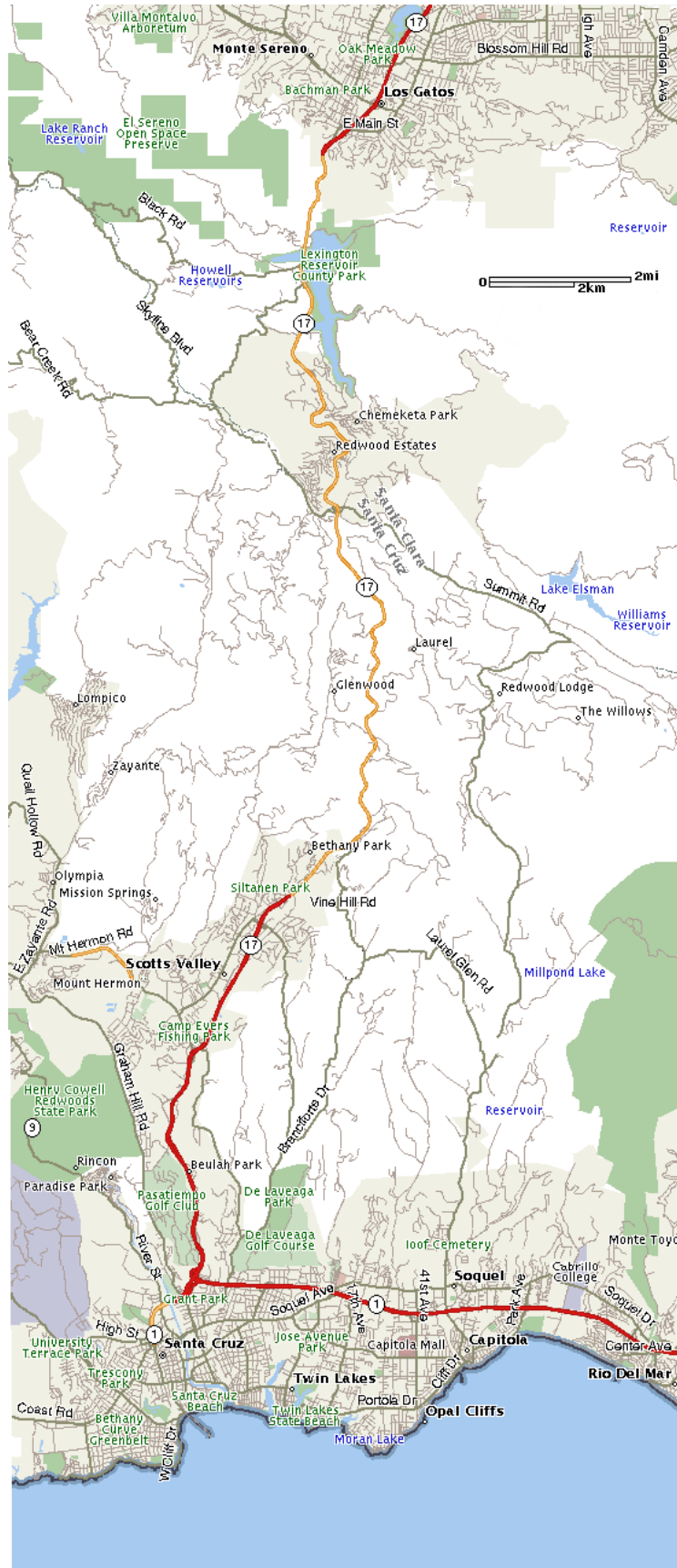


FIGURE 13. SR-17 from Santa Cruz to Los Gatos.

average northbound, leading the PSR to speculate that drivers are more likely to underestimate the speed risk going downhill.²⁴

7.2 Problem Context

The problem with this section of roadway is threefold: congestion, accidents, and delay from incidents. These are, of course, generic problems; they each have many possible treatments. Knowing these problem symptoms allows a range of alternatives to be generated, but provides no basis for selection of suitable treatments. Thus it is necessary to go to a finer level of detail.

A description of the problem with respect to SR-17 could include the following factors:

- (1) Four lane (two in each direction) facility divided by a median barrier.
- (2) High commuter volumes, meaning that v/c ratios are close to 1.0 during morning and evening peak periods in the peak direction.
- (3) High recreational traffic volumes on seasonal weekends, meaning that v/c ratios are high on summer weekends.
- (4) The terrain is mountainous, meaning many steep grades, some of them long, many sharp curves, and shifts between up and down grades.
- (5) Narrow or nonexistent shoulders, often protected with jersey barriers or guard rails.
- (6) Several at-grade intersections, none with traffic signals. The portion from Scotts Valley to the summit is not constructed to expressway standards.
- (7) Less-than-standard sight distances.
- (8) Weather hazards in the form of fog and rain, but not snow.
- (9) Few or no alternative routes.

²⁴Although the Kimley-Horn (2002) “Strategic Plan” is for Bay Area freeways, its enumeration of “Benefits” from “Caltrans TOS/TMC Enhancement and Completion” is relevant to the Santa Cruz context: “Upgrading and enhancing the TOS is a vital element to the overall freeway management program in the Bay Area. Once the existing TOS is brought to full functionality, and benefits demonstrated, the TOS should be completed for the remaining freeway mileage. This strategy represents a group of strategies that, combined, provide a phased approach to upgrading, enhancing, completion and operations of the system to optimal functionality. Other strategies that are not necessarily exclusive to the TOS/TMC (...) will need to be considered as part of the overall TOS Completion Program. With the TOS performing satisfactorily, the operations of the freeway network will be improved by more rapid detection of incidents and quicker response to clear the freeway and restore it to normal operation” (p. 8). Aside from the lack of any quantitative estimates, the connection between the TOS/TMS enhancements and more rapid incident detection is simply assumed.

These characteristics allow us to begin to consider various treatments that could alleviate the symptoms.

7.3 Alternative Treatments

A checklist and some heuristic estimates of likely cost and effectiveness are included in Table 3. Effectiveness may be broad or specific to one of the three problem symptoms (congestion, accidents, incident delay). The reason for separating incident delay from addition to congestion and accidents is that the difficulties of incident clearance on SR-17 result in delay that is greater than normal for similar incidents in other contexts. The treatments are sorted into the arbitrary categories of physical improvements, ITS treatments, and other operations treatments.

TABLE 3. Alternative Improvement Actions for SR-17

Alternative Treatments	Expected Effectiveness	Cost	Additional Information
Physical Improvements:			
1 access control	M	MH	accident cause
2 widen lanes	M	H	accident cause
3 vertical realignment	H	VH	acc. cause, incident type
4 horizontal realignment	H	VH	acc. cause, incident type
5 add/widen shoulders	H	VH	acc. cause, incident type
6 add lanes	H	VH	acc. cause, incident type
7 add guard rails	L	L	accident cause
8 add pullouts	M	M	acc. cause, incident type
9 add/enlarge post mile markers	LM*	VL	acc. cause, incident type
10 HOV/HOT lanes	L	M	range of choice
ITS Treatments:			
11 variable tolls	L	M	range of choice
12 add (smart) call boxes	LM	L	type of incident
13 improve incident detection	M	L	type of incident
14 improve incident verification	M	M	type of incident
15 improve incident dispatch/clearance	M*	M	type of incident
16 improve incident equipment	M*	M	type of incident
17 changeable message signs	M*	L	type of incident
18 extinguishable message signs	M	M	range of choice
19 highway advisory radio	LM	M	range of choice
20 pre-trip traveler information	M	M	range of choice
21 curve warning	M	L	accident cause
Other Operations:			
22 speed enforcement	H	M	accident cause
23 DUI enforcement	L	M	accident cause
24 aggressive driving enforcement	M	M	accident cause
25 motorist awareness program	M	M	range of choice
26 ridesharing (car)	L	L	range of choice
27 ridesharing (van)	L	L	range of choice
28 bus transit	L	M	range of choice
* effectiveness depends upon implementing the particular treatment in conjunction with other treatments.			

- (1) **Access Control.** Access control is mainly a safety measure, but may reduce delay for entering or crossing traffic. Two intersections (Glenwood and Virgin Hill) are not grade separated. Summit (Figure 14) and Mt Hermon Roads are separated access-controlled crossings. Considerable patience is required to enter SR-17 and travel northbound from Glenwood Canyon Road. The volumes of traffic on the intersecting roads is very light. If these intersections create a disproportionate share of accidents, then separation might be an effective treatment.



(simulated message)

FIGURE 14. VMS/CMS on SR-17 northbound at Summit Road.

- (2) **Widen Lanes.** If the lanes are less than 12' wide, bringing lane width up to standard will reduce accidents and increase capacity, especially on roads with tight curves. Costs would be exceptionally high for such an improvement in mountainous terrain, and would have limited value without realignment.
- (3) **Vertical Realignment.** Smoothing grades would have some beneficial impacts on improving traffic flow and reducing accidents, but would be enormously expensive.
- (4) **Horizontal Realignment.** Straightening out curves would improve flow, increase capacity, and reduce accidents, perhaps more than vertical realignment, but at very high cost.

- (5) **Add/Widen Shoulders.** Wider shoulders would create significant benefits for incident management by letting disabled vehicles get out of the travel lanes, and allowing emergency equipment to get to the scene more quickly.
- (6) **Add Lanes.** Additional lanes would increase capacity and relieve congestion, for at least some period of time.²⁵ The cost of additional lanes, measured as construction plus environmental degradation, or as construction cost (higher) that mitigates environmental damage, would be very high.
- (7) **Add Guard Rails.** Guard rails provide safety by deflecting cars away from running off the road. There are not many stretches of SR-17 that are suitable to guard rails and do not already have barriers or guard rails.
- (8) **Add Pullouts.** Pullouts allow disabled vehicles to get off the traveled roadway with minimum disruption, easing incident congestion and enhancing safety. Most opportunities for pullouts in the southbound direction are already utilized, and few opportunities occur northbound because the northbound direction is typically on the outside of the mountain (farthest from the face of the hill). Figure 15 and Figure 19 show pullouts.
- (9) **Add/Enlarge Post Mile Markers.** A possible use of post mile or milepost markers is to permit vehicle occupants with cell phones to know and communicate their precise locations more accurately. At present, cell phone calls are not used to verify incidents or pinpoint accident location, for a number of reasons including their unreliability. If the markers were larger and more widely understood (see Figure 15), they might be used more effectively (they are already numerous, but often obscured by guardrails).
- (10) **HOV/HOT Lanes.** Carpool lanes are intended to encourage ridesharing by offering a faster trip to those who do. Because neither people nor lanes can be divided into less than integer values, there is no minimum vehicle occupancy that will both maintain consistent full utilization of the HOV lane and free flow on the lane. Two lanes in the same direction is probably too few to make one into an HOV lane. A mechanism for countering this lumpiness problem is to allow SOVs on the HOV facility for a price, or toll, hence High-Occupancy Toll (HOT) lanes.²⁶ While there always are opportunities for increased carpooling, the trends are away from it, i.e., lower occupancy.²⁷ With only two lanes to work with, keeping them separated is difficult, especially if there is a breakdown in one. Reducing lane changes could

²⁵The relationship between capacity and travel volumes is a complex subject, but a significant reduction in the travel time cost of highway travel will induce additional travel in both the short run (more trips, lower vehicle occupancy) and the long run (work-housing-recreation decisions). Commuters in Santa Cruz enjoy lower housing costs than in Silicon Valley at the cost of having to travel SR-17 twice each workday; if this becomes less onerous, more people will live in Santa Cruz and work in Santa Clara, leading to both more travel and higher housing prices in Santa Cruz. Similarly, if weekend travel to Santa Cruz beaches becomes easier, more Bay Area residents will choose to do it.

²⁶HOT lanes are being studied for implementation on Highway 1 just east of the city of Santa Cruz.

²⁷The SCCRTP (2002) shows some year-to-year variation around a narrow band, but no particular trend up or down; nationally, however, the trend is down for the past decade or so.



FIGURE 15. Pullout with motorist call box and post mile marker.

have a beneficial effect on safety, but speed differential between lanes could increase accidents.

- (11) **Variable Tolls.** Congestion tolls or value pricing, similar to HOT lanes, maintain free flowing traffic by varying the price or toll to manage demand. Several HOT lanes have been established in California, and time-of-day charging schemes are in use in other cities in the US and around the world. The responsiveness of traffic volume to the level of the toll—referred to by economists as elasticity—depends upon opportunities for shifting trip schedules, ridesharing, alternative modes, and alternative routes. There is always some elasticity to demand, but in Santa Cruz County peak pricing would need to be tied to bus or alternative service that represented a reasonable substitute for the prevailing SOV mode.
- (12) **Smart Call Boxes.** Basic call boxes are frequently placed in pullouts along SR-17, and serve to provide communication as well as precise location of the caller. An example is shown in Figure 15. “Smart” call boxes can collect other information as well, such as traffic volumes.²⁸
- (13) **Improved Incident Detection.** A specific deployment for incident detection would be PTZ (pan-tilt-zoom) video cameras (CCTV) spaced at intervals of no more than 1/2 mile, along with loop or other vehicle detectors. These would be linked through communications (wireless or fibre optic cable) to a traffic operations center with computer algorithms that monitored detector and camera data for

²⁸See the Central Coast ITS Strategic Plan (2002) for a description of “Smart” call boxes.

indications of abnormal events and raised an alarm with the TMC operator. This is also known as surveillance.

- (14) **Improved Incident Verification.** Action cannot be taken to clear an incident or mitigate its consequences until the existence of the incident and its exact location can be verified. Speeding up this process could reduce incident delay. Surveillance can sometimes provide verification, perhaps in conjunction with cellphone users and “landmarks” in the form of frequent milepost markers.
- (15) **Improved Incident Dispatching/Clearance.** Accurate location information is important for clearance, especially where access to incidents is restricted due to lack of shoulders. If an emergency tow truck can use a shoulder where available, an alternative road that meets SR-17 at a nearby location, or travel the wrong way on a temporarily closed section of the opposing lanes, the incident can be cleared faster. Not only must the information be accurate, but finding and selecting the best access routes in real time requires close attention on a moment’s notice and good communications among emergency services and the TMC. The effectiveness of incident treatments depends upon the types of incidents that occur, whether mechanical breakdowns, collisions, or rock slides.
- (16) **Improved Incident Equipment.** Tow trucks might be constructed to take into account the typical access conditions, such as narrow access route and steep grades.
- (17) **Changeable Message Signs (CMS).** Changeable or variable (VMS) message boards allow information to be provided to motorists en route. Information content may include warnings of potential hazards (e.g., weather),²⁹ warnings of incident delay, and information about construction or other scheduled lane closings. The messages are typed on a computer at the TMC and posted on the applicable sign-board. Standard or frequently used messages may be canned and selected from a list. Effectiveness depends in part on what options the traveler can take in response to the information; in this corridor, they may amount to getting off the road until the incident is cleared, or turning around and going back. The messages need to be removed when the information is obsolete, to maintain credibility with travelers.³⁰ CMS are shown in Figure 14 and in Figure 16.
- (18) **Extinguishable Message Signs (EMS).** An EMS has a fixed message that is displayed if it is turned on but otherwise blank. The signs used on SR-17 announce to motorists if there is a message on the highway advisory radio that is pertinent to their situation. An example at the entrance to SR-17 in Santa Cruz is shown in Figure 17. This particular message is a more elaborate version of the sign that says

²⁹“Fog Warning” (Pittsburgh Post-Gazette, 2004) describes a Maryland deployment on an Interstate that displays messages and flashing lights when fog of a high density is detected automatically.

³⁰Some anecdotes that may or may not be representative suggest that messages have been allowed to remain displayed after traffic had returned to normal. Messages are posted by Caltrans District 4 in Oakland; their attention may be distracted by incidents of greater severity and taking place more centrally in the Bay Area.



FIGURE 16. VMS southbound near Summit Road.

“Tune to AM 840 When Flashing,” accompanied by a yellow flashing light that is turned on when messages are posted. An en-route EMS is shown in Figure 18.

- (19) **Highway Advisory Radio (HAR).** Most vehicles have working AM radios, but how quickly the recommended station can be located by a single-occupant driver is somewhat variable. The radio message can be longer and contain more useful information than either the VMS or EMS. The stations are low power and have a range of about 2 miles.
- (20) **Pre-Trip Traveler Information.** For SR-17, some of the most valuable information would best be delivered to motorists before they started their trips. This can be communicated via broadcast or cable TV, telephone, an internet site, or radio



(message display simulated)

FIGURE 17. EMS at entrance to SR-17 northbound in Santa Cruz



FIGURE 18. EMS on SR-17 northbound near Scotts Valley.

broadcast, or even an in-vehicle device. Evidence so far suggest that not many people consult such sources on a routine basis, but those who do claim they are likely to change trip behavior as a result. If the information is reliable, easily

accessed by the user, and potentially valuable, then affected travelers are likely to make use of it.³¹

- (21) **Curve Warning Signs.** Curves that are sharp enough relative to the average geometrics for a road that slower speeds are required are posted with a warning sign indicating recommended maximum speed. Because the design speed tends to determine actual speeds more than do speed limits, drivers may enter curves going faster than the posted speed limit, and be unprepared for the sharpness (or super-elevation) of the curve. SR-17 has several such curves, which are signed in the standard way. Because, however, many accidents are thought to be caused by excessive speed on curves, a more aggressive warning may be warranted. Such a sign could read the actual speed of the nearest approaching vehicle, display that speed to the driver, and remind the driver what the recommended maximum is for the next curve. The sign is shown in the speed readout state in Figure 19 and in the speed limit state in Figure 20. Advantages of this device are, one, it is the first mechanism considered so far on this list that serves to prevent incidents as opposed to mitigating them, and two, it can be deployed as a self-contained stand-alone device. With data on the frequency of incidents that actually reduce capacity and on their locations, it could be determined whether the accidents are concentrated in a few locations, then these locations could be a focus for speed advisories and signs giving motorists their actual speeds.
- (22) **Speed Enforcement.** If accidents are caused by excessive speed, and such accidents are a major source of delay, then a productive strategy might be aggressive enforcement of speed limits. Excessive speed would tend to result in vehicles running off the road or into guard rails or jersey barriers, perhaps secondarily colliding with other vehicles going in the same direction. Traditional enforcement requires the presence of state troopers at the side of the road or in the traffic stream. Because pullouts are limited, issuing citations is more time-consuming than on typical arterials and expressways. Actual speeds could be monitored at particular locations (as in the curve warning sign above) to identify places needing patrolling. Remote electronic enforcement could also be feasible, but is generally not permitted by law. Speed limit enforcement is intended to prevent accidents and the attendant incident delay.³²
- (23) **DUI Enforcement.** If accidents are disproportionately caused by drivers operating under the influence of alcohol, then enforcement specifically targeted at drunk drivers could be effective. Commuters, however, are less likely to be DUI, at least on the way to work, nor are recreational travelers at midday. If returning travelers (southbound weekday peak, northbound weekend) have accidents at a higher rate, then alcohol might be a factor.

³¹ A phone-in traveler information service is available throughout the Bay Area by calling a single number where ever the caller may be. A web-based service is under development.

³² The "Safe on 17" campaign sponsored by the California Highway Patrol has been in operation for several years and emphasizes enforcement of speed regulations and outreach to increase driver awareness (SCCRTC (2001) "Plan").



FIGURE 19. Actual current vehicle speed readout on curve warning VMS.



FIGURE 20. Speed limit message on curve warning VMS.

- (24) **Countering Aggressive Driving.** Aggressive driving consists of not only excessive speed but frequent lane changes and following other vehicles too closely to allow for contingencies. Another undesirable behavior is driving too slow in the left-hand lane, preventing faster vehicles from passing. Police observations can

assess the degree to which aggressive driving or other behaviors are contributing to accidents.

- (25) **Motorist Awareness Program.** Efforts can be taken to ensure that motorists are cognizant of hazards such as excessive speed as causes of accidents and delay. Many of the treatments mentioned above can be taken in conjunction with motorist awareness efforts to improve their effectiveness.
- (26) **Ridesharing (car).** Congestion can be reduced, or more person-trips accomplished with the same vehicle trips, if vehicle occupancy can be increased. Converting one lane to a HOT lane is one device (see [10] above). Carpool matching can be attempted at both origin and destination locations, depending upon the characteristics of travelers in the corridor, but it is likely that both are spread out. Casual carpooling or “slug lines” can arise in conjunction with an HOV or HOT lane, or other toll facility favoring high-occupancy vehicles. The pickup locations occur at transit stops because commuters know they can always resort to transit if they do not get a ride, and they may use transit for the return trip; with no transit alternative, casual carpooling is less likely to occur spontaneously.³³
- (27) **Ridesharing (van).** Vanpools are subsidized ridesharing arrangements that are most effective for long-distance commuters, for whom the inconveniences of schedule coordination and consistency are offset by the reduced cost and not having to drive for a substantial distance. Assembling pools of compatible riders is typically done from destinations, i.e., people who work near each other or in the same building. While the programs can be successful, the effect on congestion is minimal. A high enough level of participation, however, could help serve to justify a HOT lane.
- (28) **Bus Transit.** Another form of ridesharing, bus transit can serve many person-trips in one vehicle. Express bus service is particularly effective for commuters when numerous origins can be collected into a single channel to a central location. The SR-17 corridor lacks an obvious central destination, but careful surveys of potential riders might identify dropoff points that would provide good service to several Santa Clara locations. Express bus service is greatly enhanced by an HOV/HOT lane. Origins could be aggregated via park-and-ride lots.³⁴

This brief review of alternatives places ITS on the same list with physical improvements, other operations treatments, and highway transit options. The same problem description can be used to drive the evaluation of each alternative as well as combinations. The characteristics of the problem context suggest the data that are needed (origins and destinations, causes of incidents) and the impacts that need to be estimated

³³SCCRTC and several local TMAs (transportation management associations) currently offer a “Commuter Solutions” program that facilitates carpools and provides ridesharing incentives for vanpools (SCCRTC (2001) “Plan”). Slug lines occur at BART stations in the East Bay for the carpool lanes on the Bay Bridge.

³⁴The Santa Cruz Metropolitan Transit District (“Metro”) offers an express bus service on weekdays from Santa Cruz County to downtown San Jose locations that carries about 178,000 trips annually (SCCRTC (2001) “Plan”). Roughly half-a-dozen park-and-ride lots in the Santa Cruz area serve Route 17 commuters.

quantitatively (changes in traveler behavior, accident rates, traffic volumes, in addition to costs).

7.4 Public Preferences

As with almost all metropolitan or regional planning organizations, many agencies and organizations participate in decisions in Santa Cruz County, and public participation is an important part of the decision process. The public participation outreach program generates many public meetings to discuss issues and allow people to speak out, and conducts systematic surveys to gauge citizen opinions on many matters. The latter show these among other results:³⁵

- (1) When asked to volunteer the “two biggest problems” in their area, respondents most frequently named “traffic congestion” (46%), considerably ahead of mentions of “overcrowded/overpopulation” (17%), and “housing/affordable housing” (15%).
- (2) When given a list of problems, 80% of respondents said that “traffic congestion” and “high cost of housing” were either “extremely serious” or “very serious,” followed by 63% indicating that “need to protect open spaces and agricultural land from development” and “homelessness” were extremely or very serious problems.
- (3) Asked about specific transportation improvements, widening Highway 1 received the most support, with support also for maintaining (but not widening) local streets, for new light rail transit, and for expanded bus service.
- (4) 70% of households generated at least one SOV trip per week.
- (5) When asked about means for financing the improvements, a sales tax was strongly preferred and a gasoline excise tax opposed, although the opposition softened considerably on probing. A property tax increase was almost as disliked, and peak period tolls on Highway 1 were strongly opposed.
- (6) Asked what assurance would add to their support of any tax measure, the most positive responses were if “all the money raised by this measure will stay here in our local community” (76%), “the money will be used for repairing or replacing old and deteriorating roads which are becoming dangerous to drive on” (63%), and “some of this money will go towards addressing some of the congestion on Highway 1” (56%).
- (7) Only 34% felt that things are getting worse, but that is more than the 18% who think things are getting better.

³⁵SCCRTC (2001) “Plan,” Appendix B.

- (8) Half the respondents had lived in the county for 20 years, half were over 50 in age, one-quarter were retired, three-quarters owned their home, and 22% commuted to Santa Clara County.

No questions directly concerned SR-17. At a superficial level, then it would appear that there is a mix of groups with differing and perhaps rigidly held opinions that have yet to be reconciled into any consensus. Renters and newcomers are confronted by the cost of housing, but they are probably not the same as the “over the hill” commuters. Older property owners resist property taxes, and favor sales taxes because somebody else (“tourists”) will pay them. Highway user taxes are opposed, local road maintenance favored, and arterial expansion favored because almost everyone drives. Most residents would like time to stand still, with oldtimers who don’t want change combining with newer residents who want to preserve the environment and acquire a home; all would like other people to ride transit, and some might do so if service were good enough. Few, it seems, are willing to give up their autos or pay more for their use.

7.5 Long Term Planning

From the standpoint of the region as a whole, Santa Cruz is on the fringe of the San Francisco Bay Area, and directly affected by the latter’s expansion. Land rents (the cost of raw land) is heavily determined by its location within the access surface of the Bay Area. This surface can be represented graphically as a tent-like structure over the entire region, with peaks in employment centers and stretching out at lower heights into commutersheds. As a region grows, the height of the tent (land value) goes up everywhere and it also spreads out. Santa Cruz has come under the edge of the tent.

While the height of the tent is roughly determined by distance to employment, it is also affected by the cost of transportation. Cost, in this sense, includes both money paid (fares or user fees) and travel time. If travel time is reduced on SR-17, accidents reduced, and reliability increased, this constitutes a reduction in the cost (or “price”) of transportation to the user.

When the cost of transportation is reduced, the tent spreads out. New land is developed (its accessibility has been increased), land values go up, the price of existing housing goes up, more people move in, and traffic increases. SR-17 currently serves as a constraint on those effects. Failure to improve the highway will not stop the demand, but the price of commuting into Santa Clara (or weekend tripping into Santa Cruz) is what keeps the price of housing in Santa Cruz as low as it is. Maintaining free-flow levels of service on highways, low highway user charges, a high-quality natural environment, low housing prices, and a constant population are not mutually compatible goals.

7.6 Improved Planning Information

It seems that everything is in place, but essential information is lacking at the point of decision. The problems with SR-17 have been recognized, if perhaps not considered in juxtaposition. The range of possible treatments has been explored, and many of them

implemented in some form. Citizens are vaguely aware of conflicts, but do not appear to understand the substance of the tradeoffs. Plans contain useful information, but no analysis or evaluation of alternatives. Project Study Reports contain specific information about the proposed deployment and its costs, but again no analysis of tradeoffs or benefits. Decisionmakers express frustration and skepticism about proposed solutions, and ask for evidence, but do not seem to be provided with information they regard as useful.³⁶

The list of alternative treatments to a given problem can be subjected to informal and formal evaluation. The former, heuristic, methods rely on experience and judgment, and serve to reduce the list to the most likely candidates. Formal evaluation of costs and benefits should be a part of every project that is included in an improvement program, with the refinement of the BCA being commensurate with the consequence of the decision.

Formal analyses of all relevant alternatives for the SR-17 “problem” exceed the resources of this report, but some example analyses are included in Appendix B.

³⁶When the SR-17 PSR (David, 2003) was presented to the SCCRTC and discussed, several of the Commissioners expressed doubts about the efficacy of the ITS treatments and requested evidence from other deployments that would shed light on how well they might work in the SR-17 context. One commissioner had encountered an obsolete message on a VMS and questioned their reliability.

8 Findings

This section contains findings from the case studies, meetings and interviews conducted for this project, previous research, and a review of Caltrans documents. Interviews and meetings for this project were conducted with the intention of filling in holes in previous research, particularly experience with actual implementation, but they were also intended to test previous findings. The project began with a meeting of the project advisory committee, whose members had previously been sent a questionnaire regarding ITS and the planning process. In addition to the project staff, 11 people attended the meeting, 8 from Caltrans headquarters divisions of Planning, Research and Innovation, Mass Transit, and Traffic Operations, one from a Caltrans district planning, and two from regional transportation planning agencies (RTPAs). After that, fifteen people who had been involved in some aspect of ITS implementation were interviewed. They included staff from the California Transportation Commission, Caltrans, regional transportation planning agencies, counties, and ITS America. Another meeting at which the project findings were presented and discussed was attended by six people. The California planning process, current plans, and planning documents were investigated, largely via websites maintained by the CTC, Caltrans, and the regional transportation planning agencies.

8.1 On Paper the Current Process Looks Good

8.1.1 The Caltrans Recommended Steps

On paper, the transportation process is rational and comprehensive. The following is from the Caltrans Transportation Planning website:³⁷

“The [transportation planning] process can be described in the following steps:

- (1) Goal Setting (What do we want the future to be?)
- (2) Problem Identification (What are the problems in reaching our goals?)
- (3) Data collection and analysis (What is the current situation, projected issues, etc.?)
- (4) Alternative Actions (What are possible solutions to fixing the problems?)
- (5) Evaluation of Alternatives (What are the pros and cons of each solution?)
- (6) Recommended Alternative (What is the best course of action to take?)
- (7) Implementation (Carry out the solution or combination of solutions)

³⁷ <http://www.dot.ca.gov/hq/tpp/faqs.htm>

- (8) Monitor and Feedback (What happened? Did the solution(s) solve the problem? Are there other problems?)”

Identification of problems, generation of a suitable range of alternatives, early and continual evaluation of alternatives, and monitoring of previous projects to improve planning and impact estimation are especially important and, unfortunately, sometimes neglected.

8.1.2 California Transportation Commission Policy on Project Evaluation

The California Transportation Commission policy on Project Study Reports specifies the use of cost benefit analysis and suggests benefits to be considered as well as measures of these benefits (See “ Appendix A: The CTC Policy on PSRs” on page 75). There is a clear delineation regarding which organizations are responsible for which planning activities and how funds will be allocated. Data bases and tools have been developed to assist in the analysis (see Section “4 Planning Tools and Resources” on page 19). People interviewed for this project who were queried about the process generally felt that although the process was complicated, it was sound, and that problems generally occurred when there were end runs around the process, such as earmarks and the previous Governor's Transportation Congestion Relief Program (TCRP) for 141 specific projects around the state.

Why then does implementation of ITS seem too slow? Why do people involved in transportation planning in California say that politics and the crisis of the moment often count more than analysis and rational planning? Is it that transportation planning is so political that the process is not really followed? This is more likely to be the case when there is a paucity of information on the actual effects of various types of improvements.

8.2 There are Few ITS Projects in the Current RTIPs

What are the barriers to implementation of ITS? How serious are these obstacles?

8.2.1 Overselling of ITS

The extravagant claims made for ITS have led to skepticism among many potential implementers. Insufficient emphasis was given to the on-going costs of power and communications for ITS services and the new skills required for their operation. In some cases this has resulted in incomplete implementation when funds were not available for operations.

Much has also been made of the benefits of ITS integration, the idea that the benefit of many services together is greater than the sum of the benefits of the individual services taken alone. But the truth of this proposition has not been tested. In fact, it seems quite possible that services might have negative interactions. For example, if a road already has a good system of changeable message signs, the additional benefits of highway

advisory radio are likely to be less than if there were no changeable message signs. Furthermore, a system designed to serve too many purposes may be more costly than separate systems each serving a single purpose. The key to the value of ITS integration lies in the interactions between the benefits of the service and the interactions between the costs. It should not be assumed that integration is always a good thing.

The unfortunate result of the emphasis on integration is that individual ITS services, rather than being seen as relatively inexpensive ways to improve transportation are sometimes seen to require combination with other ITS services, making them too costly to pursue.

8.2.2 Problems Encountered With Overly Ambitious ITS Projects

Knowledge of these projects may also discourage consideration of ITS. Many people interviewed noted the difficulties of large projects that required several agencies to work together. Such projects were often formed in order to seek earmarked funds or respond to special funding opportunities. In these circumstances several problems arose:

- the projects were often larger than could be easily managed and implemented in a timely fashion,
- they sometimes included elements of little value to participants,
- conflicts arose over responsibility for maintenance, reimbursement for project costs, and the like, and in some cases agency legal advisors became involved, hardening positions, reducing implementation flexibility, and ultimately increasing costs, slowing implementation, and reducing project value,
- projects focused on hardware and how it worked and insufficient attention was given to what the agencies would do with the hardware,
- the same group of projects, if implemented incrementally by the smaller number of agencies involved in each project could have been implemented sooner and more efficiently,
- when a project is implemented by a committee of agencies, the project may wither after it is implemented because no one agency feels responsible for its continued operation, and
- lack of project ownership can also slow implementation because no one agency is sufficiently motivated to move it forward.

Projects implemented by cities are often very effective because the people in the cities are close to the problems, understand them, and care about mitigating them. They have the incentive to make projects work. For example, loop detectors in the Silicon Valley Smart Corridor are used to observe traffic in order to control signal timing. Because they are used, people notice when they do not work and they are quickly repaired, unlike the freeway loop detectors discussed in Section “8.3.2 Data Regarding the Current Transportation System may be Difficult to Find” on page 62

8.2.3 Architecture Requirements Can Inhibit Implementation

Few people, even those involved in ITS completely understand what is needed to comply with the National ITS Architecture. Despite volumes written about the architecture the actual requirement is difficult to find.³⁸ All that is required is a regional architecture and a systems engineering approach. But it is a rare transportation agency that has a systems engineer on staff, and costly consultant assistance is usually needed. This adds to the agency resources required to implement ITS, and can be enough to prevent consideration of ITS.

The ITS stovepipe uses the “architecture” and “systems engineering analysis” mechanisms for several purposes, including information exchange, standardization, interoperability, and design. The architecture provides a checklist of considerations for any type of ITS application, and does so at a performance rather than hardware level. Systems engineering tries to ensure that requirements have been thoroughly reviewed and possible problems have been anticipated as much as possible. Both are necessary because most ITS projects involve the joint participation of several if not many agencies; roles and responsibilities need to be articulated, and a forum created to obtain buy-in and a platform for advocating the projects to both participants and to decisionmakers. A downside of this process is that potential participants may be scared off by the need to conform to the architecture and comply with the systems analysis requirements, and innovation may be inhibited by having to achieve consensus among an unnecessarily large group. Using the architecture as recommended guidance rather than mandatory requirements would reduce the threatening aspect.

While this process is fine for generating alternatives and serves some value in reducing the range of possible actions, it does not perform any economic evaluation of either the best way to solve a given problem (which alternative to select) or whether the project is high priority in comparison with other projects (the programming problem). Ideally, the options studied in scoping, designing, and engineering the project would serve to provide justification at the programming stage, but this does not currently happen.

8.2.4 ITS Plans Are Not Always Problem Driven and May Inhibit Consideration of ITS in Developing Regional Transportation Plans

Much ITS planning follows a comprehensive approach that gives more attention to interoperability than to benefits and costs. It emphasizes hardware over well-thought-out operating procedures. ITS planning has not often produced prioritized lists of cost-effective ITS projects that could be included in regional investment programs either as stand-alone projects or part of other projects as funding opportunities arise. For example, the 1999 California ITS System Design, developed for the California Intelligent Transportation Systems (ITS) Deployment Initiatives Project identifies these broad program areas:

³⁸ See http://www.calcit.org/itsdecision/ITS_Architecture/what_is.htm for information on the national architecture; see Kimley-Horn et al. (2004) for the California ITS architecture (<http://www.kimley-horn.com/Caarchitecture/index.htm>).

- Traveler Information
- Electronic Payment
- Goods Movement
- Public Transportation
- Vehicle Safety and Control

The document is not specific and is more a wish list and recitation of issues than a plan. The Metropolitan Transportation Commission's ITS planning effort produced a list of all ITS projects in the Bay Area in September 2003. This represents only the first of 11 tasks intended to culminate in a regional ITS Architecture, which will likely not deal with specific projects and their benefits or costs.

Such plans and architectures offer little help to local agencies trying to apply ITS to address their particular problems. In fact, the very comprehensiveness of such plans may suggest to local planners that ITS is something very difficult to implement and that ITS is generally not relevant to their needs.

8.3 There is Little Estimation of the Benefits of ITS Projects at Any Stage of the Planning Process.

The efficacy of ITS services seems to be taken for granted. Ramp meters are installed without establishing operated rules and determining how the ramps will actually affect traffic. Systems for diverting traffic in the event of an incident are implemented without analyzing how frequently an incident that would warrant diversion would occur.

8.3.1 Data on the Effects of ITS are Scarce

Because estimation of benefits rarely occurs, the information for such estimates is not demanded, and thus is not produced or is not easily available. Information on the effects of actual ITS implementation is particularly scarce. For example, what is the benefit of having information regarding the time before the next bus will arrive? Will providing this information cause more people to use the bus? Or, how much will accidents be reduced if an automated red-light running enforcement system is installed? Until experience is acquired on the effects of services such as these, there will be no data on which to estimate or value these benefits.

Projects of these types have been implemented, but little effort has been made to estimate or model the impacts, with the result that current implementation of such ITS applications as traveler information, traffic surveillance on freeways, and HOV lanes is based on speculation rather than good estimates of their efficacy.

Evaluations have been conducted, but these generally address field tests and demonstration projects that entailed problems and delays that would not occur with routine implementation of such projects. The USDOT has developed databases of ITS Benefits and Costs (Section "4.2.3 FHWA ITS Benefits Database" on page 20), and the PATH pro-

gram has develop a website that provides what is known about the performance of various ITS services and technologies (Section “4.3.1 ITS Decision Website” on page 21). But more information from actual ITS deployments is needed to test the validity of analytical models and microsimulation models, and improve them. It could be argued, as well, that more information about the effects of conventional transportation investments is also needed.

8.3.2 Data Regarding the Current Transportation System may be Difficult to Find

Caltrans collects large amounts of traffic data.³⁹ The PeMS project has archived loop detector volume, density, and speed data as well as incident data for most urban state highways.⁴⁰ These sources use loop detectors to provide the data. But despite the thousands of loop detectors installed around the state, good traffic data for a particular section of road is not likely to be immediately available. Many sections of road do not have detectors. Even when such connections exist, the data were not be saved prior to PeMS. Even where the data are saved, the data may not be accurate—the loops may be faulty, the communication link may be faulty, or there may be an error in processing.

Because of these problems, many people have given up on loop detectors, even though they have been shown to be accurate and reliable when used for signal timing. There is a vicious circle with highway loop detectors: data are not widely used because they are not perceived as being accurate or available; because they are not widely used errors are not noticed and corrected, and monitoring and maintenance are not given high priority, causing the data to be inaccurate or unavailable. Therefore, in most cases, data for projecting the effects of transportation investments must be collected especially for that purpose. Methods for doing this are generally costly. Without good data, analyses tend to be perfunctory because careful analysis is not warranted without credible input data.

8.3.3 Evaluations Can Still Be Done, Even With Limited Data

The aim of “Appendix B: BCA Evaluation of ITS Pilot Projects” on page 79 is to show how the available data can be used to conduct an analysis that is good enough to determine if a project is likely to be worthwhile. Values can be assumed and sensitivity analysis can be used to determine how different values would affect project benefits or costs.

8.3.4 There is Little Guidance Regarding How to Conduct Analyses

Except in rare cases (the CMAQ cost-effectiveness guidelines) the documents specifying the planning processes do not specify the nature of the analysis to be conducted or the data to be used. Caltrans has developed a website, however, that provides guidance

³⁹ See <http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/2000all.htm> for daily and peak hour counts on all segments of California state highways.

⁴⁰ <http://pems.eecs.berkeley.edu/Public/index.phtml>

in benefit cost analysis for transportation planners and engineers with all levels of knowledge of benefit cost analysis (“4.4.2 Benefit/Cost Website” on page 24).

Black box analytical tools, such as IDAS (“4.3.3 ITS Deployment Analysis System (IDAS)” on page 21), are not likely to provide as accurate an estimate of benefits in a particular situation as a simpler analysis tailored to the situation.

8.3.5 Interorganizational Gaps in Communication

How in actual practice does the current planning process differ from the model Caltrans planning process outlined above and the problem-solving paradigm proposed in Section 1.4?

Although the structure of the decision process is sound, the actual practice has some glitches. At a somewhat abstract level, they can be represented by the relationships shown in Figure 21. Planning is a process of identifying problems, generating alternatives to address them, estimating the impacts of the alternatives, and evaluating the impacts to select the best action. Plans should provide context, strategy, and balance. At the end the decision process, programs contain lists of adopted projects whose costs make up the budget. In between, choices are made about which projects to fund and, indirectly, which goals or impacts are most valuable (e.g., travel time, air quality).

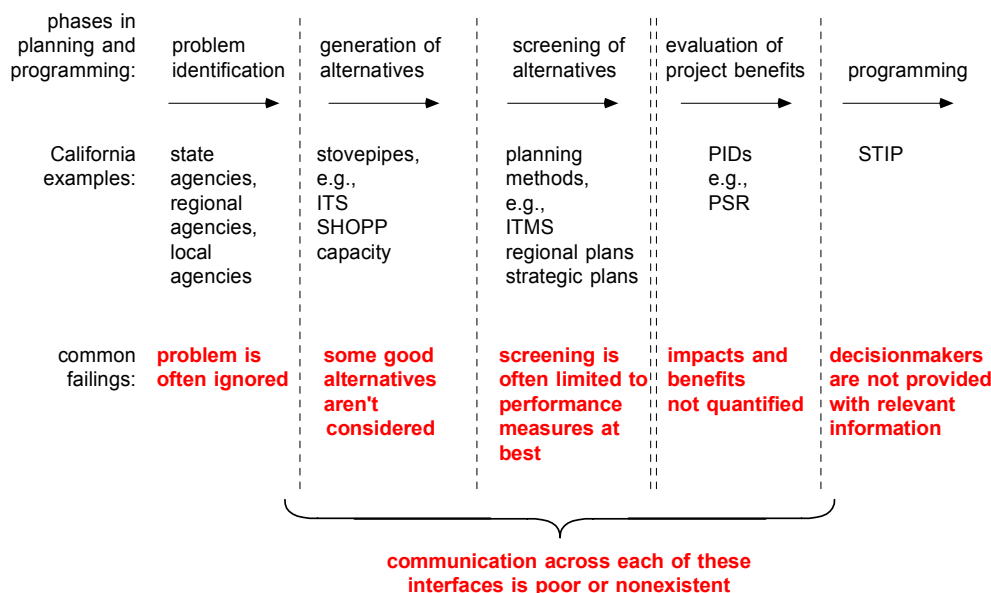


FIGURE 21. Schematic of the project investment decision process.

At present, the data or models developed at one step of the process are often not used in subsequent steps. This may be due to a failure to make the tools and data accessible to potential users, or, more often, a difference between what is developed and what is

needed by the ostensible customers. The customers ultimately may be commissioners and politicians, but the direct users are mainly other professional staff, at Caltrans headquarters, districts, regional agencies, counties, and local agencies.

8.4 Other Factors

8.4.1 ITS Projects May Have Unforeseen Uses

Because ITS is still relatively new, it is likely that new uses will be found for ITS elements. For example, the Silicon Valley Smart Corridor, proposed and funded as a tool for diverting traffic around incidents, has proved to be even more useful as a tool for conducting intersection studies. Like the ATSAC system in Los Angeles, it allows staff to remotely study and control traffic signal operations.

8.4.2 Highway Operations Are Not Given Much Importance

Several people interviewed for this project noted that one problem in implementing ITS within Caltrans is that operations are not considered as important as construction. This is manifested in the allocation of resources and personnel within Caltrans. Funding is often not sufficient to allow follow-through on projects.

Furthermore, when there is an emergency, the California Highway Patrol is in charge. Patrolmen are not expected to be trained in highway operations. Interestingly, the Metropolitan Transportation Commission, the regional transportation planning agency for the San Francisco Bay Area, has become involved in traffic operations with Caltrans, including the electronic toll system, the freeway service patrol, and the TravInfo travel time collection and monitoring system.

8.4.3 Caltrans Decentralization Can Retard Progress

On the one hand, decentralization of Caltrans into districts of manageable size and relatively homogeneous conditions can facilitate the development of smaller, more appropriate ITS projects than would be likely if ITS projects were implemented statewide. On the other hand, it can retard the development of ITS projects because districts are less likely to learn from each other and are more likely to duplicate development efforts, leading to higher than necessary development costs and slower development. Districts want to have their own systems rather than a system invented in another district. There is a need to facilitate ITS information sharing and development between districts, but without developing systems that are so generally applicable and complicated that they become overly complex, or so standardized that they do not meet regional needs.

9 Recommendations

The transportation planning and decision process in California is a marvel of creative adaptation. It takes many different forms in different places, but, at least at the regional level, it seems to be workable. The challenge is to overcome some failures in providing the most useful information to participants in the process at critical points in planning and choosing among investment alternatives. In particular, PSRs do not contain enough information specific to the particular project alternative about what impacts can be expected from the project and the estimated value of the benefits.

Two approaches that will *not* help to improve decisionmaking are (1) development of how-to guidance “cookbooks” that provide idiot-proof step-by-step instructions for preparing a benefit-cost analysis, and (2) “user-friendly” software packages that require the analyst to enter some specific data and then generate an officially-sanctioned “answer.” Complex problems are not solved by such mindless devices; real thought will always be required. What can be provided are suggestions, general requirements (do a BCA and have it reviewed by knowledgeable engineers and economists), examples of good practice, and access to a knowledge base that provides a deeper understanding.

9.1 Integrate ITS Planning into the Planning Process

California's budget crisis will likely result in a shortage of transportation funding for some time to come. In this environment, it is especially important to use the available resources to achieve the maximum public benefits. The transportation planning process is designed to achieve this. Earmarks and special ITS programs may have been helpful during the time when ITS was still in the demonstration phase. But even then, such projects often tried to do too much, too soon, and in the wrong order. Too many agencies were involved, resulting in high development costs and slow project delivery. Now, much more is known about which ITS services are likely to be effective in various circumstances, and ITS projects can compete with other projects on their merits.

9.2 Encourage Benefit-Cost Analysis in the Planning Process

The use of the analytical methods noted in section “4 Planning Tools and Resources” on page 19 should be strongly encouraged, and project study reports should be reviewed to make sure they meet the requirements outlined in the CTC policy (see “Appendix A: The CTC Policy on PSRs” on page 75). To support this, more attention must be given to collection of the required data so that the analyses are based on facts, and to post-implementation evaluation so that more can be learned about the effects of projects (including non-ITS projects), thus enabling better estimates of the effects of similar future projects.

9.2.1 Make Basic Data More Readily Available

The findings in section “8 Findings” on page 57 indicate that data required to assess needs and evaluate proposed projects are often not available. Although Caltrans' long

range plans call for an extensive traffic monitoring infrastructure, much planning will be done before such a system is in place. The need for data applies not only to ITS projects but to all types of projects, even pavement rehabilitation and safety projects. Data collection is expensive, but the cost is likely to be less than the losses that could be expected from less than optimal investment choices.

First, the data that are already collected should be made available. The PeMS project at the University of California is archiving existing loop detector and incident data from highly urbanized areas of the state, but in many locations either the loop data are not good or the communications links are faulty. Caltrans should establish a unit of skilled technicians that can assess what is needed to make existing loops in a particular location provide reliable and accurate data to PeMS and then do what is needed, from repairing loops and establishing a reliable power source to repairing or installing new communications links between the loops and the TMC. In each location it should train local technicians in how to maintain and monitor the loops and communications links. The unit should utilize PeMS daily diagnostics to identify loops that are not working or that may report inaccurate data. Research should continue to determine the likely cause of missing or inaccurate data, and inform the local technicians so that they can fix the problem. The unit would move from location to location getting the system functional until all loops that provide information of interest are reporting to PeMS. Caltrans Districts would share in the funding of the unit. Priority would initially be given to locations from which data is currently needed for planning purposes. A PATH report (Wright and Dahlgren, 2001) outlines a method for setting priorities for establishing traffic surveillance. Efforts should continue to make the PeMS website more user-friendly and to facilitate extracting data from the PeMS database.

For locations where there are no loops, the key question is how to collect the information needed for project evaluation at minimum cost. The first step is to determine exactly what data are needed and what are not needed. This depends on the analyses that will be needed to determine the extent of the problem and the best way to address it. If the problem is delay at a certain time in a certain area, then data is needed on the volumes and speeds throughout this area during the entire congested period, as well as those on alternate routes. If one of the alternative projects being considered is to improve transit service, then data are needed on trip origins and destinations by time of day both via transit and highway. Continuously collected data are not needed for planning and ITS project development; data for a representative sample of days should be sufficient. If conditions vary seasonally, data collected in the different seasons would be desirable. In framing the analysis, it is important that the problem be defined as something that affects travelers and freight carriers, such as “45 minute delays at location x”, and not in terms of the perceived solution, such as “travelers need more choice of modes.”

To collect data on freeways where there are no loops, moveable radar sensors could be used. PATH used these sensors to monitor traffic at a work zone on I-710. The sensors cost \$5,000-10,000, and installation on an existing pole costs \$1,000-2,000. Calibration is also needed. Information can be stored in the device until it is moved, at which time the data can be downloaded to a PC. A sensor is needed for each direction. The Minnesota DOT developed a portable pole-mounted radar sensor system that is attached to a

standard highway sign. It is battery powered and can be transported in a work van and set up in an hour. It can operate for 48 hours. Cost for the system was \$6,100 plus a laptop to program the sensor.⁴¹ Virginia DOT developed a similar system.

Nu-Metric count cards can be used on ramps or arterials. Origin-destination data and other trip data can be collected by recording license plates, getting mailing addresses of registered owners from the Department of Motor Vehicles, and mailing surveys to the owners. There are firms that provide this service. The cost is on the order of \$20,000 per site.

Because data collection is a non-routine process requiring specialized equipment, Caltrans should consider establishing a special technical unit or units that could provide these services to Districts as needed. The unit personnel could also arrange for archiving of the data and a process for retrieval. This might be a new function for an existing Caltrans unit, such as the Census.

9.2.2 Encourage Retrospective Evaluations of Projects

Projects are rarely evaluated after they are implemented. Such implementations would provide a much needed information base for estimating the effects of proposed projects. But evaluation has costs, and agencies are likely to be reluctant to have their predictions regarding performance tested. Therefore post-implementation evaluation could be a requirement to receive funding or could increase the funding allocation or funding priority for projects that agree to such evaluations. Caltrans Division of Planning should establish an evaluation unit to minimize the costs of the evaluations and to ensure that evaluations are done correctly and consistently. This unit would also compare actual effects to predicted effects in order to either confirm the validity of methods used to predict effects or to modify them or develop better methods. The results could also be used to build case-bases of the type described in section “4.3.1 ITS Decision Website” on page 21.

9.2.3 Establish an Economic Analysis Group

The mission of the EA group is to ensure that PIDs contain relevant information about the impacts and resulting benefits of a given project. The group achieves this mission by:

- Assembling relevant project description and impact information from other sources.
- Preparing EAs or helping to prepare EAs for specific projects to be included in the applicable PIDs.
- Offering formal and informal training and assistance in EA to planners and project engineers and others involved in the screening and

⁴¹ <http://www.dot.state.mn.us/guidestar/pdf/pnitds/mndotpsp.pdf>.

evaluation of project alternatives and projects seeking to be programmed.

The group should be permanently staffed with people having training and expertise in economics and traffic analysis.

When decisions are made (at whatever stage, and cumulatively rather than all at once), information about impacts and benefits should be included as well as costs. This is widely agreed upon and supported by expressed policy and guidance. Yet such information does not seem to be available at decision points. Thus it is clear that benefits specific to a project should be expressed as a justification for implementing or continuing to develop the project, but they are not expressed in practice. Rather than abandon the policy of having benefit information at decision points, the information should be developed.

If the information is not in the relevant plans and project information documents, how should it be introduced? We propose an organizational unit whose mission is to see that the information is present when decisions are made. Such an organizational unit would need to adopt an entrepreneurial stance toward outreach to other organizations, to overcome suspicion and resistance. A joint MPO/Caltrans team or other multi-sponsor group with local buy-in might be possible. The task is a challenging one, and strenuous efforts would be needed to offset natural hostility and indifference.

9.3 Develop Realistic County and Regional ITS Plans

In order to make sure that worthwhile ITS projects are considered and that potential positive interactions between them are utilized, a realistic ITS plan and architecture should be developed by each county and region in which ITS can offer benefits. The plan would be based on the benefits that could be provided by each ITS project, the dependencies of various projects on others, and how the project would be operated. For example, if the desired benefit is traffic information for travelers, then the system for obtaining the information must precede the system for delivering the information. If the benefit is en-route traveler information and guidance, then operating procedures for guidance in the case of potential disasters must be developed. During the recent fires in Southern California, the changeable message signs on the highways were not utilized to maximum effect to encourage travelers to avoid roads blocked by the fires.

The plan development can be sponsored and supported by the regional planning agency, whose role would be to provide expertise and a forum for counties, transit agencies, and Caltrans to share ideas and learn from one another. But each agency's plan should grow out of its own needs and preferences. It should be based on needs, not philosophy. It should not focus on hardware, but on the functions that would be performed and how they would be performed. The only required coordination with other agencies would be where there were interactions between systems. Examples of this would be signal priority on city streets for a transit agency and coordination of ramp metering rates with signal timing on city streets approaching the ramps.

After each agency has developed a tentative plan, possible linkages between them should be examined to make sure that interfaces are compatible and to see if there are opportunities to share resources or to obtain economies by shared procurements. Each agency's ITS architecture should be determined by the functions to be performed and any interfaces with other agencies. The regional architecture should be determined by the individual agency architectures.

9.3.1 Create Near-term ITS Plans that are Problem Driven

These plans should address real problems and should be based on real benefits and costs and thoughtful implementation. Such plans have been created in some areas. The Central Coast ITS Steering Committee, under the leadership of the Association of Monterey Bay Area Governments (AMBAG) and with funding from Caltrans, developed a strategic ITS plan. As a result of the plan, the region has tailored its ITS development to its own needs, opting to postpone implementation of 511 until it had a traffic data collection system adequate to support a credible traffic information service. The Southern California Association of Governments (SCAG) worked with 20 agencies in the Inland Empire to develop a regional ITS architecture identifying feasible near-term and mid-term projects.

Rather than trying to do everything that might conceivably be beneficial, it is better to start with those projects that offer the highest potential benefit in relation to their cost. If combining these with another cost-effective service would provide greater benefits than implementing the other service separately or would provide the same benefits but cost less than if implemented separately, it makes sense to combine these into one project. Otherwise, it may not. Of course, some services have multiple components that must be implemented together. An information system requires a data gathering system. Each by itself is useless.

9.3.2 Ease Conformance with the National ITS Architecture

The need to conform to the National ITS Architecture has frightened many agencies. They have seen the complicated charts and the diagrams of data flows in the architecture documents. However, conformance is quite simple:

- A regional ITS architecture is required by April 8, 2005 if the region had an on-going ITS project on April 8, 2001, or within four years of the final design of a region's first ITS project.
- Until a regional ITS architecture is in place, all major ITS projects must have a project level architecture to ensure proper consideration of regional integration.
- All ITS projects must be developed using a systems engineering approach. This requires project developers to consider all phases of the system's life cycle from system conception to installation. The stages of planning, design, procurement, deployment, operations, maintenance, expansion, and retirement of the system or subsystems must be considered.

- Once a regional ITS architecture is in place, all subsequent ITS projects must be designed in accordance with it.

Unfortunately, the systems engineering processes have sometimes focused on the “how” rather than the “what” of ITS. But the first consideration should be “what,” that is, the functions it will perform that will provide benefits. Then the “how” can be determined, including the intelligence needed to perform the functions. If the function is to “provide traveler information,” it must be determined what type of information will be provided, under what circumstances, by whom, and where the information will be obtained. Only then can the information flows and the hardware be specified.⁴²

9.3.3 Use ITS Plans for Information Exchange

Caltrans planners from various districts already get together to share information. A similar system of meetings of people involved in developing and implementing ITS (or operations) plans could be instituted. It would develop an esprit among these people and lead to the type of information sharing and cooperation discussed in section “5.1 The Value of Incremental Development and Learning Networks” on page 27 and section “5.4 Lessons from Case Studies” on page 29.

9.4 Change the Emphasis of ITS to “Operations”

ITS involves building technically-advanced physical infrastructure as well as utilizing intelligent operational management. It includes many systems that are not subject to public sector decision-making, such as in-vehicle equipment, and it does not bring a clear picture to everyone's mind. Operations, such as the following, are better understood and seem more amenable to implementation:

- providing information for travelers.
- controlling traffic via signals, signs, and other means to reduce delay caused by heavy travel demand, work zones, incidents, emergencies, and special events.
- sensing dangerous driving conditions or vehicle behavior and providing information, traffic control, or roadway treatment to reduce the danger.
- collecting traffic information to support the above activities and support decision-making regarding all transportation projects.

This shift from “ITS” to “Operations” has already begun with the National Dialogue on Transportation Operations and the resulting National Coalition for Transportation Operations led by the FHWA.

⁴²More details on the systems engineering process can be seen at <http://www.its.dot.gov/aconform/Arch2a.htm>.

10 References

- “Fog Warning to Prevent Pileups,” *Pittsburgh Post-Gazette*, April 2, 2004.
- “Message Boards May Cause Congestion as well as Relieve It,” *Minneapolis Star Tribune*, August 28 2003.
- Alexiadis, Vassili, Krista Jeannotte, and Andre Chandra, “Traffic Analysis Tools Primer,” prepared for US DOT/FHWA, Oakland, CA: Cambridge Systematics, June 2004.
- Al-Sahili, Khaled A., and William C. Taylor, “Evaluation of Bus Priority Signal Strategies in Ann Arbor, Michigan,” *Transportation Research Record*, 1554 (1996), pp. 74-79.
- Association of Bay Area Governments, “Silicon Valley Projects 2000,” prepared for Silicon Valley Manufacturing Group, San Francisco, CA: ABAG, 2000.
- Avgoutis, A., Michel Van Aerde, and Hesham Rakha, “A Model for Quantifying the Safety Impacts of Intelligent Transportation Systems,” prepared for US DOT FHWA/FTA Joint Program Office, Blacksburg, VA: Virginia Institute of Technology, 1999.
- Booz Allen & Hamilton, “California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C): Technical Supplement to User’s Guide,” Sacramento, CA: Caltrans, September 1999.
- Booz-Allen & Hamilton, “California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C),” prepared for California Department of Transportation, Sacramento, CA: Caltrans, September 1999.
- California Department of Transportation, “Regional Planning Handbook,” Sacramento, CA: Caltrans, October 2003.
- Caltrans, et al., “Memorandum of Understanding,” San Jose, CA: Santa Clara County, 1997.
- Carvell, Jr., James D., Kevin Balke, Jerry Ullman, Katherine Fitzpatrick, Lewis Nolin, and Christopher Brehmer, “Freeway Management Handbook,” prepared for Federal Highway Administration, Washington, DC: US DOT/FHWA, August 1997.
- Center for Urban Transportation Research, “Florida’s ITS Integration Guidebook,” prepared for District Seven Florida Department of Transportation, Tampa, FL: CUTR, College of Engineering, University of South Florida, October 2002.
- Chatterjee, K., N. B. Hounsell, P. E. Firmin, and P. W. Bonsall, “Driver Response to Variable Message Sign Information in London,” *Transportation Research (C)*, 10, 2 (2002), pp. 149-169.
- City of San Jose, “2002 Transportation Report,” San Jose, CA: City of San Jose, 2002.
- Cohen, Harry, and Frank Southworth, “On the Measurement and Valuation of Travel Time Variability Due to Incidents on Freeways,” *Journal of Transportation and Statistics*, 2, 2 (1999), pp. 123-131.

- Dahlgren, Joy, Stein Weissenberger, Mark Hickman, and H. Lo, "Lessons from Case Studies of Advanced Transportation and Information Systems," California PATH Working Paper, Berkeley, CA: UC Berkeley PATH, July 1997, <http://database.path.berkeley.edu/reports/index.cgi?reqtype=displayrecord&record=638>.
- Davis, Floyd E., "Project Study Report: On Route 05-SCR 17 0.0/20.1 Between SR 17 and SR 1 Separation," San Luis Obispo, CA: California Department of Transportation, December 2003.
- Deakin, I., S. Cheon, J. Ni, A. Leigland, S. Park, and M. Shirgaokar, "Mainstreaming Intelligent Transportation Systems," Berkeley, CA: Institute of Transportation Studies, University of California, Berkeley, November 2002, <http://www.uctc.net/Mainstream/>.
- Deysher, Elizabeth, David W. Jackson, and Allan J. DeBlasio, "Incorporating ITS Solutions into the Metropolitan Transportation Planning Process," Cambridge, MA: US DOT/Volpe Center, November 2000, http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/@6101!.PDF.
- Dion, Francois, Michel Van Aerde, and Hesham Rakha, "Mesoscopic Fuel Consumption and Vehicle Emission rate Estimation as a Function of Average Speed and Number of Stops," Blacksburg, VA: Virginia Polytechnic Institute and State University, July 1999.
- DKS Associates, "Highway 17/880 Smart Corridor Feasibility Study," prepared for City of San Jose, Oakland, CA: DKS Associates, November 1994.
- Dowling, Richard G., and Willis W. K. Cheng, "Evaluation of Speed Measurement and Prediction Techniques for Signalized Arterials," *Transportation Research Record*, 1564 (1996), pp. 20-29.
- Federal Highway Administration, "Guidance on Including ITS Elements in Transportation Projects," prepared for Office of Travel Management, Washington, DC: US DOT/FHWA, January 2001.
- Federal Highway Administration, "National Transportation Operations Coalition," website, Washington, DC: US DOT/FHWA, 2004, http://ops.fhwa.dot.gov/nat_dialogue.htm.
- Fehon, Kevin, Raymond Chong, and John Black, "Adaptive Traffic Signal System for Cupertino California," presented at the Asia-Pacific Transportation Development Conference, Oakland, CA: DKS Associates, April 2003.
- Fehon, Kevin, and Jon Elson, "Development and Expansion of Santa Clara County's Traffic Operations System," Santa Clara, CA: Santa Clara County, 2001.
- Heminger, Steve, "Arterial Operations Program Status Report," memorandum, Oakland, CA: MTC, March 7, 2003.
- International Business Machines Corporation, "TMS Arterial Signalization Business Plan," prepared for California Department of Transportation, Sacramento, CA: IBM, 2002.

- Jeannotte, Krista, Andre Chandra, Vassili Alexiadis, and Alexander Skabardonis, "Traffic Analysis Toolbox Volume II: Decision Support Methodology for Selecting Traffic Analysis Tools," prepared for FHWA, Oakland, CA: Cambridge Systematics, June 2002.
- Kimley-Horn and Associates, "Final Report and Scope of Work for the Interim Center-to-Center System: Deliverable No. 37," prepared for California Highway Patrol Caltrans, and MTC, *Bay Area Freeway Concept of Operations*, Oakland, CA: Kimley-Horn, April, 2003.
- Kimley-Horn and Associates, "Strategic Plan: Deliverable No. 15," prepared for Caltrans, California Highway Patrol and MTC, *Bay Area Freeway Concept of Operations*, Oakland, CA: Kimley-Horn, June 2002.
- Kimley-Horn and Associates, and Consensus Systems Technologies Corp, "California ITS Architecture and System Plan: DRAFT Functional Requirements," prepared for Caltrans, Oakland, CA: Kimley-Horn, May 2004.
- McFarland, William F., Jeffrey L. Memmott, and Margaret L. Chui, "Microcomputer Evaluation of Highway User Benefits," *NCHRP Project 7-12*, College Station, TX: Texas Transportation Institute, October 1993.
- McFarland, William F., Jeffrey L. Memmott, Margaret L. Chui, M.L. Richter, and A. Castano-Pardo, "MicroBENCOST: User's Manual," *NCHRP Project 7-12*, College Station, TX: Texas Transportation Institute, October 1993.
- Metropolitan Transportation Commission, "Smart Corridors Task Force Notebook," Oakland, CA: MTC, 2002.
- Minnesota Department of Transportation, "Traffic Studies/Data Collection: RTMS Portable Support Post," MNDOT, September 2003, <http://www.dot.state.mn.us/guidestar/pdf/pnits/mndotpsp.pdf>.
- PB Farradyne, "California Intelligent Transportation Systems (ITS) Deployment Initiatives Project: Task 7 California ITS System Design Final Deliverable," prepared for California Alliance for Advanced Transportation Systems, San Francisco, CA, October 1999.
- Rakha, Hesham, and Michel Van Aerde, "Benefits of Traffic Signal Coordination along Scottsdale/Rural Road Using GPS Data," prepared for US DOT FHWA/FTA Joint Program Office, Blacksburg, VA: Virginia Institute of Technology, 1999.
- Rakha, Hesham, A. Medina, F. Dion, and Michel Van Aerde, "Inter-jurisdictional Coordination of Traffic Signals along Scottsdale/Rural Road: Field and Modeling Results," prepared for US DOT FHWA/FTA Joint Program Office, Blacksburg, VA: Virginia Institute of Technology, May 1999.
- Rizzo, David J., "Smart Thinking in Silicon Valley," *Traffic Technology International* (2001).
- SAIC, "Silicon Valley Smart Corridor: Final Evaluation Report," prepared for US DOT FHWA/FTA Joint Program Office, Washington, DC: USDOT/FHWA, September 2003.

-
- SAIC, and Cambridge Systematics, "Silicon Valley Smart Corridor: Draft Addendum to the Phase II Evaluation Report," McLean, VA: SAIC, April 2002.
- Santa Cruz County Regional Transportation Commission, "Caltrans' Highway 17 Traffic Operating Systems (TOS) Project Study Report," Agenda and Minutes, Santa Cruz, CA: SCCRTC, August 2 2001.
- Santa Cruz Regional Transportation Commission, "2001 Santa Cruz County Regional Transportation Plan," Santa Cruz, CA: SCCRTC, December 2001.
- Santa Cruz Regional Transportation Commission, "Santa Cruz County 2002 Regional Transportation Improvement Program," Santa Cruz, CA: SCCRTC, December 2001.
- Skabardonis, Alexander, "ITS Benefits: The Case of Traffic Signal Control Systems," paper for TRB, Berkeley, CA: University of California ITS, January 2001.
- Sullivan, Edward, Sam Taff, and James Daly, "A Methodology for Measurement and Reporting of Incidents and the Prediction of Incident Impacts on Freeways," prepared for US DOT/FHWA, San Luis Obispo, CA: Cal Poly State University, April 1995.
- Teal, Roger, "Estimating the Full Economic Costs of Truck Incidents on Urban Freeways," Irvine, CA: Institute of Transportation Studies, 1988.
- Transcore, "Central Coast ITS Strategic Plan," Vol. I, prepared for Association of Monterey Bay Area Governments (AMBAG) et al., Pasadena, CA: Transcore, June 2000.
- Weissenberger, Stein, "Why ITS Projects Should Be Small, Local, and Private," *ITS Quarterly*, 7, 1 (1999).

Appendix A: The CTC Policy on PSRs

Project Study Reports (PSRs) occupy a critical position in the selection of projects to implement, and appear to be falling short of providing the information requirements for making decisions, so the intended role of PSRs, as stated in California Transportation Commission policy, is of considerable interest:

“Criteria for Measuring Performance and Cost-Effectiveness

“In order to maximize the state's investments in transportation infrastructure, it is the Commission's policy that each RTIP and the ITIP will be evaluated, as they are developed, for performance and cost-effectiveness at the system or project level as appropriate. For large projects for which major investment studies are undertaken, a project level evaluation is preferable. The evaluation should be done by each region and by Caltrans before the RTIPs and the ITIP are submitted to the Commission for incorporation into the STIP. Beginning with the 2002 STIP cycle, each RTIP and the ITIP submitted to the Commission will be accompanied by a report on its performance and cost-effectiveness. Ideally, as performance measurement concepts and techniques mature, regional agencies and Caltrans will, as part of the transportation planning and programming process, monitor transportation systems and projects for performance and refine performance forecasts for use in evaluation of future RTIPs and ITIPs.

“The Commission will consider the evaluations submitted by regions when making decisions on RTIPs as described in Section 60 of these guidelines. The Commission will consider evaluation submitted by Caltrans when making decisions on the ITIP as described in Section 62 of these guidelines. The evaluation report should clearly demonstrate how effective the RTIP or the ITIP is in addressing or achieving the goals, objectives and standards which are established as part of the respective regional transportation plan (RTP) or Caltrans' Interregional Transportation Strategic Plan (ITSP).

“The purpose of the evaluation report is to assess the performance and cost effectiveness of each RTIP and the ITIP based on its own merits, not to attempt a comparative assessment between individual RTIPs or RTIPs and the ITIP. RTIP evaluations should also address how the RTIP relates to the ITIP at key points of interregional system connectivity. Caltrans' evaluation of the ITIP should address ITIP consistency with the RTPs. Each region is responsible for establishing the transportation goals, objectives and standards to be used in its evaluation of RTIP performance. However, the Commission urges each region to consider including improvements to mobility, accessibility, reliability, sustainability and safety as part of the fundamental goals of any long-range transportation plan.

“Regions and Caltrans are responsible for determining the techniques and methodology to be used in evaluating the performance and cost-effectiveness of RTIPs and the ITIP. The Commission recognizes that many measures of performance and benefit are difficult to evaluate and may be more subjective rather than measurable in quantifiable units. In order to facilitate statewide consistency, regions and Caltrans, should also consider

using (when appropriate) values of performance and benefits and evaluation methodologies which are commonly accepted and which represent accepted or standard practice. The Commission encourages regions to consider using (when appropriate) values of time, safety, vehicle operation costs and discount rates which are developed by Caltrans for benefit cost analysis of transportation projects.

“The Commission does expect that evaluations of performance and cost-effectiveness will be for a 20-year period or on a life cycle basis. Reports to the Commission on evaluations of performance and cost effectiveness should be presented in a format which is disaggregated to the level of the benefits and measures used.

“In establishing the following criteria the Commission recognizes that it may be difficult to develop and utilize criteria that is relevant in both urban and non-urban regions and that different criteria may apply depending on the complexity of the region and its RTP and RTIP. To this end, each region should select and utilize criteria most applicable to its own jurisdiction. Regions and Caltrans should consider the following criteria for measuring performance of RTIPs and the ITIP:

- (1) Change in vehicle occupant, freight and goods travel time or delay.
- (2) Change in accidents and fatalities.
- (3) Change in vehicle and system operating costs.
- (4) Change in access to jobs, markets and commerce.
- (5) Change in frequency and reliability of rail/transit service.
- (6) Change in air pollution emissions.
- (7) Change in passenger, freight and goods miles carried.

“Regions and Caltrans should consider the following criteria for measuring cost-effectiveness of RTIPs and the ITIP:

- (1) Decrease in vehicle occupant travel, freight and goods time per thousand dollars invested.
- (2) Decrease in accidents and fatalities per thousand dollar invested.
- (3) Decrease in vehicle and system operating cost per thousand dollar invested.
- (4) Improved access to jobs, markets and commerce per thousand dollar invested.
- (5) Increased frequency reliability of rail/transit service per thousand dollar invested.
- (6) Decrease in air pollution emissions per thousand dollar invested.

- (7) Increase in annual passenger, freight and goods miles carried per thousand dollar invested.

“The policy is not entirely clear on the distinction between performance measures and benefit-cost analysis. “Change” or “decrease” could refer to performance measures over time, or between the project and the base case. If the former, there is no measure of the base alternative, and hence no measure of the benefits of the project(s) or program. If the latter, then it is necessary to not only monitor what actually happens but to also estimate what would have happened in the absence of the project(s). A “before-and-after” paradigm is not equivalent to BCA, which requires a “with-and-without” comparison; for BCA, at least one of the alternatives cannot be observed, and both are estimated rather than observed for prospective BCA. Prospective BCA is what is needed for planning purposes.”

Appendix B: BCA Evaluation of ITS Pilot Projects

A finding of this study is that focused information on the impacts of an ITS (and other types of projects) is lacking or insufficient at the point that decisions are made. Members of boards and commissions seem frustrated at the lack of information on the effectiveness of the various kinds of investments they are asked to approve, and there is no evidence that they get the information they seek even when they ask for it.

This appendix is an effort to show how the relevant information on project impacts can be generated, using relatively simple methods and mainly available data. Evidence on the effectiveness parameters for ITS types of projects are weak, but California could readily obtain data from its own projects as well as seeking experience from other states. Thus useful information tailored to the decisions at hand could provide a high yield in strengthening current decisionmaking, and also lead to continuing improvement in making decisions in the future.

A.1 Analytic Strategy

In simplified terms, the purpose of evaluation is to determine what will actually be done, how those actions will change the state of the world from what it would have been without the actions, and what value can be placed on the differences. If, for example, diversion of traffic during an incident from a freeway to an arterial results in shorter travel times for the same distance, then the value of the time savings can be compared to the cost of causing the diversion.

Analytically, the method is to construct impact linkages between the actual deployment and the potential impacts that might be counted as benefits. Deployment, for example, might consist of traffic signal timing changes; benefits that would ensue if the deployment was successful would be faster speeds for the same traffic, resulting in time savings for users. Linkages connect the changes in signal timing to changes in the traffic flow, the number and duration of stops required of all or representative motorists, and estimation of the aggregate net travel time savings from all motorists affected.

As an example of how this analytic process might be constructed, the portion of the SV-ITS project that addresses traffic diversion during an incident as a means for lowering overall delay will be presented.

The general strategy is to

- (1) Build a model incorporating the relationships that explain the causes of delay, etc., including the instruments used in the deployment.
- (2) Test the sensitivity of the model to model parameters, for the purpose of extracting the critical variables.
- (3) Monitor, observe, collect data on the performance of these parameters.

Examples are delay on arterials, duration of congestion, variability of travel time, etc.⁴³

A.1.1 Methods and Models for Project Evaluation

The objective of “mainstreaming” ITS is to include ITS projects alongside other types of improvements when making decisions about capital investment, whether the investment is in physical infrastructure or hardware/software infrastructure. The benefit-cost framework potentially allows such side-by-side comparisons of ITS and non-ITS improvements, so long as costs and benefits can be measured in commensurate terms. Choosing between a highway expansion and a new school building shouldn’t be necessary; each project is separately worthwhile or not worthwhile, within its own program. When expenditure constraints force some projects to be given up, the competition is within projects of the same type. It is not necessary, however, to treat ITS and non-ITS improvements as separate categories

A.1.2 Benefit-Cost Evaluation

Methods for project evaluation have been fairly well developed, and are available in many forms. Evaluation, however, is not a cut-and-dried procedure; the analyst must always apply creativity and resourcefulness, while staying within the bounds of good practice in both letter and spirit. For example, the evaluation should be neutral with respect to the outcome, arguing neither for nor against on a priori grounds, but letting the evidence reveal to the extent it can be produced the weight in favor or against. The evaluation should not set out to “prove” anything, but to interpret what is known and what is uncertain.

The obstacle is that inadequate effort is devoted to estimating the impacts and benefits of investment alternatives, and the analysis is often inadequate as a consequence, even in those relatively rare instances when a BCA is actually attempted. Benefit-cost is widely recognized as a desirable standard, but it is less frequently implemented (“too costly, spend the money on improvements”) and even then, often conducted in an unsystematic and ad hoc fashion.⁴⁴

The two case studies are meant to illustrate both how to generate the information that provides for prospective evaluation (before the fact) of projects, and how that information can be used better to inform the decision (the information is not intended to substitute for the decision, but to base the decision on the right grounds).

⁴³ Caltrans (December 2002) proposes the following steps to quantify TMS benefits:

- (1) Select two routes for simulation, with the same congestion.
- (2) Calibrate base simulation models and obtain forecasts from regional agency models.
- (3) Quantify benefits of individual TMS recommendations and combinations.
- (4) Validate against real-world and reported results in California and the rest of the country.
- (5) Extrapolate results statewide. (some minor editing).

This is consistent with our strategy, but the Caltrans/IBM approach suggests complex black-box models and a quasi-experimental design that is not very workable; the emphasis is transferable secondary results rather than original local data and specific parameters.

A.2 Freeway-Arterial Diversion in the Silicon Valley

The central ideas underlying the SR-17/Bascom Avenue portion of the SV-ITS (which runs from north of I-280 down to Los Gatos) appear to be:

- (1) An incident on SR-17 during congested periods can reduce the capacity of the freeway sufficiently that point-to-point travel times become temporarily faster using a parallel arterial, and
- (2) During such periods, flow on the arterial can be enhanced by adjusting signal timing to favor the additional load of through traffic.

Whether a program exploiting these ideas can be put into practice and generate benefits depends upon a set of conditions and underlying relationships:

A.2.1 Line Haul Function

Travelers on the highway are in the process of moving between diverse origins and diverse destinations; SR-17 may form a large or small portion of the distance traveled, but most origins and destinations do not lie immediately on this route. Vehicles move from their origins to the facility, use the facility as a line haul or trunk carrier, and leave the facility to travel to their destinations.

A.2.2 Users Make Choices

Vehicle operators are free agents who make decisions based on their applicable prior knowledge, supplemented by current evidence or information, of which they may or may not choose to avail themselves. The primary (though not sole) decision of interest in the present context is which route or path to take. We assume that users are trying to get from an origin to a destination in the shortest amount of time, subject to constraints on risk, convenience, etc. (changing destination or arrival time will be considered later).

A.2.3 Supply and Demand

In economic terms, this behavior can be viewed as a market—or set of interrelated markets—that are in equilibrium. From the driver's viewpoint, the choice of route is made

⁴⁴As stated in the Smart Corridors Task Force Notebook (MTC, 2002), the Task Force was formed “to provide a forum for in-depth discussion of common issues...” Two pages in the Notebook describe the “Cost/Benefit Evaluations” being conducted for four smart corridors projects. To the question “are cost/benefit evaluations part of the project?” all projects answered yes, with qualifications such as limited data and qualitative rather than quantitative. To the question “how are benefits measured?” the SV-ITS project noted that “it has proven to be a difficult task to demonstrate benefits on a sub-regional basis.” These and other entries suggest a tendency for wishful thinking to supplant actual performance. A memo report from S. Heminger (2003), in discussing the “Smart Corridors Task Force 2003 Work Plan,” stated “...the Task Force decided that during 2003 it would focus on defining and measuring the benefits and costs of investments in smart corridors in the Bay Area.” No evidence of results from these efforts has been turned up.

with (typically, and especially for commuters) a good deal of knowledge about times of congestion, expected levels of service, and alternate routes. The price in the market is travel effort—mainly time—and the demand curve is the aggregation of all drivers who might use the (or any) facility to serve their trip. In an urban area, there are many drivers, many origins and destinations, and many routes. Each road link, then, is a market, seeking to maintain an equilibrium between supply (capacity) and demand, via the price mechanism (travel time).

One characteristic of this equilibrium (or many equilibria) is that, at any given moment, a driver is unlikely to achieve a faster door-to-door time by changing route. Traffic volumes have adjusted to facility capacities such that each vehicle is on its optimal path, and—when the network is congested—cannot improve its travel time by choosing an alternative route.

A.2.4 Recurring Delay and Incident Delay

Transportation planners have made a categorical distinction between normal or recurring delay, on the one hand, and non-recurring or incident delay on the other. Although the distinction has heuristic value, drivers are well aware that incidents are much more likely if traffic heavy, and incorporate that understanding into their estimates of expected conditions. So long as actual congestion does not deviate dramatically from anticipated congestion, the markets remain fairly close to equilibrium (there is considerable random variation, and hence “poisson” moments when one path is faster than another simply because drivers happened to randomly bunch up in time or space).

A.2.5 Preconditions for Benefits

Thus the circumstances under which the diversion concepts might be applied require as one of several preconditions that there be a major incident, whose duration is measured in hours. The concepts have some applicability for major incidents (those that block all lanes, or severely constrict capacity relative to volume) at off-peak times, but such incidents with large delay costs are much more likely during peak periods (recognizing that travel at or close to capacity on SR-17 may occur for 10 or 12 hours per day).

For any diversion process to generate an improvement during a period of significant disequilibrium (meaning that travel times are noticeably faster on another route for a period of time of at least half and hour to an hour) drivers must make decisions to exit the freeway and divert to the arterial.

A.2.6 Traveler Information

In order to divert from their normal equilibrium (including minor incident delay), drivers must detect a significant anomaly. This could be a queue that is much further back than normal, but that information is only available after substantial delay has already built up and there may be no diversion options at that particular point. Alternatively, drivers could be notified of an “incipient” major incident (one that has severely reduced

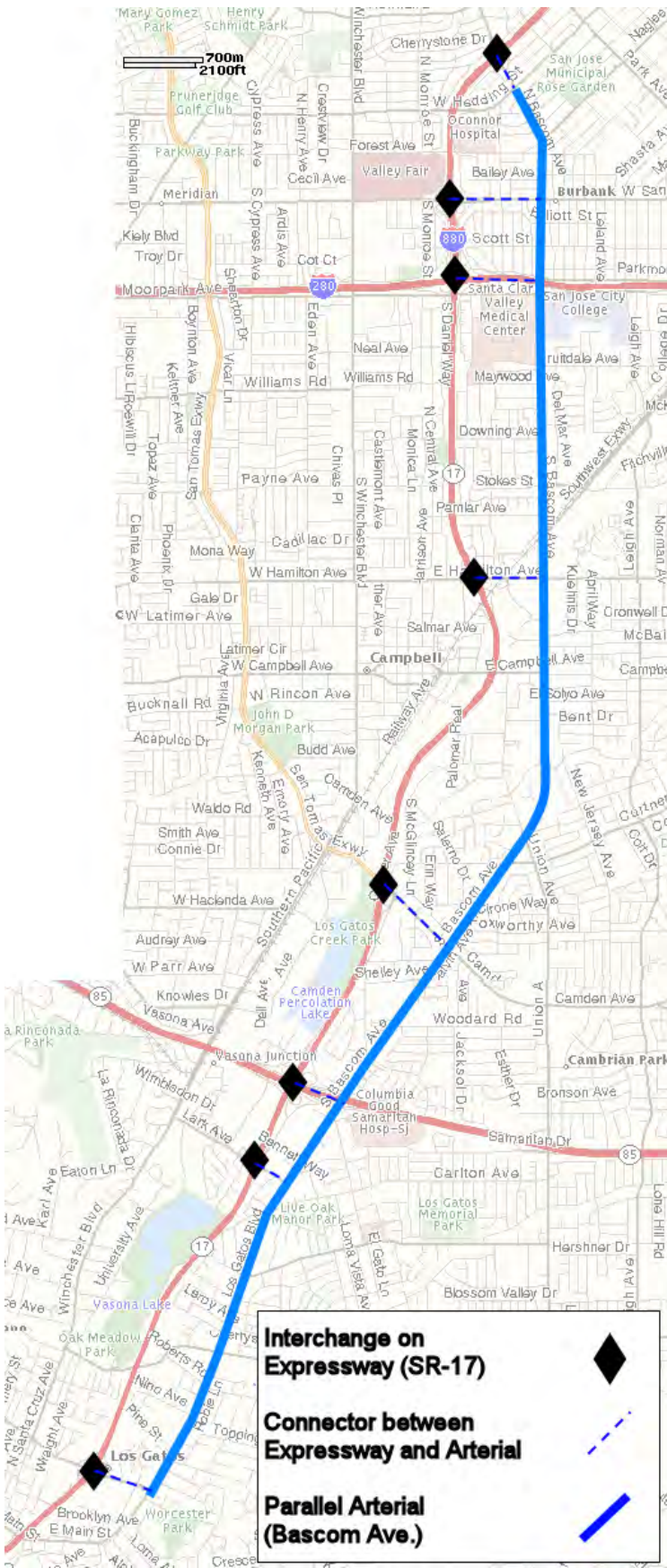


FIGURE 22. Freeway-Arterial incident delay diversion.

capacity but not yet caused a large backup) through media such as broadcast radio traffic advisories or variable message signs (VMS), highway advisory radio (HAR), in-vehicle traveler information systems (e.g., navigators), or internet-based traveler information sites (accessible via desktop or wireless computer). These information sources have limitations, but a two-step process might be effective, such as a simple roadside sign that urges travelers to consult HAR or a web site.⁴⁵

Without supplementary information (beyond congestion that can be observed upon encountering it), travelers face a risky choice: they do not know how long the delay will last, they may not know the alternate route, they may not know the travel speeds on the arterial (which are dependent upon the diversion rate), and they will not know when they can return to the freeway unless they can see the freeway from the arterial. With this uncertainty, drivers are less likely to risk diversion.

A.2.7 Whether Diversion is Faster

Freeways have much higher capacity than arterials. SR-17 has three lanes in one direction and limited access, providing for 6-7,000 vehicles per hour; Bascom Avenue also has three travel lanes in the same direction, but punctuated with traffic signals every few hundred yard and parking between intersections. The freeway-arterial diversion portion of the SV-ITS is shown in Figure 22. Thus the arterial is preferable if the freeway is completely blocked for several hours, but may not be much help for lesser delays. The ability of the arterial to increase its throughput by adjusting signal timing is limited; the arterial cannot be made into an approximation of an access-controlled freeway.

A.2.8 Estimating Benefits of Arterial Diversion

A very basic spreadsheet has been developed to estimate the range of conditions that would need to occur for an incident diversion program to yield positive benefits. The structure of the spreadsheet is based upon impact linkages shown in Figure 23.

The structure of the model has two primary components:

- (1) A component that estimates diversion from the freeway and calculates whether those who divert save time and how much, given the resulting speeds on the arterial.
- (2) A component that estimates speeds on the arterial, with and without diversion, based on procedures in the highway Capacity Manual (HCM2000).

The first component is summarized in Table 4. It is assumed that information about the incident including its location and duration will encourage more drivers to divert to the arterial; knowledge about the conditions on the arterial is also important in this choice

⁴⁵ At least one EMS has been installed, directing motorists to consult the HAR; what messages will be posted is not known by the authors. See Figure 6 on page 36.

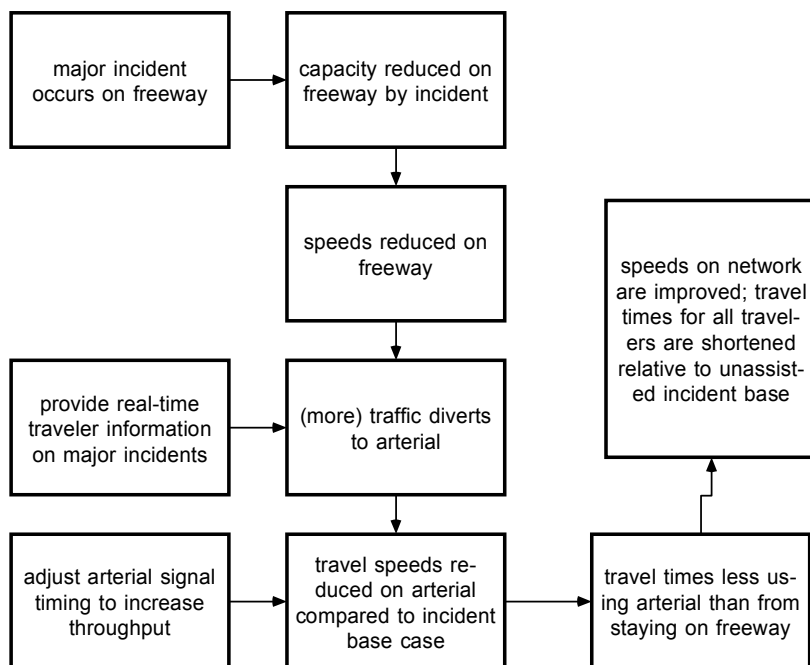


FIGURE 23. Impact linkages for Freeway/Arterial diversion.

of route. The first four items in the table are ballpark estimates of factors that might indicate the likelihood of diversion, based on information provided via VMS. The optimum diversion rate is unknown, however, and depends upon specific conditions on both the freeway and the arterial.⁴⁶ If the arterial is well below capacity, some additional traffic can be absorbed, whereas if the arterial has little excess capacity it can be overloaded by a small share of diversion. The “connecting distance” is the distance between the freeway and the arterial. Although the particular parameters that apply in the SV-ITS corridor under incident conditions have only been roughly estimated here, it is clear that although the capacity of the arterial is less than that of the freeway, modest diversion rates from the freeway can be handled on the arterial, especially with some adjustment in signal timing to favor through traffic.⁴⁷

For modeling purposes, two types of incidents are considered: major (lasting two hours) and moderate (lasting 20 minutes). Minor incidents are assumed to stimulate no diversion, and no benefits would derive from such diversion if it occurred. For the conditions shown, those that divert are shown to benefit, but most parameter combinations within plausible ranges would result in negligible time savings for those who divert during moderate incidents.

⁴⁶The model assumes the freeway is not completely closed; if it is, then 100% of the traffic is diverted, and the arterial functions as well as it can until the freeway is reopened.

TABLE 4. SV-ITS Diversion model

Diversion from Freeway with Incident			
information about incident	0.6	VMS	
information about duration	0.5	VMS	
information about location	0.5	VMS	
information about conditions on arterial	0.8		
traffic volume on freeway (vph one way)	6,000		
diversion with perfect information (percent)	50%		
	major	moderate	
duration of incident (min)	120	20	
average delay per vehicle (min)	180	24	
average spacing between interchanges (mi)	2		
diversion with actual information (percent)	6%	3%	
vehicles diverted during incident (vph)	360	180	
base traffic volume on arterial (vph one way)	3,000		
normal speed on arterial	28.0		
speed on arterial with diversion (mph)	26.0	28.0	
number of interchanges skipped	2		
connecting distance (one way)	0.5		
length of detour (miles)	7		
time on detour (minutes)	16.2	15.0	
time savings from diversion (minutes/vehicle)	163.8	9.0	
savings per incident (hours)	983	54	

Using an estimate of 10 major incidents per year, and a value of time of \$15 per vehicle hour, the time savings per major incident translates into around 10,000 hours or \$150,000 annual benefit. Some additional benefits come from being able to use the arterial signal adaptations to respond to special events.⁴⁸

⁴⁷A study was conducted by SAIC (September 2003) of the SV-ITS freeway-arterial diversion component, including an appendix to the study (SAIC, April 2002) with additional data collection. The study was unable through empirical measurement to detect any impact of the diversion or signal timing. They attribute this result to the sudden decline in economic activity in the study area between the time of initial (“before”) data collection and subsequent (“after”) data collection. The lack of conclusions is the result of several weaknesses in their methodology: (1) The before-and-after paradigm is a poor framework exactly because it expects the rest-of-the-world to remain unchanged while something of interest is changed. Even if nothing else does change, it is rare that the relevant performance measures (e.g., travel time savings) can be isolated from other sources of statistical noise. Hence, an approach is required that uses a “with/without” paradigm, modeling of the key relationships, and data collection focused on critical parameters that are observable. (2) The SAIC data collection sought to measure a reduction in the level of service on Bascom Avenue after an incident, but no attempt was made to measure whether there was an increase in traffic volume. Nor was there any measure of diversion at SR-17 off ramps. Because Bascom is a signalized arterial, changes in LOS are predictably hard to detect against normal random variability. (3) Because no *a priori* analysis of the type described here in section A.2 was done, the study participants were not aware that only major incidents would be likely to cause any diversion, especially with no information posted on the freeway. Since their week-long data collection period did not coincide with any major incidents on the relevant stretch of SR-17, it is unlikely that any significant impacts occurred.

⁴⁸An incident log covering the SV-ITS area from April through December 2002 showed 8 incidents rated “severe,” 6 of which occurred on freeways including 2 on or near SR-17. For the 5 freeway incidents with reported duration, the average was two hours.

Reducing the impacts of freeway incidents through arterial diversion was a prominent goal of the Silicon Valley Smart Corridor deployment, but the results seem fairly modest. There may be other benefits that have not been clearly identified, or additional applications that are still under development.

A.2.9 Estimating Benefits of Carpool Lanes

An HOV or HOT lane is intended to induce SOV travelers to carpool, vanpool, or take the bus, by offering a faster and smoother service on reserved lane. This is a form of multi-class service, in which the price for the premium service is the inconvenience of arranging to travel with other travelers in the same vehicle. A HOT lane transforms the price into money terms, and allows the LOS in the reserved lane to be fine-tuned to maintain faster speeds than on the regular lanes.

A simplified analysis is shown in Table 5. The facility has three lanes in each direction, including one HOV, and widely-spaced signalized intersections. If it is assumed that the traffic volume is the same with or without the lane designation, then the problem is simply one of allocating traffic to the two types of service. Using a basic speed-volume

TABLE 5. Arterial HOV/HOT lane model

one direction:			
total volume (vph)	4,200		
section length (miles)	5.0		
number of HOV/HOT lanes			
value of time (\$/hr/person)	\$ 15.00		
capacity/lane (vph)	1,400		
	regular	HOV/HOT	
number of lanes	2	1	
share of vehicle traffic	70%	30%	
volume	2,940	1,260	
capacity (vph)	2,800	1,400	
v/c	1.05	0.90	
speed (miles/hr)	44.39	53.59	
travel time per mile (min/mi)	1.35	1.12	
total travel time (hrs)	331.18	117.56	449
occupancy	1.2	2.2	
value of time per vehicle hour	\$ 18.00	\$ 33.00	
total travel time cost	\$ 5,961	\$ 3,879	\$ 9,841

function to estimate speeds, the maximum vehicle flow and speed occurs when traffic is assigned equally to each lane, i.e., 67% to the two regular lanes. Total vehicle hours in this scenario (in effect, all lanes regular) is 449 instead of the 438 in the table, with a total time cost of \$10,062. Given the occupancy differences, however, the minimum vehicle hours balance is not the lowest travel cost, which occurs at about the 70% shown in the table, yielding a total time cost of \$9,841.

All this analysis does is to find (by trial and error) the allocation of traffic to the two services so as to minimize total travel cost, by letting the high-occupancy vehicles (who were already on the facility) go to the head of the queue.⁴⁹ Vehicle hours of delay are worsened. No elasticity is incorporated, either in higher occupancy or more travelers as a result of the reserved lanes. If it is supposed that without the HOV lanes the total volume of traffic would have been 4,600 per hour, and the effect of the HOV lane is to reduce total traffic by 400 vehicles while still carrying the same or more people, then the comparison shown in Table 6 can be made. With no carpool lanes, vehicle hours are 564 and travel cost is \$12,983; switching 400 SOVs to carpools reduces vehicle hours to 449 and cost to \$9,841 (as shown in Table 5). Thus if a multi-class service can induce significant behavioral change, the benefits can be noticeable.

TABLE 6. HOV performance under two volumes

volume	4200		4600	
	max speed	min cost	max speed	min cost
vehicle hours	438	449	564	588
travel time cost	10,062	9,841	12,983	12,695

Due to the lumpiness of designating occupancy levels, the allocation of traffic to lanes may be far from optimal without some form of pricing incentive such as that provided by a HOT lane.

A.3 SR-17 From Santa Cruz to Los Gatos

The second project is a four-lane expressway through mountainous terrain between the Silicon Valley and Santa Cruz on the coast.

A.3.1 Incident Delay

Managing incidents is a challenging activity that attempts to be ready to respond to problems on the highway that interrupt or restrict traffic flow temporarily, until they can be removed. Information needs to flow from the highway to the operations center and thence to emergency services and travelers. If these linkages are broken, or not connected, or slow, traffic delay builds up rapidly and lives may be lost as well. A schematic of some of the linkages is shown in Figure 24. The left side shows the components of the deployment that operators can work with, using them to obtain information and provide information to travelers and services, who may then respond.

If the process works well, then vehicle delay can be minimized. A simple deterministic queuing model can be used to estimate total vehicle delay per incident. Table 7 shows the parameters and intermediate results for an incident that closes the highway completely for 40 minutes. Volume counts show an AADT of about 63,000 at Scotts Valley, with a peak of about 6,300 vehicles per hour. Assuming a directional split of 57% (for a commuting route), a capacity of 2,000 vehicles per hour, and an hourly flow somewhat

⁴⁹See paper by Ken Small.

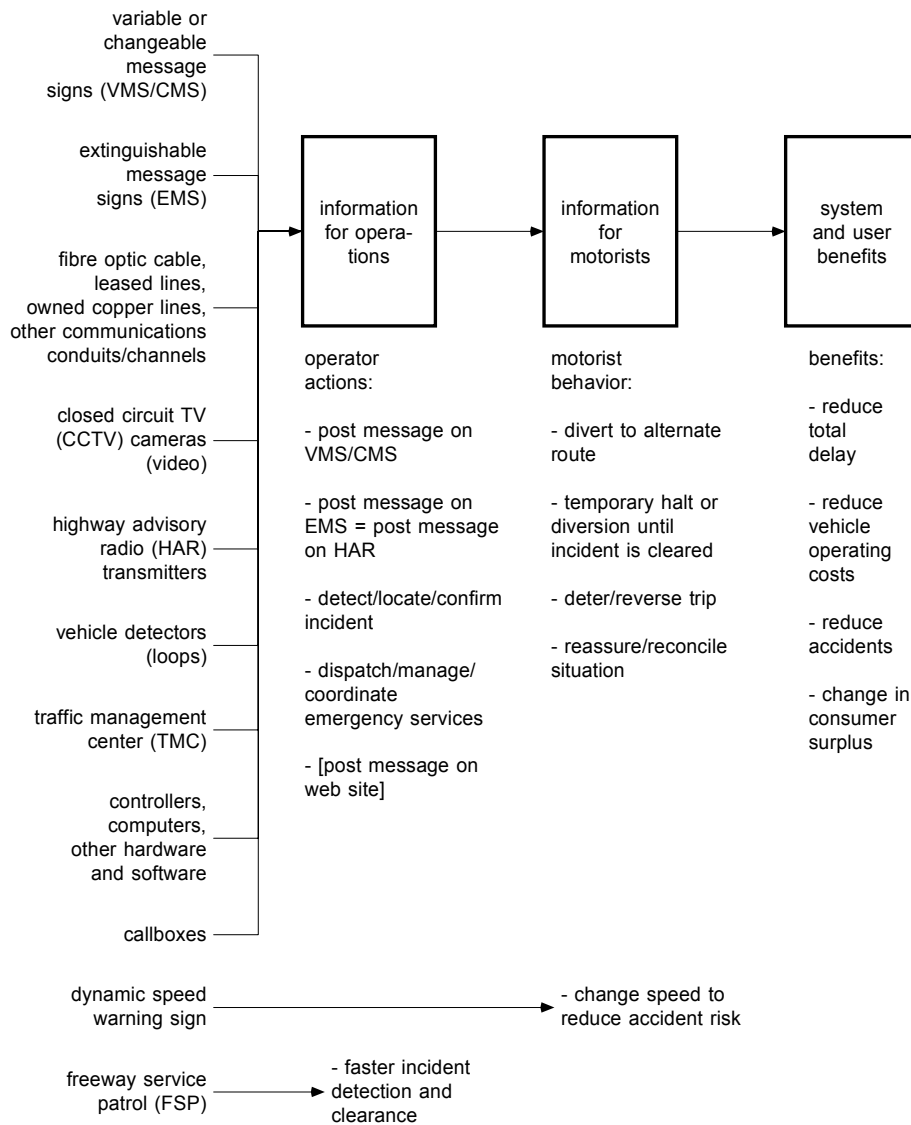


FIGURE 24. Impact linkages for incident management.

below the peak, the delay from one incident is calculated as about 850 hours. Message logs for one year for the most popular southbound message sign show 48 messages posted for an average duration of 76 minutes each. Assuming that the messages were cleared when the queue dissipated, an incident duration of 18 minutes would produce a dissipation time of 60 minutes for a total duration of 78 minutes (this assumes all incidents completely block the highway; actual duration with partial blockage would be longer but queue buildup less rapid, yielding about the same results).

TABLE 7. Queuing model for incident delay

deterministic queue, constant arrivals, zero service rate				
number of lanes	4			
AADT	63,000			
		base case		reduced incident duration
traffic volume both directions (vph)	5,400	1-way flow	minor dir	
directional split	57%	3,078	2,322	
capacity (vph) 2-way	8,000	4,000	4,000	
(avg) duration of closure (min)	18			14
dissipation time (min)		60	25	47
max queue at end of closure (veh)		923	697	718
incident duration (min)		78	43	61
delay per closing (hours)		601	249	467
delay both directions per event (hrs)			850	661

An ITS treatment that reduced incident duration by 4 minutes per incident would result in a total delay of 660 hours; valued at \$12 per vehicle hour, the savings is around \$2,200 per incident or \$110,000 per year in incident delay savings. Injury and property damage costs savings are additional.

The queuing model itself can be represented in a diagram such as shown in Figure 25. The horizontal axis shows elapsed time, and the vertical axis shows cumulative vehicle flow. The straight diagonal line represents the average flow rate of 3,085 vehicles per hour in the major direction. If the highway is blocked, time passes (horizontal movement) but no vehicles pass (no vertical movement). Once the incident is cleared, traffic flows again at capacity (4,000 vehicles per hour), but some time is required for the queue to dissipate because new vehicles continue to arrive at the average flow rate.

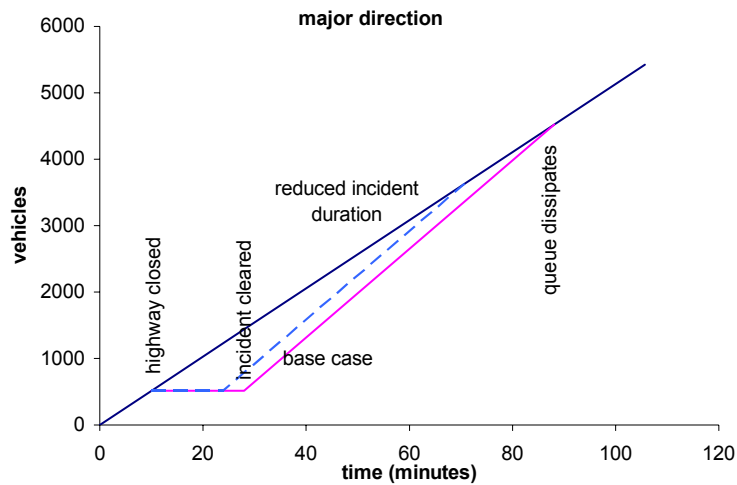


FIGURE 25. Deterministic queuing model of incident delay.

Shortening the incident duration shifts the dissipation line to the left, and the time savings is represented by the area between the original line and the (dashed) shortened duration dissipation line.

A.3.2 Estimating Benefits from a HOV/HOT Lane

An analysis similar to that done above in section “A.2.9 Estimating Benefits of Carpool Lanes” on page 87 could be done for the SR-17 facility in Santa Cruz County. Flows and capacity are higher than for a signalized arterial, and perhaps more opportunities are available for carpooling, vanpooling and express bus service to utilize the reserved lane.

