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Report to the Chairman, Subcommittee on Transportation, Committee on Appropriations, U.S. Senate

May 1991

SMART HIGHWAYS

An Assessment of Their Potential to Improve Travel

144029

GAO

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Program Evaluation and Methodology Division

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May 1, 1991

The Honorable Frank R. Lautenberg
Chairman, Subcommittee on Transportation
Committee on Appropriations
United States Senate

Dear Mr. Chairman:

This report responds to your request that we examine the potential of Intelligent Vehicle and Highway Systems (IVHS) technologies. Our study encompassed a synthesis of major IVHS research, a review of federally sponsored IVHS field tests, and an analysis of potential barriers to a domestic IVHS program. Our purpose in providing this review is to assist the Subcommittee as it considers policies for an effective federal role in researching, developing, testing, and deploying IVHS technologies.

As agreed with your office, we will send copies to interested congressional committees and the Department of Transportation, and we will make copies available to others upon request.

If you have any questions or would like additional information, please call me at (202) 275-1854 or Mr. Kwai-Cheung Chan, Director of Program Evaluation in Physical Systems Areas, at (202) 275-3092. Other major contributors to this report are listed in appendix V.

Sincerely yours,

Eleanor Chelimsky
Assistant Comptroller General

Executive Summary

Purpose

The nation's highways, streets, and transit systems provide a basic source of mobility for the citizens of this country. However, congestion problems from the growth of automobile ownership and use now threaten this mobility. Experts estimate that delays from congestion alone result in productivity losses of up to $100 billion annually. Other negative effects include accident-related fatalities, increased air pollution, and inefficient fuel consumption. In a previous report, GAO noted several possible areas for federal action aimed at reducing traffic congestion. One such approach involves the development and application of intelligent vehicle and highway systems (IVHS), more commonly known as smart highways. The goal of IVHS is to provide technology-based approaches that enhance the overall effectiveness of the nation's surface transportation system.

Over the next few years, the Congress will have the opportunity to consider the appropriateness of federal support for IVHS through both surface transportation appropriations and reauthorization legislation. This study, conducted for the Senate Appropriations Subcommittee on Transportation, is aimed at assisting in such deliberations. Specifically, this review provides a detailed examination of both the potential of these technologies to improve traveling conditions and the obstacles that may prevent full realization of this potential.

To achieve this objective, the study addressed the following questions:

- What have the major studies concluded about the potential effects of IVHS, and to what extent are these findings empirically based?
- What additional information can be learned from IVHS field tests under way?
- What major obstacles could impede the realization of transportation benefits possible through IVHS technologies?

Background

Advances in computer and related technologies are now unfolding new possibilities for improving the nature and quality of travel. There are three general clusters of IVHS technologies with application to commuter mobility: advanced traffic management systems, advanced traveler information systems, and advanced vehicle control systems. These technologies involve a spectrum of configurations and capabilities ranging from centralized traffic control centers to driver information systems located in the vehicle to fully automated freeways.

Compared to efforts made by other nations, U.S. support for IVHS, as measured by funding, has been relatively low but is increasing. In fiscal year 1990, the Department of Transportation (DOT) devoted about $2.3 million to IVHS research. Funding in this area grew to $20 million for fiscal year 1991. Planning efforts are now under way to consider a substantially enhanced federal IVHS program as part of the 1991 Surface Transportation Act reauthorization, which could total over $100 million annually by fiscal year 1994.

Results in Brief

From its review of 38 major studies completed over the last decade, GAO found that the empirical basis for judging the effects of IVHS is limited but nonetheless positive and promising. The major studies have a high degree of consensus that these technologies can not only improve mobility but, under certain configurations, could also achieve other policy goals of economic benefits, improved safety, energy conservation, and air quality. An additional examination of nine IVHS operational tests under way further revealed an important federal role in ensuring sound evaluations as new IVHS technologies are tested in field settings.

GAO identified three types of barriers—cost, institutional, and technological—that could be critical to the overall success of a domestic IVHS program. In particular, the proper mix of burden-sharing among private sector interests and federal, state, and local governments for the costs of IVHS—both developmental and operational—must be found. Inappropriate distribution of costs could prevent full realization of the IVHS potential. Further, the ability of various levels of government to work together—and to work in an integrated way with the private sector—represents a key element to the success of an IVHS program.

Principal Findings

Potential Effects

A broad research consensus exists that IVHS can have noteworthy transportation effects, although the empirical basis for this consensus is limited. The most examined effect was on traffic congestion; 36 of the 38 IVHS studies GAO reviewed examined this effect, and all 36 noted positive congestion benefits likely from IVHS. However, only 4 of the studies provided results based on direct field testing, while the other results were based on either analytical projections (19 studies) or expert opinion (17 studies).

Findings were most often reported on the congestion effects attributable to near-term technologies (for example, advanced traffic management systems and advanced traveler information systems), and these results indicated that a wide range of moderate gains are possible—such as a 2-percent to 50-percent improvement in travel time—depending on the circumstances surrounding the technologies' deployment. Conversely, while less empirical support exists on the possible effects of long-term options (namely, automated freeway systems), one major simulation study of advanced vehicle control systems found dramatic possibilities in terms of capacity and safety improvements, such as a doubling of freeway capacity. This report did, however, caution about the potentially travel-inducing aspects of these systems, which could counteract some of the capacity gains.

While other effects were less frequently assessed than congestion, several studies did provide preliminary indications of effects possible in the areas of economic benefits, human safety, fuel savings, and environmental quality. Empirical examination of these other effects were similarly positive, although notes of caution were raised as well. For example, while simulation studies in Europe have found a potential reduction in accidents from IVHS, other authors have nonetheless warned of potentially adverse safety effects of having screens located in the vehicles.

Field Test Evaluations

Several operational tests are under way around the country to gain a better understanding of IVHS technologies. These will produce additional evaluative information, mostly on near-term advanced traffic management systems, although some operational tests involve advanced traveler information and automated freeway control. A review of these projects' evaluation designs reveals how important the role of the federal government is in ensuring that sound information is gathered from both major field tests and locally orchestrated projects. The Pathfinder and TRAVTEK projects provide examples of the conduct and evaluation of major field tests to gain empirical data on IVHS.

Barriers to Deployment

GAO found that three types of barriers will need to be overcome to ensure full realization of IVHS benefits. One critical obstacle is the possible lack of the needed resources to finance the deployment of IVHS technologies. This barrier encompasses cost burdens associated with the anticipated federal involvement, resource limitations at the state and local level, an uncertain consumer market, and possible liability problems. While initial funding for research and testing has been forthcoming, a more detailed analysis is needed of the costs and benefits of IVHS before each party (federal, local, and private) can be expected to commit to the $34 billion investment estimated for IVHS over the next 20 years.

The difficulty of integrating and coordinating the myriad systems, resources, and initiatives needed to plan and implement IVHS is another likely barrier. Indeed, the ability of the various institutions to work together is crucial to success. For example, DOT will have to execute the complex and sensitive work of technically guiding an integrated national program while encouraging decentralized private sector research. Further, both the government (federal, state, and local) and private sector will have to develop interorganizational agreements that allow for cooperation.

The third obstacle to an effective IVHS program is the arduousness of setting technological standards. Since there is general agreement in the field that IVHS does not depend on any major technological breakthroughs, the critical technological barrier is that of standard-setting. As with institutional barriers, resolving a lack of consensus related to standards will require cooperation and coordination among participants.

Recommendations

GAO concludes that IVHS technologies hold promise for improving the nation's surface transportation system. However, while some empirical evidence of their effectiveness exists, there are numerous uncertainties regarding the likely success of a domestic IVHS program. For this reason, GAO supports an aggressive research and testing program over the course of the Surface Transportation Act reauthorization period (1992-96) in order to gain a firmer understanding of the potential of IVHS before major deployment decisions are made. GAO makes three legislative recommendations aimed at ensuring that important considerations are addressed during this crucial research and testing period.

First, IVHS legislation should explicitly note the goals of improvement in the areas of congestion, safety, the economy, energy, and the environment, and DOT should be required to develop and execute research aimed at determining the role of IVHS technologies in achieving these goals. Second, IVHS legislation should require DOT to select, design, and evaluate high-priority operational field tests in accordance with a strategic IVHS research plan. Third, IVHS legislation should require an analysis of optimal funding options for achieving desired IVHS benefits, and such analysis should include a consideration of alternative federal, local, and private partnership arrangements.

The next few years will offer an opportunity to find answers to some core questions regarding the application of IVHS technologies to the nation's highways. Consequently, federal policy should be aimed at guiding the development of evaluative information that will allow for, among other benefits, knowledgeable decisions about the appropriate federal investment in IVHS and how best to target it.

Agency Comments

At the request of the committee, GAO did not obtain formal agency comments on this report.

Contents

Abbreviations

ATIS	Advanced traveler information systems
ATMS	Advanced traffic management systems
ATSAC	Automated Traffic Surveillance and Control System
AVCS	Advanced vehicle control systems
DOT	U.S. Department of Transportation
FHWA	Federal Highway Administration
GAO	General Accounting Office
INFORM	Information for Motorists
IVHS	Intelligent vehicle and highway systems
PATH	Program on Advanced Technology for the Highway
TRAVTEK	Travel Technology

Introduction

The Problem

The nation's network of roads, combined with many different types of transit operations, constitutes a transportation system that provides us with a basic source of mobility. However, we pay a high societal cost for this mobility. In many parts of the country, growth in automobile use has outpaced infrastructure investment, creating disruptive levels of traffic congestion. For example, in 1987, congestion accounted for over 2 billion vehicle hours of delay on urban freeways. In addition, high use of automobiles results in tens of thousands of accidents and fatalities annually. Expert estimates of the societal costs of both congestion and accidents are staggering. Productivity losses from congestion alone are estimated to cost the nation up to $100 billion annually, and the overall societal cost of accidents and fatalities is estimated to be even higher (for example, it was $130 billion for 1988).[1]

The environmental and energy effects of automobile use are also of continuing concern. Serious air pollution exists in many of the nation's metropolitan areas, noxious emissions from transportation being a major polluting source. For example, in Los Angeles, motor vehicles account for 87 percent of carbon monoxide emissions and 59 percent of nitrogen oxide emissions. In the energy area, 63 percent of the nation's petroleum use is consumed by the transportation sector, with congestion alone resulting in approximately 2 billion gallons of fuel being wasted each year.[2]

Because of the magnitude of these problems, several approaches are being undertaken to reduce the negative effects of automobile use. In a previous report, we noted several possible areas for federal action aimed at reducing traffic congestion.[3] For example, one approach involves techniques to reduce the demand for automobile travel, including the use of carpools and vanpools and expanded transit use.[4]

In the previous report, we also noted that increasing attention is being paid to the potential of advanced technologies to achieve improvements in our transportation system. These systems, known as intelligent

[1] Robert L. French, "Safety Implications of Automobile Navigation Systems," presented for the 46th annual meeting of the Institute of Navigation, Atlantic City, N.J., June 26-28, 1990.

[2] Mobility 2000, Reports on Major Aspects of IVHS (College Station, Texas: Texas Transportation Institute, March 1990), p. 6.

[3] U.S. General Accounting Office, Traffic Congestion: Federal Efforts to Improve Mobility, GAO/PEMD-90-2 (Washington, D.C.: December 1989).

[4] We evaluate these demand management and other transportation systems management techniques in a separate, forthcoming report.

vehicle and highway systems (IVHS)--or, more commonly, as "smart highways"—represent a technology-based approach to improving the nature of transportation. Researchers in the IVHS area envision the emergence of a computer-enhanced driving environment that would be more congestion-free, more environmentally benign, and safer.

Intelligent Vehicle and Highway Systems

Three general clusters of IVHS technologies have been associated with improvements in commuter mobility: advanced traffic management systems (ATMS), advanced traveler information systems (ATIS), and advanced vehicle control systems (AVCS). These three clusters represent a variety of approaches to improving mobility. (See appendix I for a complete list of these technologies.) The most near-term among them are ATMS. These technologies entail an integrated system of road sensors, traffic lights, and ramp meters coupled to a traffic operations center that uses computers and special algorithms to analyze incoming data and adjust traffic signal systems so as to minimize traffic delays.

ATIS technologies build upon ATMS approaches by providing travelers with real-time navigational information and customized routing advice based on traffic data analyzed at the traffic operations center. Drivers can then use this information to alter their time or route of travel, thereby avoiding (and reducing) congestion. Under certain configurations, ATIS systems can also provide information on alternative travel options, such as ridesharing and transit use.

AVCS is the most advanced application of the IVHS technologies and includes the fully automated highway system. AVCS technologies under development include variable speed control, radar braking, and automated headway and steering control. In some research programs, an investigation of AVCS is being done in conjunction with roadway electrification and electric vehicle research.

IVHS Policy Efforts

Interest and support for IVHS has been increasing dramatically in the last few years. For example, a current European effort (by a consortium of six countries) called PROMETHEUS plans to devote $750 million to IVHS over an 8-year period. Japan has also initiated major IVHS efforts. In the United States, IVHS has only begun to emerge as an area for federal policy action. The Secretary of Transportation first endorsed IVHS as part of the 1990 national transportation policy and has subsequently included an IVHS component in the administration's proposal for the 1991 reauthorization of the Surface Transportation Act.

Growing federal funding for IVHS reflects this emerging domestic interest, though it still lags behind efforts being conducted in Europe. Nonetheless, the Federal Highway Administration (FHWA) funding for IVHS has increased from $2.3 million in fiscal year 1990 to $20 million in fiscal year 1991. Further, planning efforts are under way to consider enhanced funding as part of the 1991 Surface Transportation Act reauthorization. The administration's proposal for such an IVHS program calls for a 5-year effort (1992-96), with funding to reach up to $100 million annually by 1994.

Objective, Scope, and Methodology

Objective

Over the next few years, the Congress will have the opportunity to consider the appropriateness of aggressive federal support for IVHS. Hence, there is a need for sound evaluative information on IVHS for use in the Surface Transportation Act reauthorization and related appropriation legislation. This study, conducted for the Senate Appropriations Subcommittee on Transportation, is meant to support such deliberations. Specifically, our review provides a detailed examination of what is known about both the likely effects of these technologies on traveling conditions and the obstacles that may prevent full realization of their potential.

To achieve this objective, we addressed the following questions:

- What have the major studies concluded about the potential effects of IVHS, and to what extent are these findings empirically based?
- What additional information can be learned from IVHS field tests under way?
- What major obstacles could impede the realization of transportation benefits possible through IVHS technologies?

Answers to these questions provide a basis for determining whether IVHS research warrants enhanced federal support and under what conditions such support, if any, would be most effective.

Scope

In answering the study questions, we examined the three commuter-related IVHS technology clusters: ATMS (advanced traffic management systems), ATIS (advanced traveler information systems), and AVCS (advanced vehicle control systems). We chose these clusters because, taken together, they provide an integrated system aimed at improving commuter mobility.[5] Moreover, they represent a range of IVHS developments that could be expected over time, from the near-term application of traffic management through ATMS to the expected application of traveler information through ATIS to the long-term prospects of automation through AVCS.

In response to the first evaluation question, which asks what the major studies have found about the possible effects of IVHS, we focused first and foremost on the congestion-reducing aspects of IVHS technologies. In addition, we examined IVHS effects on safety, the economy, energy, and the environment.

As is conveyed by the second evaluation question, we added a review of current IVHS operational tests to our analysis of major studies. The purpose of doing this was to complement our review of previous IVHS assessments with information on current IVHS field testing in this country. Specifically, we examined project objectives, the role of the federal government in planning and conducting these tests, and, finally, the extent to which evaluations are being conducted to address the effectiveness of IVHS technologies. Our review focused on federally sponsored IVHS operational tests and, based on information provided by FHWA, included nine different projects in seven states.

The third question of the study was on possible barriers to effective IVHS deployment. The purpose of this component was to examine likely obstacles to a successful IVHS program. In contrast to the past and present orientations of the first two study questions, this one was more prospective, looking toward the future deployment of IVHS. We examined three classes of potential obstacles: cost-related, institutional, and technological barriers. In addition to identifying critical barriers, we explored possible ways of overcoming them.

[5] A fourth cluster of technologies, commercial vehicle operations (CVO), involves the use of IVHS for commercial and emergency vehicle applications and, hence, is distinct from the commuter orientation of this study.

Methodology and Analysis

We answered the evaluation questions by using three complementary methods: a research synthesis, site visits, and an expert panel (see table 1.1). These methods were geared to the differing information demands of the three evaluation questions, the synthesis providing the empirical information needed for the first evaluation question, the site visits providing current information for the second question, and the expert panel providing an assessment of potential barriers for our use in answering the third and final evaluation question. Our data collection and related field work activities occurred between April and September 1990. This assignment was conducted according to generally accepted government auditing standards.

Table 1.1: Study Overview

	Methodology	
Evaluation question	**Primary**	**Secondary**
1. What have the major studies concluded about the potential effects of IVHS, and to what extent are these findings empirically based?	Research synthesis	Expert panel; operational test site visits
2. What additional information can be learned from IVHS field tests under way?	Operational test site visits	Expert panel; research synthesis
3. What major obstacles could impede the realization of transportation benefits possible through IVHS technologies?	Expert panel	Research synthesis; operational test site visits

Research Synthesis

We conducted a research synthesis of major reports published in the last decade that evaluated the effects of ATMS, ATIS, or AVCS. We identified 75 candidate reports for our research synthesis through an extensive search of three automated bibliographic retrieval systems, two university transportation research libraries, and eight IVHS report bibliographies. These reports included domestic, European, and Japanese IVHS studies.

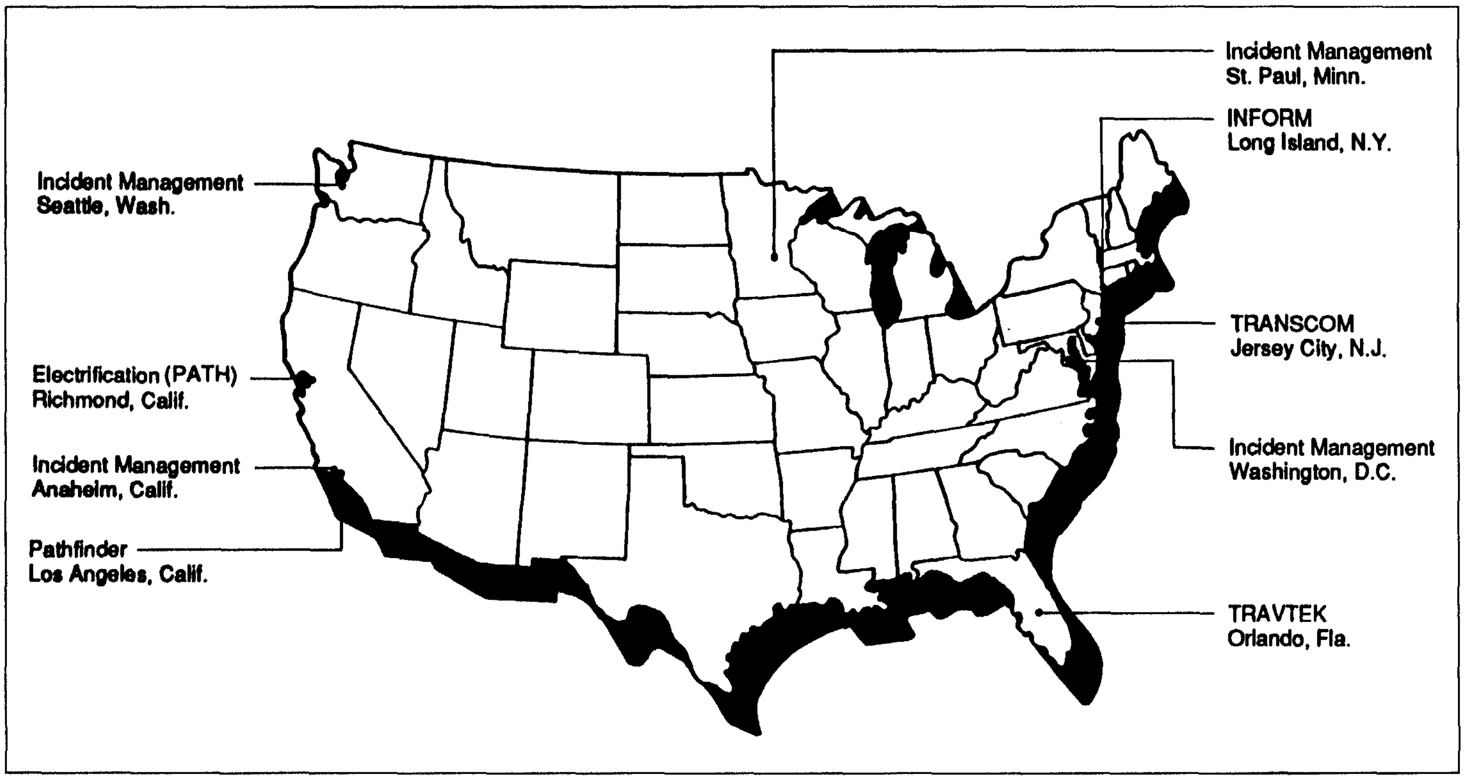
We submitted this preliminary list of reports to 54 transportation researchers, including our eight expert panelists. These researchers reviewed our list of studies to identify those they considered major reviews of IVHS effects. On the basis of their feedback, we refined our bibliography to 38 reports, which formed the basis of our research synthesis. (The reports in our review are listed at the end of this report.)

We reviewed each study to obtain information on (1) the technologies investigated, (2) the effects addressed, (3) the methodologies used to determine effects, and (4) the results reported. We then analyzed and synthesized this information by using both descriptive statistical and qualitative procedures. The results of this analysis are presented in chapter 2.

Operational Tests Review

Our review of IVHS operational tests included nine projects conducted or initiated since FHWA's emphasis in this area began in 1988. These projects are shown in figure 1.1.

Figure 1.1: IVHS Operational Test Sites



We reviewed implementation and evaluation plans as well as other written materials obtained through site visits to each IVHS project. During these visits, information was collected on (1) the smart highway technologies being examined; (2) the operational tests' objectives; (3) who the principal funders were and how much they contributed; (4) the evaluation objectives, such as possible effects on congestion, safety, air quality, and energy; (5) the evaluation methodology (for example, simulation, before-and-after measures, and user surveys); (6) the evaluation results; and (7) the opinions of stakeholders in the projects. The results of this review are presented in chapter 3.

Expert Panel

A panel of eight experts, selected for this study, was queried as to their views of likely barriers to IVHS development. The panel represented the wide range of interests inherent in IVHS. Our selection criteria included representation from the private, public, and academic sectors and coverage across the range of IVHS effects and across the range of IVHS technologies involved. (A brief description of each panelist is provided in appendix IV.)

The panel's primary mission was to identify and assess the magnitude of potential impediments to achieving the benefits of IVHS technologies. This assessment was provided to us in a structured, written format. The panelists first read a background paper we had drafted from the literature in which we describe 14 potential obstacles to development. The experts then rated each item on this list of barriers according to importance, adding other items as appropriate. Within this effort, they provided written statements supporting their ratings and offered solutions for overcoming problems.

We then carefully analyzed this information to identify the most critical barriers to IVHS. The results of this analysis are presented in chapter 4.

Study Limitations and Strengths

This study was designed and implemented during early IVHS deliberations in the United States. A major restriction was imposed upon it by the realities of conducting a study during this period of rapidly unfolding events and the need to provide information that would be timely to decisionmakers. This context necessitated three limitations to our data collection effort. First, only major reports within the last 10 years could be included in the research review. Second, while we were able to distinguish the types of methods the studies used—and concentrate on direct testing of IVHS—we were not able to independently verify the rigor with which each result was achieved. That is, we could not provide an independent calculation of IVHS benefits achievable. Third, we did not have time enough to systematically include all Japanese and European research in the review. While we do not think that these three restrictions affected the direction of our overall findings, they do limit the comprehensiveness of the research results reported in this review.

A major strength of our study arises from multiple methods used to examine IVHS technologies, which are in various stages of research and development. We overcame what might otherwise have been a data limitation by drawing upon a diversity of information in answering the evaluation questions. In the research synthesis, we included not only the few available field study results but also analytical projections and even, where appropriate, expert opinions. Further, we supplemented the research synthesis with visits to ongoing operational tests and with input from a variety of experts. This diversity of research methods provides an uncommonly rich source of timely information that strengthens both the study's conclusions and its contributions to the policy debate on IVHS.

The Organization of This Report

Chapters 2, 3, and 4 constitute the main body of the report. These chapters present the results relative to each of the three evaluation questions and corresponding analyses: a review of IVHS research reports (chapter 2), operational tests (chapter 3), and barriers analysis (chapter 4). Chapter 5 provides the conclusions and recommendations of the report.

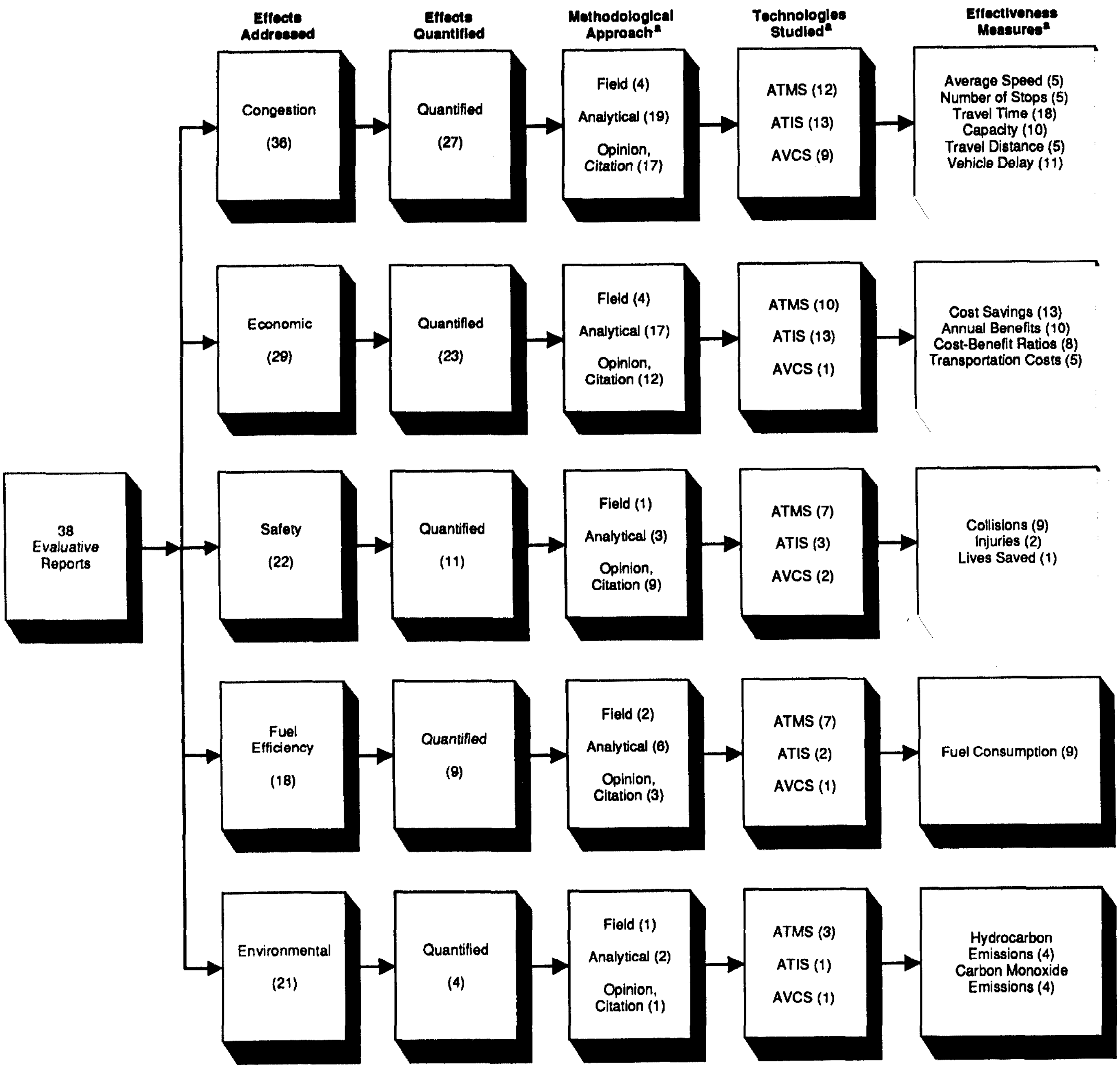
Synthesis of Major Research

IVHS is a relatively new concept in the transportation field. Consequently, our review revealed that while a variety of literature has been produced over the last decade, empirically based results are relatively sparse, particularly in reference to the more advanced technologies. Nevertheless, the 38 reports that we analyzed demonstrated a strong consensus that the implementation of IVHS technologies could result in noteworthy transportation benefits, particularly in the area of congestion reduction. Attendant economic benefits, safety improvements, reduced fuel consumption, and air quality improvements are also possible and in some cases have been documented. The magnitude of projected transportation benefits varies widely, depending upon numerous factors such as the IVHS technology under investigation and the level of existing traffic congestion.

Major Effects of IVHS Technologies

Our synthesis of IVHS research covered 38 major studies published over the last decade. Figure 2.1 breaks these studies down into several methodological and effect categories. As the figure indicates, we examined the extent to which the studies addressed any of five potential IVHS effects: congestion, safety, the economy, the environment, and fuel efficiency.

Figure 2.1: Number and Type of Studies in the Research Synthesis



[a]Applies only to reports containing quantified effects.

To distinguish differences in results across methodological approaches, we grouped the reported results into three categories, based on the methodologies employed to derive these results: (1) field tests, for results derived from actual field demonstrations; (2) analytical projections, for results derived from computer modeling or mathematical analyses; and (3) opinion or citation, for results based on expert opinion or on studies cited but not fully included in our review.[1]

Regardless of the methodology employed or the technology addressed, all 38 reports cited positive effects possible from IVHS. However, the degree of improvement varied widely, depending upon numerous factors, including the particular technology being investigated, the size of the field operational tests, its location, and how bad the previous conditions were. Six of these 38 reports, however, not only addressed possible benefits of IVHS but also included researchers' opinions on some potentially negative IVHS effects that need to be guarded against.

Congestion Effects

The growth of urban congestion with its attendant problems has been a primary motivation for investigating the potential of IVHS. Not surprisingly, therefore, 36 of the 38 reports we reviewed assessed potential congestion effects. Of these 36, 4 employed field tests, 19 used analytical projections, and 17 contained either expert opinions or references to other studies.[2] As described below, while different technologies were addressed in these studies, all the studies reported that the technologies in question could have a positive effect on reducing traffic congestion. Three studies did, however, contain cautionary opinions concerning possibly negative effects.

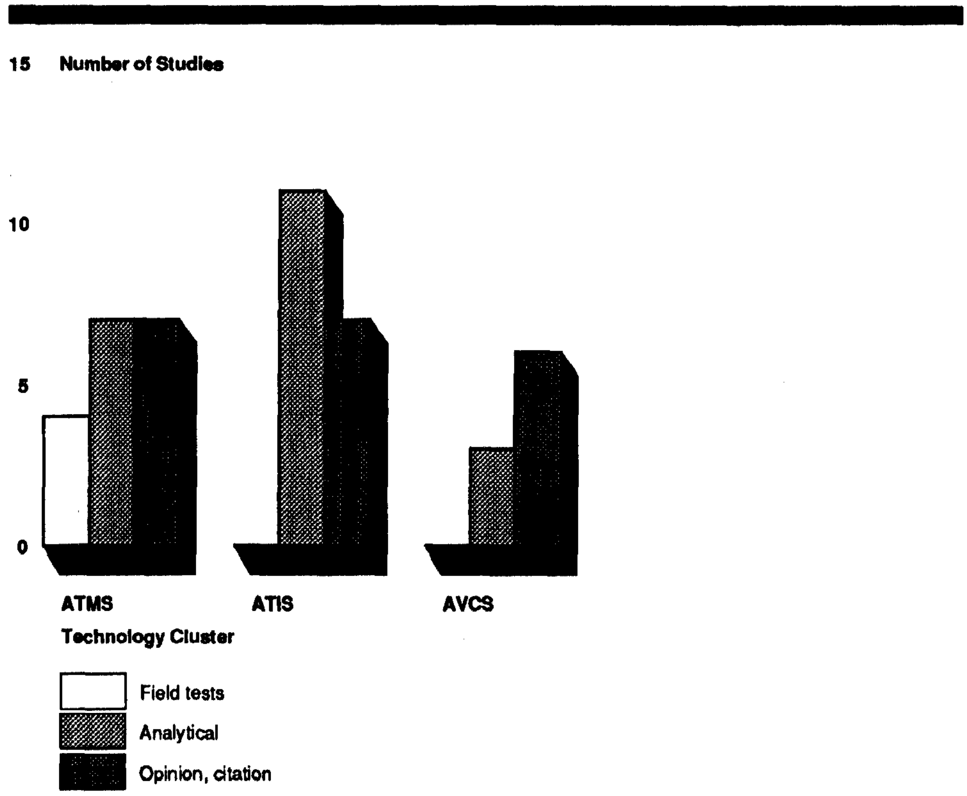
While certain ATMS technologies have been deployed in the United States and overseas, reported results of field tests are scarce and pertain primarily to the more current technologies, such as traffic signal control improvements and freeway surveillance and control techniques. Of the 36 studies that addressed congestion, 4 studies documented actual

[1]While a retrospective research synthesis would have focused exclusively on empirical work, because of the prospective nature of our review we determined that the researchers' opinions associated with the empirical work would be useful in our assessment of these technologies' potential effects.

[2]The total of methods employed exceeds 36 because several of the studies used more than one type of methodology.

results of domestic field tests of ATMS. (See figure 2.2.) These 4 constitute the only field-based evaluations included in our review, since operational testing of ATIS and AVCS technologies have just begun.

Figure 2.2: Methodologies Used to Assess Congestion Effects of Three IVHS Technology Clusters



These evaluations focused on traffic management systems, included a variety of measures, and produced results showing notable positive effects of ATMS technologies on traffic operations. (See table 2.1.) Three of the studies looked at traffic signal control systems. These operational tests addressed the effectiveness of computer programs and related technologies that aim to better coordinate traffic signal patterns and, in doing so, reduce stops and delays on surface streets.

Table 2.1: Reported Benefits From ATMS Operational Tests

Name of study	Author[a]	Study date	Evaluation methodology	Technology demonstrated	Reported benefit
National Signal Timing Optimization Project (11 cities nationwide)	FHWA	1982	Before-after; simulation model	ATMS, improving traffic signal timing plans	For each average intersection: 15,000 vehicle hours of delay saved; 455,000 vehicle stops eliminated; 10,000 gallons of fuel saved; $28,695 average annual benefit; 8.5% improvement in travel time; benefit-cost ratio of 63:1
Fuel-Efficient Traffic Signal Management (FETSIM) (61 cities & 1 county in Calif.)	ITS	1986	Before-after; simulation model; field test	ATMS, improving traffic signal timing plans	15% reduction in vehicle delays; 16% reduction in vehicle stops; 7% reduction in travel times; 8.6% reduction in fuel use; $231 million savings over 3 years; benefit-cost ratio of 58:1; reduced emissions; increased safety; improved public transit operations; improved traffic operations data base
Automated Traffic Surveillance and Control (ATSAC) (Los Angeles, Calif.)	L.A Dept. of Trans.	1987	Before-after	ATMS, computer control of traffic signals	13% reduction in travel time; 35% reduction in vehicle stops; 14% increase in average speed; 20% decrease in intersection delay; 12.5% decrease in fuel consumption; 10% decrease in hydrocarbon emissions; 10% decrease in carbon monoxide emissions; benefit-cost ratio of 9.8:1
Chicago Area Expressway Surveillance and Control Project (Chicago, Ill.)	McDermott et al.	1979	Before-after	ATMS, large-scale freeway surveillance and control system	30% reduction in peak period congestion; 18% reduction in accidents; decreased travel times; increased average speeds; expedited emergency responses; benefit-cost ratio of 4:1 (ramp metering)

[a]Complete reference citations are provided at the end of the report.

Of these operational tests, only the 1982 signal timing optimization project can be considered national. Conducted in 11 cities, the project implemented and evaluated the results of an advanced computer program (TRANSYT-7F) for optimizing lights on local streets.[3] Before-and-after comparisons and vehicle travel time studies noted positive results. In sum, the study found an average 8.5-percent improvement in travel time and 15,000 vehicle hours of delay saved (as averaged across all involved intersections for a 1-year period).

The most recent and frequently cited evaluation is the 1987 study of the Automated Traffic Surveillance and Control System (ATSAC) in Los Angeles. Started during the 1984 Olympics to better coordinate traffic

[3]Test cities for the study were Charleston, South Carolina; Denver, Colorado; Des Moines, Iowa; Fort Wayne, Indiana; Gainesville, Florida; Milwaukee, Wisconsin; Nashville, Tennessee; Pawtucket, Rhode Island; Portland, Oregon; San Francisco, California; and Syracuse, New York.

around the Coliseum, the system is now the most advanced signal control system in the United States. The 1987 evaluation examined changes in traffic before and after the system's implementation on 118 traffic signals and 396 system detectors. The study found a 13-percent reduction in travel time and a 35-percent reduction in vehicle stops.

These results provide empirical evidence of benefits actually achieved through early versions of ATMS. To estimate the effects of future ATMS systems, 7 studies employed computer modeling and mathematical analysis techniques. While less strong than actual operational tests, such analytical methods permit prospective consideration of future technology performance.

In general, the analytically based studies have projected similarly positive effects for future ATMS technologies. For example, one study evaluated the probable effects of an advanced traffic management system on a heavily traveled corridor in California.[4] The study reported potential travel time reductions of 11 to 15 percent, intersection delay reductions of nearly 2 million vehicle hours per year, and vehicle stop reductions of approximately 35 percent per year.

Finally, 7 studies provided information on either actual benefits cited in other reports or potential benefits that experts believe may occur with ATMS deployment. While the information presented varies as to the degree of improvement expected, each study reported positive effects on congestion. Reductions in travel time and delays of between 10 and 50 percent, increases of average speed of between 29 and 35 percent, and increases of capacity of between 12 and 40 percent were reported. For example, one study summarized reported benefits from a number of installations of freeway ramp metering systems around the nation over the last 10 years.[5] Evaluations in Minnesota, Washington, and New York show average peak period freeway speeds increasing up to 35 percent and travel time decreases up to 50 percent.

ATIS technologies build upon ATMS technologies in providing route guidance and real-time information to commuters. These technologies are not as developed as ATMS, and consequently there are no completed domestic

[4]JHK & Associates, Smart Corridor for the City of Los Angeles: Demonstration Project Conceptual Design Study, final report, vol.1 (Los Angeles, Calif.: October 1989).

[5]Mobility 2000 Working Group, Intelligent Vehicle Highway Systems: Advanced Traffic Management Systems (ATMS) (Dallas, Tex.: March 1990).

field experiments to report on.[6] Therefore, investigations into the potential effects of these technologies using analytical methods (computer modeling and mathematical analysis) are especially prominent.

Eleven reports addressed the congestion-related effects of ATIS using analytical methodologies. These studies examined the potential effectiveness of various technologies that could provide the traveler with route guidance and real-time traffic information. Different ATIS configurations were represented in the analyses, such as whether travelers received the information before or after they began their route or whether the ATIS system provided just traffic information or provided route guidance as well. Depending on the testing circumstances and ATIS configurations tested, these reports showed possible reductions in travel time ranging from 2 to 50 percent, with a concomitant range in congestion reduction.

Table 2.2 provides an overview of 7 of these reports that employed some form of computer modeling of expected congestion results from ATIS. For example, one study examined the effect of in-vehicle information systems under different traffic demand and incident scenarios.[7] Simulating results using 12 different scenarios, the study found that ATIS technologies can have a range of effects depending on the severity of existing traffic congestion. Under highly congested conditions with accidents, up to 14-minute savings on a 30-minute trip were estimated (a 47-percent time savings). In contrast, under moderate traffic conditions with no accidents or other disruptions, estimated savings were marginal.

[6]Major ATIS operational tests have recently been initiated in Los Angeles, California, and Orlando, Florida. See chapter 3.

[7]Haitham Al-Deek and Adolf D. May, "Potential Benefits of In-Vehicle Information Systems (IVIS): Demand and Incident Sensitivity Analysis," Institute of Transportation Studies, University of California, Berkeley, Calif., July 1988.

Table 2.2: Reported ATIS Benefits Based on Simulation Models

Name of study	Author[a]	Study date	Estimated benefit
Smart Corridor for the City of Los Angeles: Demonstration Project Conceptual Design Study	JHK & Associates	1989	Overall corridor effects: travel time reduced by 3.8 to 5.2 million vehicle hours per year (11-15%); fuel consumption decreased by 1.3 million gallons per year (2.5%); annual hydrocarbon emissions reduced by 8%; annual carbon monoxide emissions reduced by 15%; intersection delay reduced nearly 2 million vehicle hours per year (20%); annual savings of $24-32.5 million Individual driver effects: Increased average freeway speeds from 15-35 mph to 40-50 mph; decreased average freeway trip duration of 12%; increased average surface street speeds during peak commute periods from 20 mph to 22 mph (11%); decreased average surface street trip duration of 13%
Potential Benefits of In-Vehicle Information Systems in a Real Life Freeway Corridor Under Recurring and Incident-Induced Congestion	Al-Deek et al.	1988	Travel time savings between 3-10 minutes per freeway trip during nonrecurring, incident -induced congestion
Potential Benefits of In-Vehicle Information Systems: Demand and Incident Sensitivity Analysis	Al-Deek & May	1988	Travel time savings ranging 0-14 minutes (0-47%) for a 30-minute average trip under different congestion scenarios
Some Theoretical Aspects of the Benefits of En-Route Vehicle Guidance (ERVG)	Al-Deek & Kanafani	1990	Typical travel time savings of 3-4%
Effectiveness of Motorist Information Systems in Reducing Traffic Congestion	Koutaopoulos & Lotan	1989	Modest reduction in travel times up to 4.4%
Study to Show the Benefits of Autoguide in London	JMP Consultants	1989	Resource cost savings of 7-9%; travel time savings of 8-11%
Some Possible Effects of Autoguide on Traffic in London	Smith & Russam	1989	Travel time savings ranging from 2.2% for unequipped vehicles to 6.9% for equipped vehicles (10% of vehicles equipped); annual benefits of 170 million pounds; reduction of 400 personal injury accidents

[a]Complete reference citations are provided at the end of the report.

Seven reports cited the results of other studies conducted in the ATIS area but were not included in our review. Information on these findings assist in filling in gaps, particularly with regard to overseas efforts. While ATIS systems are very recent in the United States, these systems have been studied more extensively in Europe and Japan.[8] For example, an early study of a Japanese real-time route guidance system showed average travel time savings of 11 percent, and a later analysis in Tokyo showed that travel time savings of between 9 and 14 percent could be

[8]In the late 1960's, FHWA conducted an analysis of a dynamic version of the Electronic Route Guidance System (ERGS), but subsequent investigations were dropped.

realized in urban settings. British simulations have also shown that drivers whose cars are equipped with real-time route guidance systems may realize similar travel time savings.

While the general consensus of the research is that ATIS may offer substantial congestion-reduction benefits, some limitations to this approach were also pointed out. One author predicted that as in-vehicle navigation devices become widely used, alternative routes could experience worsening congestion as their capacity is exceeded.[9] The report suggested that eventually better communication between a central routing facility and vehicles would be necessary to counteract the flooding of diversion routes by those receiving congestion information.

Although the majority of the studies we reviewed addressed the more near-term and familiar ATMS and ATIS technologies, the 9 reports that discussed AVCS technologies concurred that they hold the promise of truly dramatic congestion reduction. These reports describe how automated freeways could substantially increase highway capacity by allowing vehicles to travel closer together at higher speeds. Further, the computer control aspects of this system are intended to eliminate traffic flow problems associated with accidents, poor drivers, or bad weather.

Because of the long-range nature of automated freeways, no field-based assessments of their potential were included in our review. However, we did include a study that simulated potential effects. In 1982, a major study was performed by General Motors under the sponsorship of the Federal Highway Administration.[10] This study analyzed freeway capacity improvements using automated highway technologies under three different average speed scenarios (40, 50, and 55 mph). The analysis estimated between a 27-percent and a 103-percent improvement in highway capacity, with the latter representing a more full-scale AVCS development scenario.

Beyond such simulations of automated highway potential, most of the discussion of AVCS has been based on transportation experts' knowledge of the individual technologies that constitute this system and their estimates of possible effects. In general, the authors of the AVCS studies that

[9] R. A. Cass, "Digital Databases for Vehicle Navigation: A Review of the State-of-the-Art," ISATA paper 89113, June 1989.

[10] J. G. Bender et al., Systems Studies of Automated Highway Systems, Final Report, report FHWA-RD-82-3, General Motors Corporation GM Transportation Systems Center (McLean, Va.: Federal Highway Administration, Office of Research and Development, June 1982).

we reviewed were optimistic that AVCS systems hold the promise of significant increases in capacity while still maintaining high average travel speeds and, therefore, reducing congestion. For example, a 1988 FHWA report concluded that, while advanced traffic control and driver information systems would permit us to get the maximum out of the present highway system, only the automated vehicle control concepts could offer a promising means of significantly decreasing congestion.[11] Similarly, other reports include estimates by some experts that eventual implementation of an automated highway system could increase highway capacity by up to 300 percent without widening existing highways or building new ones.

However, notes of caution were also voiced concerning AVCS, similar to those expressed on potential negative benefits of ATIS. One author hypothesized that while an urban automated highway system would provide more efficient vehicle travel, it could also generate additional vehicle mileage because of its increased convenience.[12] Depending on the existing circumstances, such additional mileage may not in fact pose a significant problem, but to the extent that it may induce further congestion and other secondary effects (reduced safety, degraded air quality, noise pollution, and increased fuel consumption), such induced travel could become a significant negative effect of AVCS.

Other Effects of IVHS Technologies

Our review produced preliminary indications of how IVHS technologies may affect other areas in addition to congestion, such as economic benefits, safety, energy conservation, and clean air. Among these effects, information was most available on economic benefits, with 23 reports providing quantified information of this type. Less frequently quantified were IVHS effects on safety (11 reports), fuel efficiency (9 reports), and environmental effects (4 reports). The following section summarizes the key findings in these areas, with additional information provided in appendix II.

Economic Effects

Research suggests that furthering the development and deployment of IVHS technology may provide noteworthy economic benefits to the nation. Twenty-three studies in our review quantified information on

[11] Federal Highway Administration, The Future National Highway Program 1991 and Beyond: Working Paper No. 7, Advancements in Vehicle and Traffic Control Technology (Washington, D.C.: Department of Transportation, February 1988).

[12] J. G. Bender et al., Systems Studies.

economic benefits potentially available from IVHS. Four of these studies reported positive cost-benefit ratios based on operational tests of ATMS. These ratios varied from 4:1 to 63:1, with the wide variation dependent on a number of factors, such as what was included in the calculations and the initial degree of system inefficiency.[13]

However, the majority of economic benefits reported were based on analytical estimates of various costs and benefits that could occur when implementing various ATMS or ATIS systems. These analytical estimates of future cost-benefits (see appendix II) were more moderate—generally under 10:1—suggesting that once initial inefficiencies have been corrected, benefits may be less spectacular though still remain attractive.

Safety Effects

Improving highway safety is of paramount importance in transportation systems design. Experts believe that advanced technologies will bring new levels of information and control to the operation of motor vehicles and may greatly improve traffic safety. Indeed, in the one operational test of ATMS that we reviewed that included safety measures, an 18-percent reduction in peak period accidents was documented.[14] Beyond this one field study, the majority of safety-related results (that is, 9 of 11 studies) were based on expert opinion or secondary reporting of positive safety effects possible from IVHS. For example, research in England and France was cited for its calculation of the number of accidents that improved driver information systems could reduce. Other research suggested that AVCS-related technologies could provide early warnings of impending danger, thereby providing the driver with the critical reaction time needed to avoid accidents.

While these reports noted positive safety effects, some safety concerns were also raised. One issue pertains to the possible distraction to a driver when using an in-vehicle driver information system. A second issue involves the potential safety risks inherent in an automated freeway system. These two issues highlight the need to gain additional empirical information on IVHS performance in order to ensure that such a system does not jeopardize the safety of travelers.

[13]For example, when estimates on construction costs were included, the 63:1 cost-benefit ratio was estimated to be much lower (that is, 4.2:1).

[14]Joseph M. McDermott, Stephen J. Kolenko, and Robert J. Wojcik, Chicago Area Expressway Surveillance and Control: Final Report (Oak Park, Ill.: Illinois Department of Transportation, March 1979).

Fuel Efficiency Effects

Preliminary indications are that IVHS technologies can contribute to fuel efficiency. However, of the 9 studies that reported on this effect, only two ATMS operational tests provided field-based data on fuel efficiency effects. These studies reported fuel consumption reductions of 8.6 percent and 12.5 percent. In addition, most simulations and projections show moderate fuel savings from ATMS and ATIS technologies resulting from savings in vehicle delays, stops, and travel times. Finally, one other simulation provided preliminary projections suggesting dramatic reductions in energy consumption potentially available through AVCS-related highway electrification or electrically powered vehicles.[15]

Environmental Effects

Congestion-related emission increases will continue to be an important contributor to air quality degradation. Some experts believe that IVHS technologies, by reducing congestion, might reduce nitrogen oxide, hydrocarbon, and carbon monoxide emissions. Four reports provided quantified assessments of emission reductions; only one was a field study. This study (the ATSAC evaluation) noted moderate emission decreases, such as a 10-percent reduction in carbon monoxide emissions. Two other studies—one based on an analytical projection and the other on secondary citations—noted similar efficiency effects possible from ATMS and ATIS (for example, an 8-percent to 15-percent reduction in emissions). More dramatic gains were projected in the one analysis of advanced AVCS-related technologies; this study concluded that electric vehicles could "dramatically and unequivocally reduce carbon monoxide and hydrocarbons."[16]

Summary and Conclusions

Our review of 38 major reports reveals a strong unanimity that the implementation of IVHS technologies can result in noteworthy transportation improvements. This consensus does have some grounding in direct experience (4 evaluations of operational tests of ATMS), but for the more advanced technologies, it is mostly based on analytical methods of varying strength and on expert opinion.

Limitations in direct experience suggest that more research is needed to fully understand the range of effects, particularly from a long-term point of view. Advanced traffic management system (ATMS) and advanced traveler information system (ATIS) technologies are to some

[15] J. G. Bender et al., Systems Studies.

[16] Quanlu Wang, Mark A. DeLuchi, and Daniel Sperling, "Emission Impacts of Electric Vehicles," 69th annual meeting of the Transportation Research Board, Washington, D.C., January 7-11, 1990.

extent already being tested and promise near-term congestion relief. However, the range of estimated effects for these near-term technologies is quite wide, often depending upon the kind of study involved. For example, one project evaluation (the Fuel-Efficient Traffic Signal Management study) documented only a 7-percent reduction in travel time, while some simulation studies estimated a possible 47-percent reduction in travel time. Consequently, increased systematic testing and evaluation are needed to determine the particular technology configuration and conditions necessary to maximize the benefits potentially achievable through near-term IVHS.

Because of the explosive nature of the urban congestion problem in many metropolitan areas, it is important to recognize that any gains in congestion reduction resulting from deployment of these two technologies could eventually be eclipsed. Substantial and long-lasting congestion reduction is expected to result only from the more advanced vehicle control system technologies. Simulation studies as well as other research we reviewed have suggested that automated freeways could eventually increase capacity up to 300 percent. Such increases could provide needed mobility for major metropolitan areas in the 21st century. However, these technologies will require substantial research, testing, and evaluation before decisions on deployment of what amounts to a truly revolutionary transportation system can be made.

In a related vein, the research results demonstrate that IVHS can have concurrent effects on human safety, fuel efficiency, and air quality but that such effects are often overshadowed by the aims of IVHS toward congestion reduction. Accordingly, future IVHS research could be aimed at explicating the role of smart highways in achieving—or at least not inhibiting the achievement of—these other national policy goals, including the use of IVHS to enhance transit and ridesharing options.

In sum, the research evidence supports the hypothesis that IVHS can have positive effects on the nation's transportation system. However, gaps in the empirical information available on IVHS limit the confidence that can be placed in this general consensus. In particular, additional direct experience with ATMS and ATIS; sustained inquiry into AVCS technologies; more attention to safety, energy, environmental, and multimodal aspects of IVHS; and more detailed analysis of national cost-benefit issues are all gaps that need to be filled by future research. Some of these areas are in fact being addressed by operational tests under way; a review of these forms the basis of the next chapter.

Review of Federal IVHS Operational Tests

Operational tests play a major part in the advancement of IVHS technologies, providing crucial tests of their actual performance. For this reason, we supplemented our review of IVHS research studies with an examination of nine federal operational test projects that are currently investigating IVHS applications. None of these projects is yet complete, none has produced a final evaluation report, and therefore no overall judgment can be drawn about their overall success. However, they display several common characteristics and suggest areas of emphasis in which any future federal involvement may be most beneficial.

Through site visits and discussions with project officials, we found that (1) most of the operational tests under way focus on near-term ATMS technologies, although field tests of ATIS and AVCS technologies have been initiated; (2) most of the projects examine congestion reduction effects, although many include measures of related effects such as improved air quality and reduced fuel consumption; (3) several of the projects illustrate the need for a federal emphasis on careful evaluation; and (4) many of the operational tests feature some form of federal, local, and private cooperation.

Types of Operational Tests

All the operational tests we reviewed have the aim of improving traffic operations, principally in the area of congestion reduction. Some have concurrent objectives, such as reduced fuel consumption. In accomplishing these objectives, eight of the projects use ATMS, while five are exploring various aspects of ATIS. Only one operational test is investigating issues related to AVCS. In this section, we briefly describe each of the nine IVHS projects we reviewed.[1] Table 3.1 provides an overview of these projects.

[1] A fuller description of each IVHS demonstration project is provided in appendix III. See also figure 1.1 for the geographic locations of the projects.

Table 3.1: Operational Tests Overview

Project	Current funding	Federal funding	IVHS component	Demonstration focus	Expected benefit
PATH (Berkeley, Calif.)	$9.4 million	$3.0 million FHWA $500,000 UMTA $300,000 NHTSA	ATIS AVCS ATMS	Automated freeways Electrification Navigation	Reduced congestion Reduced air pollution Improved safety
Pathfinder (Los Angeles, Calif.)	$2.5 million	$1 million	ATIS	In-vehicle navigation systems	Reduced congestion
TRANSCOM (Jersey City, N.J.)	$3 million	$3 million FHWA	ATMS, ATIS	Incident management; automatic vehicle identification	Reduced congestion
TRAVTEK (Orlando, Fla.)	$8 million	$2.6 million	ATIS	In-vehicle navigation systems; traveler information	Reduced congestion, air pollution, and fuel use
INFORM (New York, N.Y.)	$30 million	$750,000-$800,000 FHWA	ATMS	Integrated systems; freeway management; variable message signs	Reduced congestion
Incident management (Minneapolis-St. Paul, Minn.)	$458,300	$100,000 yr. (fiscal years 1989-90)	ATMS	Traffic information; incident response	Reduced congestion; improved safety
Incident management (Seattle, Wash.)	$150,000	$100,000	ATMS	Incident response	Reduced congestion; improved cooperation; improved public perception
Arterial control & integration (Seattle, Wash.)	$130,000	$100,000	ATMS	Integrated systems	Reduced congestion; demonstrate low-cost systems integration
Urban Congestion Alleviation Project (Washington, D.C.)	$1.16 million	$800,000 FHWA	ATMS	Video detection; traffic advisory radio; variable message signs	Reduced congestion
Anaheim Integrated System Project (Anaheim, Calif.)	$2.1 million approximately	$720,000 (1987) $200,000 (1990 FHWA)	ATMS ATIS	Events management; institutional coordination	Reduced congestion; related motorist and fuel savings

TRAVTEK

Travel Technology (TRAVTEK) is a 3-year operational test project in Orlando, Florida, and together with California's Pathfinder project, it represents the first major domestic field test with advanced traveler information systems using in-vehicle displays. The TRAVTEK project will employ various ATIS technologies intended to maximize consumer use of traffic and service information. The project involves the deployment of 100 specially equipped vehicles that will provide tourists and high-mileage local drivers with information on traffic conditions and facility locations around the Orlando area. Each of these vehicles will be equipped with an in-vehicle TRAVTEK device that will provide real-time information on traffic congestion, as well as information on items such as motels, restaurants, and the location of government and entertainment facilities.

Pathfinder

The other major operational test of advanced traveler information technology is the Pathfinder project in Los Angeles, California. This study focuses more exclusively than the TRAVTEK project on the use of in-vehicle driver information as a means of reducing congestion. The project will use 25 vehicles equipped with guidance systems that will convey real-time traffic information, such as traffic congestion, time-of-day restrictions, and information on both recurring and nonrecurring incidents through the use of video screens located in the cars. The project will examine whether the provision of such traffic condition information can cut travel time, be integrated with other traffic information systems, and provide motorists with accurate, timely, and understandable information.[2]

PATH

Only one of the federally funded projects we reviewed addresses automated freeways. Researchers at the University of California's Institute of Transportation Studies are involved in a project called the Program on Advanced Technology for the Highway (PATH). PATH is intended to develop electrification, automation, and navigation technologies to progressively higher levels so that they may then be tested at state and university facilities and, later, in operational tests. The PATH program builds and expands on earlier efforts in electrification technology and currently includes 27 smaller projects. The majority of the PATH projects concentrate on AVCS technologies. For instance, one of the projects involves the use of high-occupancy vehicle lanes as test tracks for future vehicle platooning. Platooning would allow vehicles to travel at high speeds in close proximity to one another, thereby increasing highway capacity.

The inclusion of electrification issues in the PATH program makes it unique among the operational test projects that we reviewed. Roadway electrification and the use of roadway-powered electric vehicles is a promising approach for significantly reducing pollution and providing

[2]The Pathfinder project has been incorporated into a larger, $48 million local effort to develop a "Smart Corridor" in Los Angeles.

an alternative source of fuel. Supported by two federal grants, PATH is testing the application of electrification for possible transit use. A special test track with a 200-foot segment of powered roadway has been constructed in Richmond, California, for these tests. The track contains an electrical conductor embedded in the pavement that inductively transfers power to the vehicle. PATH plans to incorporate the results of these tests in its overall report to be submitted to the Congress in 1992.

TRANSCOM

TRANSCOM involves a group of 14 transportation and public safety agencies in managing a heavily traveled corridor between northern New Jersey and New York City. TRANSCOM will make use of highway advisory radio, remote video surveillance, and a computer networking system. It will also include a test of an automatic vehicle identification system for automatic toll collection installed in 1,000 commercial trucks, 500 New York City Transit Authority buses, and approximately 300 fleet vehicles from certain member agencies. Eventually the system will be enhanced to assess its capability in performing traffic monitoring activities for collecting real-time congestion information (for example, speed, travel times, and accidents) and communicating them through variable message signs and highway advisory radio.

INFORM

INFORM (Information for Motorists) is a computerized traffic management and information system operated by the New York State Department of Transportation in the highly congested Long Island corridor. This project covers roadways along a 35-mile long corridor, encompassing three freeways and adjacent arterials on Long Island. Using electronic sensors implanted in the roadways, INFORM gathers information about the volume, speed, and flow of traffic and communicates it to motorists through variable message signs and commercial radio broadcasts. The system also automatically adjusts traffic signals and entrance ramp metering signals in response to current traffic patterns.

Four Incident Management Projects

As part of FHWA's urban congestion action plan, seed funding was initiated in 1989 for four incident management projects.[3] In each case, the federal funds augmented local efforts already under way. For example, the Washington, D.C., project includes the provision of video cameras in

[3]These projects are located in Anaheim, California; Seattle, Washington; St. Paul, Minnesota; and Washington, D.C.

the vicinity of the Woodrow Wilson Bridge as part of a multifaceted program to reduce congestion on this heavily traveled section of the Washington beltway.

The four projects use various ATMS-related and (to a lesser extent) ATIS-related technologies to monitor traffic conditions, adjust traffic signals and ramp systems, and respond to congestion-inducing accidents. For example, the Integrated Traffic Management System project in Anaheim, California, focuses on providing a computerized traffic control system and current traffic information for drivers through a series of variable message signs. Central to this project is its traffic management center, where all signalized intersection control functions and freeway advisory information messages are coordinated and executed.

Operational Test Evaluations

As these projects were ongoing operational tests at the time of our review, no final evaluations had been completed. However, the likelihood that these evaluations will obtain the data needed to improve our estimates of the benefits and obstacles associated with IVHS applications can be ascertained by examining their evaluation designs. Of the nine operational test projects we reviewed, all specified some form of evaluation to be conducted, with a smaller portion of these projects having detailed evaluation plans. In particular, the Pathfinder and TRAVTEK projects involve designs that are noteworthy for their employment of multiple evaluation approaches to assess ATIS technologies.

The Pathfinder project intends to employ multiple measures to determine whether travel time improvements occurred and to assess how useful an ATIS guidance system is for motorists. To this end, the evaluation has been designed to test and compare travel time savings under three different experimental treatments: traveling with a blank screen (control condition), traveling with in-vehicle navigation equipment ("MAP" condition), and traveling with in-vehicle and real-time congestion data ("Pathfinder" condition).

Data will be collected by having test vehicles drive on a series of preestablished routes over an 8-month period. Data on travel times and related trip characteristics will be recorded by the central communications center and supplemented by daily driver logs. By comparing travel times under the three test conditions, the evaluation will attempt to assess relative savings from both in-vehicle equipment and real-time congestion data. The usefulness of the data to drivers will also be addressed through two different techniques: daily travel logs and weekly driver surveys.

TRAVTEK's evaluation design is broader than Pathfinder's and reflects the broader objectives of this project. While still under development, the current evaluation plan consists of 10 different evaluation approaches, ranging from a field study of local and rental car users to modeling studies of potential system effects on traffic, environmental, economic, and other community benefits. As with the Pathfinder study, several test conditions will be used to assess travel time savings. Surveys of drivers will also be conducted to obtain their perceptions of the usefulness of both the traffic and service information.

In contrast to the Pathfinder and TRAVTEK projects, evaluations of the incident management projects tend to be less comprehensive, in keeping with the more modest aims of the projects. With the exception of the Anaheim project, none had detailed evaluation plans, and what information was available suggested that these projects will entail simple evaluations based on user surveys, case study write-ups, and so on.

The one exception is the Anaheim project evaluation, which will be designed and conducted by a local university. It will evaluate the extent to which the traffic management center improves travel times through signal coordination and special events management. The evaluation will initially focus on improvements to a selected "super street" corridor and will include empirical measures of delay reductions and corresponding effects on travel speed, fuel savings, and emissions. The study will also entail an empirical examination of travel improvements attributable to institutional coordination. A series of before-and-after measures will be taken to measure reductions in delay and other related improvements, while simulation models will be used to examine the effects of institutional coordination, with specific regard to timing pattern coordination across participating cities.

The Federal Role in Operational Test Projects

While the small number of field tests we reviewed reflects the early stage of the domestic IVHS program, these projects nonetheless provide an opportunity to examine the role of the federal government in testing and evaluating IVHS technologies. A key aspect of this role has been to ensure that quality information is developed on the performance of IVHS. Indeed, where FHWA has concentrated on the evaluation component of these projects, comprehensive evaluation designs have been developed. Two of the largest ATIS field tests recently undertaken by FHWA—TRAVTEK and Pathfinder—have developed or are in the process of developing detailed evaluation plans. FHWA has been actively involved in designing these projects and, in particular, in designing their evaluation. For example, approximately $1 million of the total $2.6 million in federal funds for TRAVTEK is being provided for evaluation. Similarly, FHWA has allocated an additional $200,000 to support the Anaheim Integrated System Project evaluation.

Summary and Conclusions

The review of current operational tests suggests important facets of IVHS field testing and the role of the federal government in developing state-of-the-art technologies. The current orientation of the projects is toward the near-term IVHS applications such as advanced traffic management systems. The results of our research synthesis are also consistent with this. What the operational test review highlights is the role of the Department of Transportation in designing field projects to test newer aspects of IVHS, as witnessed by the two major operational tests involving advanced traveler information systems.

The great majority of the operational tests have a congestion-reduction orientation to them. Again, this is consistent with the findings from the research synthesis. A major exception is the PATH program, which through its work on AVCS also emphasizes energy, environmental, and safety-related aspects. The all-encompassing nature of PATH—and the role of the federal electrification grants—suggests that a greater range of objectives is possible in IVHS operational tests and that the federal government can play an important role in realizing it.

Finally, while the operational tests we reviewed often contain a mix of policy objectives—namely, solving local problems as well as testing new aspects of IVHS—DOT has played a consistent role in obtaining evaluation information that can help enhance the national data base regarding direct experience with IVHS technologies. While current federal involvement in evaluation can be viewed as promising, it should be noted that none of the planned evaluations of operational tests has been completed, and only four evaluations have been initiated to date. Nonetheless, given the growing need for demonstrable evidence of IVHS effectiveness, it will become increasingly incumbent on DOT to ensure that sound evaluation designs are developed and implemented so that the findings can be used to structure future IVHS funding priorities in a way that maximizes the potential benefits of these technologies.

Analysis of Potential Barriers

While our review of IVHS research and current operational tests suggests that IVHS can have a positive effect on the nation's transportation system, a variety of factors could influence the overall effectiveness of any future IVHS program. This chapter is about the major barriers that could prevent the realization of expected IVHS benefits. In our analysis of information collected from our expert panel, we found three types of IVHS barriers: cost barriers, institutional barriers, and technological barriers. Overall, we identified eight specific barriers. Four of these are cost barriers: the magnitude of the federal share, an IVHS consumer market, state and local cost burden, and liability. Three are institutional barriers: the capabilities of DOT, private and public sector cooperation, and intergovernmental cooperation. The technological barrier has to do with technological standards.

Cost Barriers

The ability of various IVHS participants—namely the federal government, the state and local governments, and the private sector—to produce the necessary IVHS funds is a major challenge to the viability of the program. This section is concerned with cost issues surrounding the domestic research, testing, and eventual deployment of IVHS technologies.

Magnitude of the Federal Share

The domestic IVHS program is still in its infancy, and the federal IVHS funding made available thus far has been relatively modest. Federal support for IVHS was about $2.3 million in fiscal year 1990 and about $20 million in fiscal year 1991. As noted in chapter 2, the cost-benefit ratios currently estimated to accrue from deploying IVHS are promising. Perhaps as a consequence of the relatively low cost levels and the promising cost-benefit ratios, federal financial support for IVHS has been forthcoming. Targets for the future federal funding, however, run as high as $100 million annually, with expected total IVHS costs for all sectors of government currently placed as high as $34 billion through the year 2010.[1] Such high funding levels could negatively affect the attractiveness of federal support for the program, and consequently the cost of IVHS would become a barrier to its implementation.

The primary reason that the cost of an IVHS program is expected to rise is that the early expenses from researching, developing, and testing IVHS are much lower than those for the later deployment phase. As shown in

[1] The estimated cost of $34 billion did not delineate the appropriate federal share and role but, rather, encompassed the costs to and involvement of all levels of government.

table 4.1, the costs to deploy IVHS have been estimated to be nearly seven times higher than the costs to research, develop, and test IVHS over the period 1991 through 2010. Federal funding of this magnitude may be difficult to achieve, especially during tight budget periods. Clearly, in-depth analyses will be required to justify federal expenditures before large amounts of federal dollars are spent on deployment.

Table 4.1: IVHS Program Investment Requirements[a]

Element	1991-95	1996-2000	2001-10	Total
Research and development	$627	$523	$245	$1,395
Field tests	504	1,290	1,325	3,119
Deployment	3,105	10,880	15,950	29,935
Total	**$4,236**	**$12,693**	**$17,520**	**$34,449**

[a]In millions.

Source: Mobility 2000, 1990.

Furthermore, there are concerns that in order to secure public and private financial support, some IVHS proponents are suggesting that large capacity gains—such as those available through automated freeways—are achievable within the near term. While such claims are unrealistic, this pressure could result in the rapid deployment of more-advanced IVHS technologies before they are fully tested and refined. Such an eventuality could produce adverse consequences to local IVHS systems. Unfavorable perceptions of IVHS would then arise out of these unmet expectations, thereby creating a barrier to a positive long-term funding climate for IVHS.

A key solution is to establish funding that is adequate to research, develop, and test the potential of IVHS but not so generous as to result in an over-promise of the near-term benefits. Given the severity of the various congestion-related problems, the federal government would be justified in conducting aggressive IVHS research and testing, especially given the existence of initially promising IVHS results. However, further inquiry is to be expected before sound decisions can be made regarding major deployment decisions.

An IVHS Consumer Market

Some IVHS technologies, such as in-vehicle information screens, are likely to be consumer items and will add to the purchase price of a vehicle. Public acceptance of IVHS—as exemplified by willingness to buy such devices—is therefore critical to the success of a domestic IVHS program. An uncertain consumer market could weaken the commitment of the private sector to the IVHS program, and the outright absence of a consumer market would likely cause the private sector to withdraw its commitment to the program entirely.

The private sector's interest in IVHS is to attain market share, and much of its attention has been on the IVHS in-vehicle components. If the cost of IVHS in-vehicle equipment to consumers is high, then few drivers may purchase the equipment and many may not be able to afford the technology. Such an uncertain public acceptance would leave many companies inactive in IVHS and would raise equity concerns about IVHS. Because of this, early federal government encouragement and funding of definitive operational tests and studies to define costs, benefits, beneficiaries, organizational responsibilities, and market projections may be a prerequisite for private sector commitment.

State and Local Cost Burden

To maximize IVHS benefits, systems must be deployed where the problems justify an IVHS solution. The number of locations that would benefit from IVHS is believed to be large. Funding the operations and maintenance costs of an IVHS infrastructure will have to come, at least in part, from state and local governments. Many state and local governments, however, could find it difficult to support these costs when local resources for transportation are hard to come by. Therefore, the implementation of IVHS technologies could impose a substantial cost burden on state and local governments and could be a barrier to local participation in a nationwide IVHS program.

One way to help with this would be to provide both the opportunity and the evidence to state and local governments that demonstrates IVHS to be a viable alternative to other capital expenditures. Evaluative evidence drawn from IVHS operational tests that shows the cost-effectiveness of a locally deployed IVHS, compared to other alternatives, could greatly enhance IVHS attractiveness to state and local governments. (As noted in chapters 2 and 3, limited empirical information is presently available.)

Once a system is deployed, it must be operated and maintained. If IVHS services prove to have a value that people are willing to pay for, funding for operations and maintenance should be available through local sources or through public or privately developed user fees (plus the private purchasing of in-vehicle equipment). Even if IVHS does not prove to be so supported in all locations needing the services, the cumulative benefits to the entire nation from IVHS (for example, in terms of congestion or air pollution reduced) might justify the use of federal-aid funds to finance IVHS deployment and even operations. This of course shifts the IVHS cost burden more directly onto the federal government, but such a pragmatic approach could ensure IVHS program viability if local funding constraints become widespread.

Liability

Tort liability is an issue that goes well beyond questions of IVHS technologies. For several years, liability has been an important issue in the medical profession, to manufacturers of a wide variety of products, and in all levels of government. The cost of defending against liability claims consumes substantial portions of many state and local transportation agencies' budgets. While there is growing concern about excessive litigation and awards, others argue forcefully that the existing system serves to deter negligent conduct. Resolution of these different views does not seem likely in the near future and could possibly affect an IVHS program.

Some serious liability issues may arise in the case of automated highways. It is one thing for drivers to follow each other too closely on their own; responsibility for resulting accidents falls on their shoulders. It is another thing for a public agency to encourage, or require, close following. In a multiple-car collision, whether caused by roadway equipment failure or vehicle failure, a public agency that has not adequately designed safeguards against these possibilities into the IVHS system might be sued for at least a share of the costs of the foreseeable harm. (However, it is not clear to what extent such lawsuits would be permitted against federal, state, and local governments, which may have some limited immunity from liability, particularly in the absence of evidence of negligence.)

How severe the liability problem might be is hard to estimate in either the short or long term. Concern about liability is partly a concern about costs. If the benefits of IVHS are large enough, then potential liability costs may be an acceptable risk. Conversely, the costs associated with new litigation could militate against state and local governments becoming directly involved in IVHS.

Overall, it is important to draw attention to liability in order that its potential adverse consequences become apparent. A first step might be to examine the liability experience of other countries in this area. Another might be to conduct IVHS operational test projects in a somewhat sheltered environment (to help reduce liability concerns and insurance requirements in at least the development phase). Such steps would provide useful information in identifying and evaluating the magnitude of any potential liability problems. However, these tests might not preclude the need for eventual legislative consideration of IVHS liability issues.

Institutional Barriers

The second major category of barriers to an IVHS program is institutional. From the material provided by the expert panel, we identified three institutional barriers: the capabilities of the U.S. Department of Transportation (DOT), private and public sector cooperation, and intergovernmental cooperation.

Capabilities of DOT

It is clear that a major IVHS program would be quite a technical and managerial challenge. To run it, DOT would need the ability to assess a wide range of complex electronics hardware and information processing software systems. In some cases, DOT might have to be directive in bringing promising technologies to fruition. In other cases, effective leadership would require that DOT play a more subordinate role in supporting local or private sector effects.

Traffic detection systems provide an example of where DOT technical leadership seems appropriate (in the ATMS area). The basis for much of the real-time information used in IVHS is traffic detection devices. Currently, inductive loop detectors are the most common method of abstracting this information, but they suffer from reliability problems. Alternatives, such as the use of video technology, are promising but have not yet engendered much local or private sector support. Consequently, DOT leadership in guiding resources toward the development of a reliable detection device would appear to be warranted.

An IVHS program would also require DOT to take account of industry perceptions and expertise. For example, a successful ATIS program would depend upon electronic systems located within vehicles, and the development of such systems would likely come mostly from the efforts of the car manufacturers. While DOT could not renounce its accountability and responsibility for progress, its role would be somewhat different in such situations.

Overall, DOT would have to possess the necessary technological understanding to support the IVHS efforts of those in the research and development and manufacturing sectors. The agency would also need to alternate between playing a directive role and a coordinating one. One way to enhance DOT's technological leadership of an IVHS program might be to establish an IVHS advisory group.[2] This, however, should not be in lieu of the development, within DOT, of the necessary technological capabilities to manage and formulate policy for an IVHS program.

Private and Public Sector Cooperation

Significant IVHS research is under way in both the private and public sectors, and at least one research project and several operational tests are already using a combination of private and public sector funds. The benefits in efficiency gained from sharing resources between the public and private sectors would certainly contribute to a successful IVHS program; conversely, a lack of cooperation between public and private sectors is a potentially critical barrier to an IVHS program.

While some cooperation already exists between government and industry in IVHS, it is not widespread, for at least two reasons. The first is that there could be a perceived lack of benefit to be gained from IVHS cooperation. As noted in the discussion of funding barriers, both the public and private sectors would expect benefits to accrue from IVHS participation. Because the program is in the beginning stages and the benefits and costs of IVHS are not yet well understood, there could be significant hesitancy by both sectors to participate fully.

The second is that intrasectoral competition among potential industrial participants could manifest itself through a lack of cooperation in an IVHS program. Naturally occurring competition within the private sector may require that the federal government take a lead in defining, organizing, and managing an IVHS program. Federal leadership, however, may not entirely solve this problem, as eventually private sector interests might need to share proprietary technologies in order to develop a cooperative nationwide program.

Intergovernmental Cooperation

The typical metropolitan area includes a central city and many smaller municipal governments located in its suburbs. The road system includes state roads that enter the metropolitan area and local roads owned by the central city, suburban cities, and county governments. City and county governments tend to guard their prerogatives and are not especially prone to entering into arrangements that are perceived as surrendering some of their home rule authority. For example, the INFORM operational test was years late in completion, in large part because of a

[2] DOT has initiated such an action by taking steps to authorize the advisory "IVHS America" organization.

lack of interjurisdictional cooperation. A past lack of intergovernmental cooperation has thus been shown to seriously impede the deployment of traffic technologies in situations similar to those expected in the deployment of IVHS technologies. Therefore, cooperative relationships among the levels of government will be essential for the implementation, maintenance, and operation of IVHS.

With regard to the technical requirements of effective traffic management, governmental boundaries are artificial. For ATMS to be effective, traffic lights should be coordinated across municipalities. Moreover, unless cooperative interagency relationships are established, certain features of ATIS, such as route diversion, cannot be successfully deployed. For AVCS to become a reality, metropolitan-wide cooperation in agreeing to and investing in automated highways will be essential if they are ever to be implemented.

Federal and state highway funding programs could contain provisions that encourage cooperative approaches to traffic management and discourage certain types of local actions that would impede metropolitan traffic programs. Policy and technical committees composed of all involved governmental agencies could be formed to coordinate the various tasks involved in the implementation, maintenance, and operation of IVHS. For example, in the operational test phase of IVHS, several metropolitan areas could be selected to pilot test different cooperative arrangements. Ideally, success would induce others to move in this direction, and eventually the barriers to intergovernmental cooperation might be overcome.

Technological Barriers

Finding technological solutions to transportation problems is the main purpose of an IVHS program. While numerous technological barriers are included in the limited number of reports in the literature on barriers (for example, unreliable technologies, upwardly incompatible technologies, or technologies that cause adverse environmental effects), only one technological barrier was considered by our panel to be difficult enough to overcome to be considered critical: technological standards.

In general, the identification of only one critical technological barrier is consistent with the view of the many researchers who have said that IVHS does not depend on any major technological breakthroughs. Rather, most of the program challenges lie in developing and deploying the technologies in a manner that is efficient, safe, affordable, and reliable.

Agreement on standards has been a frequent hurdle in many technological developments. There is a recognized need for standards, protocols, and recommended practices in many facets of IVHS. Communications, digitized map data standards, system architecture, and upwardly compatible technologies are examples. Without adequate standards for IVHS, vehicles with IVHS systems may not function on all roads that have an IVHS capacity. Real-time traffic information signals transmitted by a traffic operations center must be received by compatible in-vehicle receivers. An automatic merge system must smoothly engage vehicles one at a time to form platoons, which can exist only when the transmitters, receivers, and shared information are fully compatible.

Establishing standards requires balancing conflicting needs. While standards can help in developing markets by lowering production costs, standards also tend to limit innovation. Commercial pressures on the standardization process can be considerable. Vendors frequently want to have their own proprietary solutions adopted as the standard. Without an orderly process for developing such standards, however, the program may flounder as a collaborative enterprise. Individual companies would then proceed to attempt to base business development upon their own proprietary standards to the likely detriment of a national program.

Both technological compatibility and innovation are requirements of a successful IVHS program. Therefore, on top of all the other requirements for a successful program, a balance is needed between the competing needs of compatibility and innovation. Overly piecemeal approaches will likely result in inefficiencies in scope and scale, and competitive issues among the industrial participants suggest a need for initiative and leadership on the part of the federal government. What is needed is the creation of a workable organizational process for discussing, establishing, and changing decisions on standards. This process should be rationally coupled to the learning stream coming out of research, development, and field testing so that permanent standards are not prematurely set.

Summary and Conclusions

Analyzing the information collected from the expert panel, we found three categories of critical IVHS barriers: cost barriers, institutional barriers, and technological barriers. While these barriers embody key issues affecting the potential success of IVHS, each is more or less amenable to policy mechanisms.

Solutions for overcoming the four cost barriers—the magnitude of the federal share, an uncertain consumer market, a state and local cost burden, and liability—center on the justifiable provision of public and private funds. Given that federal funding to support IVHS research and development exists and is rising, there is an immediate and sustained need for the federal government to evaluate the benefits to the nation from IVHS. National policy can be thus aimed (in the short term) at explicating and demonstrating the range of IVHS effects relative to costs. Such information could then be used by the private sector, state and local governments, and indeed the federal government, in determining deployment investment levels and options for IVHS. Furthermore, attention to the potential liability issue should be a part of the early investigations into IVHS, especially as to the potential hazards to an IVHS program from liability costs.

Even if the cost barriers are at least to some degree overcome, a variety of institutional issues are still to be confronted. DOT will have to develop the necessary technological capabilities to manage and formulate IVHS policy. Also inherent to IVHS technologies is a requirement of intergovernmental cooperation. This will require that local jurisdictions give up some autonomy in order that entire metropolitan areas may gain the benefits of IVHS. Policy and technical committees composed of all involved governmental agencies could be formed to coordinate IVHS activities. If a lack of interjurisdictional cooperation hampers the program, federal and state highway funding programs could contain provisions that encourage cooperative approaches to traffic management.

Technological barriers do not appear to be the most serious barriers to IVHS. The one exception in this area pertains to the setting of standards. As with institutional barriers, resolving discrepancies related to standards will require cooperation and coordination among participants. The federal government's involvement in the IVHS program will require addressing the standards problem in an effective way. One solution would be to create a workable organizational process for discussing and recommending decisions on standards so that standards are established so as not to detract from IVHS progress.

Finally, a solution common to all these barriers is to design the IVHS program cooperatively so that all sectors have a stake in the program. If the research and testing results are favorable to the participants' interests, and the program is designed to exploit these interests, then the needed commitment should be forthcoming.

Conclusions and Recommendations

We conclude that IVHS has the potential to improve traveling conditions. However, the next several years represent an important research and testing period to further ascertain the extent to which such a potential is in fact realizable. On the basis of our review, we make several legislative recommendations aimed at ensuring that federal IVHS research efforts produce the information needed to better determine the appropriate role of these technologies in improving the nation's surface transportation infrastructure.

Conclusions

Given the pervasiveness of the various problems associated with the nation's surface transportation infrastructure, the application of technology to improve its performance is a matter warranting serious deliberation. We undertook this review to assist congressional decisionmaking relative to this issue. As noted in the introduction, our review had three questions:

- What have the major studies concluded about the potential effects of IVHS, and to what extent are these findings empirically based?
- What additional information can be learned from IVHS field tests under way?
- What major obstacles could impede the realization of transportation benefits possible through IVHS technologies?

From our research synthesis, presented in chapter 2, we conclude that IVHS technologies can contribute to the improvement of traveling conditions. While IVHS should not be viewed as a panacea for the nation's transportation problems, the empirical basis of the possible effects of IVHS, while limited, is nonetheless positive and promising. The major studies in the area have a rather high degree of consensus that these technologies can improve mobility. However, direct evidence on performance pertains mainly to the nearer-term technologies, while it is the proposed advances in the automated control area that are projected to have the greatest effect on mobility. Further, preliminary indications are that the technologies can have additional application to improving safety, alleviating the air quality problems, and contributing to energy conservation.

Our review of operational tests in chapter 3 highlights the use of these projects to produce needed empirical information on the effects of IVHS. For example, both the Pathfinder in Los Angeles and TRAVTEK in Florida represent prominent tests of the viability of traveler information systems within real-world settings. Moreover, demonstrations such as these illustrate the key role that the federal government can play in designing, funding, and evaluating operational tests that advance IVHS experience in this country.

Our research synthesis did identify several examples of positive cost-benefit outcomes. These outcomes ranged from very high ratios for initial demonstrations and improvements to more modest ratios expected for future IVHS systems. However, cost appears to be a looming concern to the viability of the entire program. Various funding barriers, from the magnitude of the federal share to the ability of local governments to absorb their share to the consumer market influence on the private sector support, can affect the ability of IVHS technologies to produce their intended benefits. The ability of various levels of government to work together, as well as with private sector interests, also represents a crucial element to the success of an IVHS program. Finally, an assortment of other obstacles including potential liability and standards issues need to be dealt with in order for IVHS to achieve its full potential.

In sum, given the growing concerns with congestion, safety, air pollution, and energy usage, the federal IVHS program represents a noteworthy step at the national policy level to investigate the possibility of technologically based solutions to these problems. Consequently, we believe that the federal government should use the next phase of surface transportation policy (1992 to 1996) as an opportunity to conduct in-depth research and testing on IVHS. Given the high deployment costs of IVHS (relative to the costs of IVHS research and testing), such a period is necessary to reduce the uncertainties of these promising technologies before committing to the quantum increases in federal funding that may be required to establish an integrated nationwide system of applied IVHS technologies.

Recommendations

We believe three issues warrant priority attention in the conduct of IVHS research and testing over the next few years. These are examining concurrent effects, conducting sound field demonstrations, and assessing optimal funding options. The recommendations provided below are aimed at incorporating these issues into legislative guidance on a federal IVHS program.

Examining Concurrent Policy Effects

Our first recommendation is for policy guidance on achieving a wide range of IVHS benefits. The thrust of IVHS research—and indeed the focus of our review—has been on the congestion-reducing aspects of these technologies. This is an understandable focus, given the emergence of IVHS from concerns about the growing congestion problems. However, our review has also noted that research suggests the potential application of IVHS in the areas of human safety and environmental quality, as well as in promoting energy conservation and economic productivity. Given that these areas represent desirable national goals, it is important to gain a firmer understanding of the extent to which IVHS can (or cannot) contribute to such concurrent improvements. For this reason, we recommend that IVHS legislation explicitly note the goals of congestion, safety, the economy, energy, and the environment and that, within this legislative guidance, the Department of Transportation be required to develop and execute research aimed at determining the role of IVHS technologies in achieving these concurrent goals.

Inherent in this recommendation is the concern that DOT examine and develop IVHS systems that maximize the congestion-reduction potential of IVHS while simultaneously achieving other policy goals. Conversely, we think it is vitally important that these technologies do not hamper gains that need to be made in areas such as safety and environmental quality. In a related vein, as part of this guidance, attention should be given to addressing how multimodal applications (such as to transit and ridesharing) and other technologies (such as more fuel-efficient or electric cars) could enhance overall IVHS effectiveness. Finally, in carrying out this guidance, DOT should be encouraged to solicit the views of other agencies as appropriate, such as the Department of Energy, the Environmental Protection Agency, and the Department of Commerce.

Conducting Sound Field Tests

Our second recommendation pertains to the major role of field tests in learning about IVHS. Our review has noted how the federal government should be active in designing operational tests that advance domestic experience with IVHS. In the face of what will invariably be increased local pressure to use proven aspects of IVHS, the need for DOT to ensure continued testing and sound evaluation of the newest developments in IVHS cannot be overstated.

To support DOT efforts in this regard, we recommend that IVHS legislation require DOT to select, design, and evaluate high-priority operational field tests in accordance with a strategic IVHS research plan. DOT should be required to establish priorities as to which IVHS issues and technologies need to be tested in the field. These priorities could then be used as criteria in determining the design, selection, funding, and evaluation of field demonstration projects. While evaluations should be required of any federally sponsored IVHS field test undertaken, legislative guidance should require DOT to take an active role in ensuring the comprehensive evaluation of high-priority demonstrations. Such action by DOT in determining the nature and contents of crucial field tests and in guiding their evaluation would ensure that needed empirical data on the effects of IVHS are obtained.

Assessing Optimal Funding Arrangements

Our third and final recommendation is aimed at addressing the cost concerns of IVHS. As our review has noted, possible IVHS cost burdens remain a central inhibiting influence on IVHS participation. Indeed, the fashioning of an IVHS program that maximizes the shared resources and management strengths of federal, local, and private sector interests could represent a key facet to the viability of the entire program. Clearly, in order to make informed funding decisions, policymakers need information concerning the relative costs and benefits of IVHS and, in particular, how these can or should be distributed and managed across the public and private sectors. For this reason, we recommend that IVHS legislation include a requirement for an analysis of optimal funding options to achieving desired IVHS benefits and that such analysis include a consideration of alternative federal, local, and private partnership arrangements.

These three recommendations are meant not to constitute an exhaustive list of issues that need to be addressed in an IVHS research and testing program but, rather, to highlight priority concerns that arise from this review. For instance, while not explicitly noted in our recommendations, our review of barriers raises related concerns about other government management limitations, potential liability problems, and lack of standards.

To conclude, the next phase of surface transportation policy represents a key phase in the future of IVHS in this country. Inherent in our recommendations is the overriding belief that the next few years should be used to gather evaluative information that will allow for, among other benefits, knowledgeable decisions about the appropriate federal investment in IVHS and how best to target it.

Description of Intelligent Vehicle and Highway Systems

Intelligent vehicle and highway systems, or IVHS, refers to a body of technologies that are applied to motorized vehicle transportation and to the transportation systems upon which they operate. Through the use of advanced computer, telecommunications, and control technology, the deployment of IVHS technologies can improve communication between drivers and traffic control centers, creating an integrated highway transportation system. Such a system could contribute to making automobile travel safer, more efficient in time, space, and energy, and more environmentally benign.

There are four major categories of IVHS technologies: advanced transportation management systems (ATMS), advanced traveler information systems (ATIS), advanced vehicle control systems (AVCS), and commercial and fleet operations. While each one is described in this appendix, the focus of our review and the body of our report is on the first three.

Advanced Traffic Management Systems

ATMS includes urban traffic control systems, incident detection systems, highway and corridor control systems, and ramp metering systems. All these technologies have been deployed in several locations in the United States. Urban traffic control systems coordinate traffic signal operations throughout a given area, based on traffic patterns as measured by detectors in the roadway. ATMS hardware consists of road sensors, traffic signals, ramp meters, changeable message signs, and communication and control devices integrated into a single system. This allows for surveillance and control of traffic in areas so equipped.

Experience with the road sensors employed in traffic control systems shows them to be susceptible to frequent failure. Infrared and machine vision systems, two newer technologies, may improve the performance and reliability of the systems. Finally, closed-circuit TV cameras have sometimes been installed to assist in traffic surveillance and incident management. They are installed at important intersections and can be panned and zoomed from the traffic operations center to provide coverage ranging from a wide view to a detailed closeup.

Advanced Traveler Information Systems

ATIS technologies are designed to provide the traveler with navigational information and routing advice based on real-time traffic data using audio or visual media contained in the vehicle. The use of this information will allow travelers to be more efficient in the use of the highway network through better route and mode choice. ATIS also provides information to public and commercial interests for fleet management and for public access by radio, TV, and computer.

Numerous technologies are aimed at providing drivers with improved information. Some of these are external to the vehicle, although the trend is toward in-vehicle information presentation, including

- traffic information broadcasting systems. These provide drivers with information on traffic conditions, enabling drivers to replan their routes.
- safety warning systems. Located on-board, these provide warnings of ice, inclement weather, and obstructions.
- on-board navigation systems. These are a more advanced means of providing information to drivers. The information is provided on video display terminals in the car or dashboard signals and can be used for route planning and on-route navigation. A highway navigation system is a means of orienting drivers and providing information that permits them to get to their destinations.
- electronic route guidance systems. These reduce the processing requirements for motorists by providing directions, instructions, or specific steps to be taken at each choice point in a trip. More sophisticated systems, electronic route guidance systems provide real-time information of traffic and other conditions on the network and the location of the traffic problems, allowing drivers to change routes and avoid the area with the problem.
- multimodal systems. These provide real-time road information to car pools and vans, which enable them to move more expeditiously from points of pick-up to the ultimate destination. Beyond this, ATIS can provide prospective car pool and transit riders with reliable information on pick-up and discharge points, even while in midtrip.

Automatic Vehicle Control Systems

AVCS technologies would be deployed to help drivers perform certain vehicle control functions and could actually perform some of these functions independent of a driver. Under most circumstances, the driver would not even be aware of the operation of the automated system. The most advanced AVCS technologies would allow driving tasks to be taken over completely on dedicated highway facilities located on heavily traveled intercity highways and in selected urban areas. These would allow more cars to travel on highways at faster speeds. Of all the systems, the automatic highway system has the greatest potential for decreasing congestion by increasing throughput and improving trip predictability; it could also provide significant safety, energy, and environmental benefits.

At least two technologies now available are considered within the AVCS group: antilock braking and speed control systems. The next generation of development beyond these consists of radar braking and variable speed control. Roughly concurrent to these advances are several new technologies designed to warn the driver of dangerous situations, including

- automatic vehicle monitoring systems, or crash avoidance systems that provide drivers with an early warning of potentially dangerous vehicle, road, or environmental conditions;
- proximity warning systems, which are aimed at preventing sideswipe and backup accidents resulting from blind spot problems;
- driver warning systems, which arouse inattentive drivers;
- collision warning devices, which address rear-end accidents in which the trailing driver misjudges the speed of the preceding vehicle.

The development of automatic headway and steering might be expected to follow on the heels of the other AVCS technologies, with the fully automatic road being the fullest expression of these technologies. These are not, however, expected to be deployed earlier than 40 years from now.

Electric Vehicles

Electric vehicles are not explicitly included as an IVHS technology. In practice, however, highway electrification has been linked to AVCS research on automatic control. Areas supporting AVCS—specifically, California—see the need to develop IVHS technologies that will effectively address air pollution as well as congestion. And, more generally, electric vehicles can be considered one of the potential pieces of an overall strategy to increase mobility while simultaneously reducing pollution. Although electric vehicles do not offer improvements in mobility vis-a-vis vehicles powered by internal combustion engines, they can help decrease harmful emissions, which, in some parts of the country, must accompany any technological deployment that adds more vehicles to roads.

In its most advanced stage, electric technology comprises a power conditioner and distribution, an electrified roadway, and battery powered cars that also have some sort of mechanism to dip into the road and draw current. Electric cars, of course, are viable without the powered roadway, but their range is dramatically increased when coupled with it.

Commercial Vehicle Operations

Technologies assisting commercial vehicle operations are aimed at improving the efficiency of operating a particular fleet of vehicles, including freight operations, bus transportation, and taxis. Some of these systems have already been deployed. Fleet management systems can provide a central controller with information on the location of all its vehicles and permit communication with them. These technologies include the following:

- automatic vehicle identification. The most commonly used are vehicle-based transponders (radio- or microwave-based), which can be read by equipment at fixed points along a route. These include optical and infrared systems, inductive loop systems, and surface acoustic wave systems. An important feature of these systems is that the vehicle need not slow down for data transfer to take place.
- weight in motion and automatic vehicle classification. These systems weigh heavy vehicles as they are moving. They use road-mounted sensors that determine vehicle weight by taking into account axle weights, vehicle length, and vehicle speed; they can also classify vehicles and determine their compliance with weight standards.
- automatic vehicle location. Their primary application is for commercial fleet operations, but police, public transit, and emergency vehicles could also benefit. These technologies typically identify vehicle location and transmit it to a central location for monitoring or dispatch purposes. The technologies used to locate vehicles are usually based on dead reckoning, map matching, proximity to roadside beacons, or radio determination. Mobile communications equipment relays this information to a central location.

Concurrent IVHS Effects

In this appendix, we describe concurrent IVHS effects summarized in chapter 2. These concurrent effects include IVHS results reported relative to the economy, safety, fuel efficiency, and the environment.

Economic Effects

Research suggests that positive economic benefits could accrue from U.S. involvement in IVHS technology development and deployment. Most of the 23 quantitative economic estimates provided in our review pertained to the costs versus the benefits of various technologies when implemented. As shown in table II.1 on page 58, 4 of the studies we reviewed involved evaluative assessments of the costs and benefits of operational tests. Three studies used analytical techniques to estimate such ratios, and 2 others cited positive results reported in other studies.

In general, these assessments showed positive cost-benefit ratios, though the ratios varied widely, depending on what was included and what was excluded. The field studies showed ratios of 10:1 or less if construction costs were included, with major variations possibly stemming from the exclusion of these costs. For example, in the ATSAC project, construction costs were included, with a resulting ratio of 9.8:1. Conversely, in the National Signal Timing Optimization Project, no construction (or operations and maintenance) costs were included in the calculation, resulting in a much higher, 63:1 cost-benefit ratio. (In fact, when estimates on construction costs were included, the 63:1 cost-benefit ratio was estimated to be much lower—that is, 4.2:1.) Both studies calculated benefits to include travel time saved, fuel saved, and vehicle savings from fewer stops.

Operational tests as well as the other studies also suggest that the cost-benefit ratio can become more modest once initial system inefficiencies are corrected. For example, the report of the National Signal Timing Optimization Project (an operational test) notes that lower cost-benefit ratios of between 10:1 and 20:1 could be expected once initial signal inefficiencies are resolved. Other studies also continue this trend, estimating future ATMS (as well as AVCS) cost-benefit ratios of generally less than 8:1. For example, an IVHS benefits report produced by Mobility 2000 estimated an overall IVHS cost-benefit ratio of between 1.3:1 and 3.2:1, depending on the size of the city.

A recent in-depth analysis of IVHS cost-benefits is provided in a 1989 report conducted for National Cooperative Highway Research Program (see Assessment of Advanced Technologies for Relieving Urban Traffic

Congestion in table II.1). This study reviewed a wide range of IVHS technologies and then performed a detailed cost-benefit analysis for three specific technologies. Using data from the Seattle metropolitan area, this study estimated the costs and benefits of an externally linked route guidance system and a radio-based traffic message system (both ATIS). Using data from 14 North American networks, the costs and benefits of an adaptive traffic control system (ATMS) were also calculated.

Analysis of these IVHS systems involved a variety of computer models using several different scenarios, as well as the calculation of overall costs and benefits. With regard to the externally linked route guidance system (that is, an in-vehicle navigation system that provides real-time route directions), the study found that the benefits would slightly exceed the capital costs after the first year, resulting in savings thereafter. For example, assuming a 14-percent market penetration, the total costs for such a system in Seattle were estimated to be $106 million, with annual operating costs of $1.7 million. Benefits accruing from the system were estimated to be $133 million annually.

Again using Seattle statistics, the model estimated that large net savings would accrue from a radio-data-system (that is, a system that provides ongoing digitized traffic information through conventional FM broadcast frequencies). With this technology, the main costs would be borne by the users, with extremely large returns offered on the public investment. For example, assuming a 10-percent market penetration in Seattle, $27.5 million of the estimated $27.8 million in capital costs would be borne by the user. Annual congestion-reduction benefits under this scenario are estimated to be $21.8 million.

Finally, using data on traffic signal networks in 14 different U.S. cities, the model estimated the costs and benefits of three sample traffic control networks. In one traffic control scenario, total capital costs were estimated at $4 million, with annual benefits estimated to be about $1.3 million. Such direct benefits of more efficient control indicate a significant return on the immediate costs of traffic control system conversion.

Safety Effects

Eleven studies quantified the effects of IVHS technologies on transportation safety. Because these advanced technologies bring new levels of information and control to the operation of motor vehicles, many experts believe that they will greatly improve traffic safety on both our

Table II.1: Reported IVHS Benefits and Costs

Name of study	Study date	IVHS tested	Method used
Automated Traffic Surveillance and control (ATSAC)	1987	ATMS	Field test
Chicago Area Expressway Surveillance and Control Project	1979	ATMS	Field test
Fuel-Efficient Traffic Signal Management	1986	ATMS	Field test
IVHS Benefits Mobility 2000	1990	ATMS, ATIS, AVCS	Analytical
National Signal Timing Optimization Project	1982	ATMS	Field test
Quantification of Urban Freeway Congestion & Analysis of Remedial Measures	1986	ATMS	Analytical
Working Paper No. 7: Advancements in Vehicle and Traffic Control Technology	1988	ATIS	Citation
Working Paper No. 10: Urban and Suburban Highway Congestion	1987	ATMS	Citation
Assessment of Advanced Technologies for Relieving Urban Traffic Congestion	1989	ATIS	Analytical
		ATIS	
		ATMS	

Benefit	Amount	Cost	Amount	Ratio
Annual Reduction in stops Savings in fuel Reduction in travel time Total Average per intersection	 $4,411,500 1,337,000 2,091,000 $7,839,500 66,400	Annualized Construction & engineering Operation & maintenance Total Average per intersection	 $654,200 148,400 $802,600 6,800	 9.8:1 (per intersection)
Not available		Not available		4:1 (ramp metering)
User (3-year total) Savings in fuel Reduced delays Reduced stops Savings in travel time Total 3-year total	 $24,100,000 1,450,000 29,100,000 22,550,000 $77,200,000 $231,600,000	Program costs (3-year total) Number of participants Number of signals retimed Average cost per signal Total grants to cities Cost of training, technical assistance, and evaluation 3-year total	 81 3,172 $980 $3,109,000 $864,000 $3,973,000	 58:1 (program costs only); 3.5:1 (with construction costs)[a]
Not available		Not available		1.3-3.2:1 (depending on size of city)
Annual (per intersection)	$28,695	Total average (per intersection)	$456	63:1 (program costs only); 4.2:1 (with construction costs)[a]
Total annual	$2,951,000,000	Total annual	$699,000,000	4.2:1
Not available				7.3:1
Not available		Not available		4:1 (freeway surveillance & control systems); 10:1 (incident management)
Net annual	$75.6-$206.8 ($M)[a]	Total capital	$71.2-$140.1 ($M)[b]	5.3-7.4:1[c]
Net annual	$21.8-$26.2 ($M)[b]	Total capital	$27.8-$73.5 ($M)[d]	3.9-1.8:1[c]
Net annual	$1.3 ($M)[d]	Total capital	$4.1 ($M)[e]	1.6:1[c]

[a]Reported cost-benefit ratios based on program costs only. To illustrate the reduction in ratio when construction costs are included, the reported benefits were recalculated based on the annualized costs (per intersection) reported for the ATSAC evaluation.

[b]Annual benefits versus total costs for the example implementation of an externally linked route guidance (ATIS) system in the Seattle metropolitan area.

[c]Benefit-cost ratios calculated over a 5-year period with capital and installation costs being borne in the first year. Annual benefits are net—that is, they include annual operating costs.

[d]Annual benefits versus total capital and operating costs for three market penetration scenarios for a radio traffic information (ATIS) system in the Seattle area. The main cost element of such a system is borne by the individual system users. The public cost to the system operating agencies is very low.

[e]Annual benefits versus total program costs for adaptive traffic control (ATMS) systems for one of three sample networks.

urban highways and rural roads, where currently 57 percent of fatalities occur. However, among the 11 studies that addressed safety quantitatively, only 1 involved field testing, while 3 were based on analytical projections and 9 on expert opinion and citations of overseas research.

The 1 field-based examination of safety was a 1979 report on ATMS implementation in the Chicago area. (See table 2.1.) The evaluation determined that the freeway surveillance and control system reduced accidents by 18 percent in the peak period.

Several projections based on analysis and expert opinion have been conducted in Europe on the potential safety effects of advanced traveler information systems. Indeed, one of the primary incentives of the current program under way in Europe is the need for road safety improvements. The hypothesis is that improper trip planning, poor direction finding, and other errors associated with manual navigation may result in slow driving, erratic maneuvers, delays, and lost or confused drivers. British researchers have made preliminary analytical projections on the number of accidents that an ATIS system might reduce in England, for example. Based on the assumption that improved routing information provided to the users of an ATIS system will reduce travel distance by 4 percent, they calculate that corollary accident reductions of 400 per year could result. Similarly, French researchers have estimated that navigational aid systems might have prevented 3 percent of the 350 accidents involved in their case study review.

Our research synthesis reveals that, while little is known about the eventual effects of more advanced AVCS technologies on safety, researchers anticipate these systems will provide great improvements to transportation safety. Only 2 reports quantified potential safety benefits resulting from these technologies, and these were based on expert opinion only. These studies noted that AVCS entails control-assist systems—such as obstacle detection and collision warning and avoidance—which could assist drivers in avoiding serious accidents. AVCS technologies may also provide additional time to expand the driver's margins for safety in high-risk environments.

One of our 38 studies attempted to estimate the domestic safety effects of IVHS overall. The estimates contained in this study are based on various assumptions that have yet to be fully verified. Based on collision types and the various advanced technologies that might prove effective in preventing such collisions, projections were first made of the rate of penetration or adoption expected for these technologies. The resulting savings in human and economic terms were then calculated for a given time period. The study reports two estimates. One calculated that by the year 2010, IVHS technologies—if aggressively implemented—could save 11,500 lives, prevent 442,000 injuries, and provide safety-related savings of $22 billion. For the second estimate, the study assumed a technology deployment delay of 5 years and a 50-percent reduction in technological effectiveness in accident prevention. Under these assumptions, the safety benefits were reduced to a calculated savings of 2,200 lives, prevention of 84,000 injuries, and dollar savings of $4.2 billion by the year 2010.

As with congestion, notes of caution have been raised regarding the potentially negative effects of IVHS on safety. According to one researcher, considerable investigation of human factors will be needed to ensure the safety of advanced traveler information systems. Little is known about people's reactions to their potential distractions. Safety concerns are also a challenge in further design and development of advanced vehicle control systems. Many of these technologies transfer vehicular control from the driver to a computer, and possible failure of such a system creates a design burden to achieve maximum safety. Indeed, given the overriding policy concern for the safety of travelers, these issues confirm the need to amply demonstrate the safety of all IVHS technologies as they are researched and developed.

Fuel Efficiency Effects

Eight reports we reviewed indicated that ATMS and ATIS technologies hold promise for moderate fuel savings related to congestion reduction—that is, in-vehicle delays, stops, travel times, and travel distance. Fuel efficiency improvements were indeed a primary motivation for upgrading traffic control strategies in two projects whose reports we reviewed, both of which provided the only direct testing of effects in this area. Fuel consumption reductions of 8.6 percent and 12.5 percent were achieved through implementation of ATMS technologies in these two different California studies. (See the FETSIM and ATSAC projects in table 2.1.)

While most reports that addressed fuel consumption benefits did so in relation to smoother traffic flow and reduced travel times and distances, one report considered the contribution that highway electrification or electrically powered vehicles might have on fuel consumption. This study calculated that in an automated highway system, an electric-powered vehicle would consume less than half the energy that a nonelectrified (internal combustion engine) vehicle would consume. The analysis, however, did not consider electrical energy generation requirements to power these vehicles.

Environmental Effects

Four reports provided quantitative information on the environmental effects of IVHS, and this information focused on possible improvements in air quality. One of these was a field-based examination of ATMS (the ATSAC evaluation in table 2.1). This study provided an estimate of the extent to which ATMS, by reducing congestion, also reduces nitrogen oxide, hydrocarbon, and carbon monoxide emissions. For example, the ATSAC evaluation estimated a 10-percent decrease in both hydrocarbon and carbon monoxide emissions. Two other studies—one based an analytical projection and the other on secondary citation—noted similar efficiency effects possible from ATMS and ATIS (for example, an 8-percent to 15-percent reduction in emissions).

More dramatic gains were estimated in the one analytical projection of the potential of electric vehicles. Calculations made at the University of California suggest that electric vehicles could reduce hydrocarbon and carbon monoxide emissions by over 99 percent by 2010 and would reduce nitrogen oxide emissions by over 80 percent. These results were unique to California, because in this state strict controls on power plant emissions limit the amount of additional pollution that would be generated by power plants as they produced electricity for car use. A slightly smaller reduction in overall pollution was projected for other areas of the country, where power plant controls are weaker.

IVHS Operational Tests

In this appendix, we describe the nine IVHS operational tests that we visited and summarized in chapter 3.

PATH (Berkeley, California)

The California Program on Advanced Technology for the Highway (PATH) was initiated in 1986 by the State Department of Transportation and the Institute of Transportation Studies of the University of California at Berkeley. PATH expands on an earlier effort by the state on highway electrification technology. The program encompasses 27 smaller projects that focus on developing electrification, automation, and navigation technologies to progressively higher levels to enhance highway performance and improve highway safety.

The PATH projects include studies of economic and social effect and institutional issues, including the feasibility studies and regional impact studies required for operational tests in an urban setting. Eight of the 27 projects address traffic management and traveler information, 9 address automatic vehicle control, 3 address clean propulsion, 2 address effects and application studies, and 5 are cross-cutting studies.

The main goals of PATH are to (1) investigate the applicability of advanced (IVHS) technology to improve the productivity, safety, environmental, and economic effects of road transportation, (2) to help improve California's international industrial competitiveness, and (3) to report their work to the Congress in 1992.

Pathfinder (Los Angeles, California)

The Pathfinder operational test is designed to perform an initial assessment of the feasibility and utility of a real-time in-vehicle highway navigation and motorist information system. The test project will use 25 vehicles equipped with in-vehicle guidance systems. These systems will convey real-time traffic information, such as traffic congestion, time-of-day restrictions, and information on both recurring and nonrecurring incidents, through the use of small in-vehicle video monitors.

Information on travel time throughout the test network as a result of feedback from the 25 vehicles will be transmitted to a traffic operations center. A radio communications system will be used to communicate this information between the center and the vehicles and also to update the in-vehicle video map display.

This operational test is a cooperative effort among several parties, including FHWA, the California Department of Transportation, and General Motors. FHWA will be directly responsible for the study up through the pilot tests; the department will be responsible for the operation, tests, evaluation, and documentation of the study; and General Motors will furnish the 25 vehicles and human factors analysis.

The Pathfinder project is being incorporated into a larger local effort under way in Los Angeles. Approximately $48 million is being devoted to developing a comprehensive "smart corridor" demonstration project, which will encompass both ATMS and ATIS elements.

TRANSCOM (Northern New Jersey and Metropolitan New York)

FHWA, the New Jersey and New York departments of transportation, TRANSCOM and its member agencies, local authorities, the private sector, and the trucking industry are working cooperatively to manage the congestion problem in northeastern New Jersey and the metropolitan New York areas. The Congress has provided funding to TRANSCOM, through New York and New Jersey (since TRANSCOM has no contracting authority). FHWA has been directed by the Congress to ensure that the results and successful strategies are widely disseminated.

Several technologies will be developed for use by TRANSCOM, including a highway advisory radio, a remote video surveillance, and a computer networking system. An automatic vehicle identification system operational test will be performed by the Port Authority of New York and New Jersey and the Triborough Bridge and Tunnel Authority. Vehicles used during the test will be using Amtech battery powered, radio frequency transponders. Readers for these transponders will be located at selected toll booths in order to test their effectiveness for automatic toll collection. The project will use 1,000 commercial trucks, 500 New York City Transit Authority buses, and approximately 300 fleet vehicles from certain member agencies.

Eventually, TRANSCOM proposes to expand an automatic vehicle identification system in order to assess the system's capability in performing traffic monitoring activities for collecting real-time information in the corridor between New Jersey and Staten Island. This expanded system will permit TRANSCOM and its member agencies to use the vehicles equipped with transponders as probes on the highway network. Information from the probes would be transmitted to TRANSCOM's operations information center, which would then be used to determine real-time traffic information such as speeds, travel times, and the occurrence of nonrecurring incidents (that is, accidents and vehicle breakdowns). This information will be communicated to motorists through variable message signs and highway advisory radio systems as well as through radio traffic services so they can be informed about coming conditions and about alternative routes, if possible.

TRAVTEK (Orlando, Florida)

TRAVTEK (Travel Technology) is a 3-year operational test project in Orlando, Florida, involving FHWA, the American Automobile Association, the City of Orlando, the Florida Department of Transportation, and General Motors. TRAVTEK will demonstrate the same capabilities of "smart car" and "smart highway" technology that could be available in urban communities throughout the country in the future.

TRAVTEK will provide the combination of a freeway management system, computerized traffic signal control, vehicle routing and location capability, traffic advisories, travel services, and two-way communications, which will aid motorists traveling through the metropolitan Orlando area. This will be done through the use of in-vehicle equipment, including a video screen, a microcomputer, and a radio for data communications. It is intended that the video monitor will display maps of the Orlando area that will depict areas of traffic congestion, incidents, and services information. Drivers will be able to input their destination, and the TRAVTEK processor will use real-time traffic information and premeasured travel times to determine the best routes.

Besides the vehicles, the TRAVTEK system includes two other elements: a travel information and services center and a traffic management center. The former will provide travel-related information to motorists. The latter will obtain information from various sources and provide combined data through digital data broadcasts to 100 test vehicles and to the various sources, including the travel information and services center. Twenty-five of the test vehicles will be used by high-mileage local drivers; 75 vehicles will be leased to AVIS for use in the Orlando area.

INFORM (Long Island, New York)

INFORM (Information for Motorists) is a computerized traffic management and information system operated by the Long Island Region of the New York State Department of Transportation, in cooperation with DOT's New York City Region. This project stretches along a 35-mile corridor and is the only system in the United States incorporating freeway surveillance control techniques for three freeways and adjacent arterials. INFORM gathers information about the volume, speed, and flow of traffic along the corridor. Vehicle movements are monitored over one of the 2,200 INFORM electronic sensors implanted in the roadways. Signals are sent to the Long Island Traffic Information Center's three computers for processing, where personnel monitor average speeds and the number of vehicles entering and exiting the road. With the aid of 74 changeable message signs and commercial radio broadcasts of traffic conditions, motorists are advised of the traffic situation and are assisted in selecting the least-congested routes for a safer trip. To complete the system, traffic signals at 112 key intersections and metering signals at 64 freeway entrance ramps are automatically controlled in response to current traffic patterns.

A highlight of the system is INFORM's 25-foot electronic panel, which displays a map of the system, with lights indicating the position of the electronic sensors. The coordinator can instruct the system to watch for a threshold speed. If the sensors detect an average speed below that threshold, the light on the map corresponding to that sensor will light up, graphically indicating a possible problem.

Incident Management Projects

Incident Management and Integrated Systems (Minneapolis-St. Paul, Minnesota)

The incident management and integrated systems program in Minnesota identified three projects for operational test and evaluation purposes: Metro Area Highway Advisory Radio, Heavy Truck Incident Management, and City of Minneapolis Access to Minnesota Department of Transportation Real-Time Information. The first two received FHWA funding.[1]

The Metro Area Highway Advisory Radio project provides information to motorists so they can assess current driving conditions and take alternative routes when major incidents occur. Broadcasts are aired over the public radio station, KBEM 88.5 FM, operated by the Minneapolis Public School System. The Heavy Truck Incident Management project was

[1]Subsequent to these two projects, Minnesota's Guidestar program received a major demonstration grant in the FHWA 1991 Appropriations to test various IVHS technologies.

designed to develop procedures on how to respond to heavy truck incidents and to provide training courses to State Patrol and Minnesota Department of Transportation personnel.

Incident Management and Integrated Systems (Seattle, Washington)

The incident management project will develop procedures for establishing and implementing an incident management system. Specifically, the project will develop a resource document that will guide other agencies wanting to develop such a system. It will also analyze the effectiveness of and costs for various development plans and determine the appropriate conditions for implementing them.

The integrated system project will demonstrate the integrated control of freeway management and arterial traffic signal systems in the I-5 corridor near Seattle's northern city limits. Specifically, the project will design and implement an integrated control system for I-5 that automatically modifies arterial timings in response to freeway conditions. It will also investigate ways to modify ramp metering based on arterial conditions and to evaluate the system to determine the success of or applicability to additional corridors and the nation.[2]

Urban Congestion Alleviation Project (Washington, D.C.)

The Beltway Demonstration project is an operational test of state-of-the-art traffic surveillance and control systems on sections of the Washington, D.C., beltway. The project involves two components that combine existing traffic operational techniques with new technology for real-time incident detection, reporting, and response.

The first component provides a look at integrating traffic advisory radio and variable message sign technologies. Both technologies would provide accurate and timely information relative to freeway congestion and traffic diversion. Information to motorists includes traffic incidents, construction and maintenance work, adverse weather conditions, and special events. The goal of this project is to provide information on the integration of the technologies and on their use for identifying problems on the beltway.

The second component will test the capabilities of the video imaging detection system for the purpose of real-time traffic flow monitoring and data collection. The system uses closed-circuit television cameras

[2]The Washington projects are part of larger local program called freeway and arterial management effort, or FAME.

for visual monitoring of highway congestion. The technology has the potential for automatic incident detection using special algorithms and for measuring traffic flow parameters by lane, including traffic volume, vehicle speed, and vehicle classification. The purpose of this project is to evaluate the system's performance and reliability in detecting traffic flow and freeway incidents.

Anaheim Integrated System Project (Anaheim, California)

The City of Anaheim's Traffic Management System is a multifaceted approach to addressing urban congestion in the City of Anaheim and Orange County. The system is a combination of a computerized traffic signal system, highway advisory radio, closed-circuit television, and changeable message signs. The system runs off a minicomputer connected to 115 intersections. The entire city will eventually be connected to 250 intersections. FHWA operational test funds are being used to conduct a multistaged evaluation of the Traffic Management System. The University of California at Irvine is responsible for designing and executing the study.

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