IVHS AND ENVIRONMENTAL IMPACTS:
IMPLICATIONS OF THE OPERATIONAL TESTS

Cheryl Little and Jean Wooster

John A. Volpe National Transportation Systems Center
Research and Special Programs Administration
U.S. Department of Transportation

55 Broadway, Kendall Square
Cambridge, Massachusetts 02142
(617) 4943215

National Policy Conference on
Intelligent Transportation Systems and the Environment

Arlington, Virginia
June 6-7, 1994

ABSTRACT

In recent years, public and private sponsors of Intelligent Vehicle Highway Systems (IVHS) have recognized the need to assess the impacts of IVHS user services on air quality and energy use. This interest has been reinforced by the mandates of the Clean Air Act Amendments of 1990, the Intermodal Surface Transportation and Efficiency Act of 199 1, as well as the desire to strengthen benefit-cost and air quality analyses.

The IVHS operational tests play a key role in the transition between research and development of new technologies and wide-scale deployment of IVHS user services. To date, the evaluation plans for most of the field tests have focused on important concerns of technical feasibility and user response. However, there remains significant, untapped potential for leveraging these tests to evaluate environmental impacts. In particular, empirical data gathered from field tests would greatly complement the use of models to assess the air quality and energy implications of wide-scale deployment.

Presently, the Volpe National Transportation Systems Center is investigating the evaluation goals and methods of the major domestic and international operational tests to gauge the state-of-the-practice for appraising environmental impacts. To date, the Volpe Center has identified approximately forty field tests with environmental evaluation objectives. Nearly all of these tests have employed or will use dissimilar methods to address the complex interactions between travel behavior, traffic operations, and the many confounding, exogenous variables that govern vehicular emissions and fuel consumption. As a step toward creating an archetype for federal operational tests in the U.S., the Volpe Center is developing a guidebook that will recommend best practices for assessing energy and emissions impacts of IVHS user services.

INTRODUCTION

An essential objective of the Department of Transportation’s Intelligent Vehicle Highway Systems (IVHS) program is to identify, evaluate, and measure the private and societal impacts of IVHS user services. The operational tests are important means for accomplishing this end. Additionally, the Clean Air Act Amendments of 1990 (CAAA) compel better understanding and assessment of IVHS’ environmental implications.

National governments in the United States, Europe, Japan, and Australia have sponsored over four hundred IVHS field tests, which are in various stages of development.’ In the United States, the Department of Transportation (DOT) has supported seventy-six tests in partnership with various organizations, including State and local governments, private companies, and academia.*

The Purpose of IVHS Operational Tests

Operational tests are implementations of IVHS user services in “real-world” field environments. As stated in the DOT’s IVHS Strategic Plan. Report to Congress, the criteria for selecting operational tests manifest the dual needs for demonstrating the technical feasibility of new technologies and services, and evaluating their public and private impacts.[3] The criteria include:

> “[O]verall contribution to the IVHS program knowledge base, the uniqueness of the proposed test...the degree of risk associated with the technologies involved, the suitability of the proposed site to support overall IVHS program test objectives, and ability of the existing infrastructure to support the test program...A major Federal responsibility in all operational tests is to ensure that impacts such as safety, mobility enhancements, and congestion relief are thoroughly evaluated.[4]

In the United States, the Intermodal Surface Transportation and Efficiency Act of 1991 (ISTEA) provides the regulatory support for the national IVHS operational test program. Although the DOT funded several major operational tests before its passage, ISTEA outlines the conceptual approach and procedures for their implementation.[5]

The DOT currently has authority to allocate approximately $15 million per year to support IVHS operational tests, with a potential increase to $30 million if Congress approves President Clinton's 1995 budget.[6] In addition, ISTEA mandates field testing in four corridors located in severe ozone nonattainment areas. These test beds, designated as "priority corridors," include the Northeast Corridor (stretching along I-95 from Washington, D.C. to Connecticut), the Midwest Corridor (centered around Chicago and extending through Milwaukee), the Houston Texas metropolitan area, and the Southern California Area Corridor (centered along I-5 from Los Angeles to San Diego).[7] For these priority corridors, ISTEA provides $86 million per year from fiscal year 1993 through 1997 to establish an "IVHS infrastructure that will support continued deployment of IVHS technologies and services."[8]

More specifically, ISTEA requires that the operational tests have written evaluation plans and charges the Secretary of Transportation with establishing guidelines and requirements.[9] To support these requirements, the Federal Highway Administration (FHWA) developed generic IVHS operational test evaluation guidelines that prescribe the necessary components and contents of formal evaluation procedures. These guidelines provide a standardized structure for operational test evaluation plans, but stop short of delineating precise methodologies for measuring impacts.”

Most recently, FHWA charged the Volpe Center with producing two guidebooks that will recommend best practices for conducting market research and for evaluating the emissions and fuel use impacts of IVHS in field test settings. FHWA is also in the process of obtaining additional staffing and expertise to "assist in the development of evaluation plans and provide technical assistance in monitoring the evaluation for IVHS operational tests nationwide.“” These efforts underscore the DOT's commitment to leverage the operational tests for improved understanding of IVHS' implications. The DOT affirms its intentions in its report to Congress:

> "The primary source for direct measurement of the impacts and benefits of IVHS user services will be the evaluations of operational tests. Evaluation requirements will affect the design of these projects, as will the need to develop and incorporate data collection systems for capture of necessary information regarding travel behavior and other impacts such as energy and environmental effects."[12]

The operational tests, therefore, are not only test beds for resolving the technical feasibility of IVHS user services, but important proving grounds for appraising their societal and private implications.

The Impetus for Environmental Evaluation

In the United States, a number of federal regulations, including the CAAA, ISTEA, and the National Energy Policy Act of 1991 (NEPA) stress the transportation sector's obligations to support environmental and energy security objectives.

In particular, the CAAA established national ambient air quality standards for ozone, carbon monoxide, nitrogen dioxide, particulate matter, lead, and sulfur oxides to safeguard human health and welfare. The U.S. Environmental Protection Agency (EPA) classifies cities and regions as "nonattainment areas" when the measured concentrations of these pollutants exceed their designated standards. To ensure that air quality objectives are met, the CAAA requires nonattainment areas to develop State Implementation Plans (SIPs), which inventory emission sources and identify control measures to ensure progressive attainment of the air quality standards.

Motor vehicles are significant contributors to the production of ozone (by emitting hydrocarbons (HC) and nitrogen oxides (NO,), which photochemically react to produce ozone), carbon monoxide (CO), and particulate matter. Although the CAAA mandates cleaner fuels and cleaner cars (through improved inspection and maintenance and more stringent emissions controls), these steps alone will not sufficiently alleviate the transportation sector's obligation to reduce its emissions. As a result, nonattainment areas will turn to transportation control measures, including IVHS user services, to meet air quality objectives. Although the CAAA emphasizes transportation control measures as proactive solutions, it also insists that transportation plans conform to the intent and objectives of the SIPs and not aggravate the frequency and severity of air quality violations. As a result, transportation planners must prove that their proposed projects will, at a minimum, "do no harm." For some environmental advocates, even the implementation of environmentally neutral projects may not be satisfactory.

Purpose and Scope

Given the DOT's objectives and the regulatory context, this paper examines the implications of the operational tests for assessing the environmental impacts of IVHS user services. The paper focuses on nationally sponsored field tests, but acknowledges, when possible, the efforts of local governments and the private sector. The contents include a discussion of the following:

- The fundamental elements and relationships that must be considered by operational tests in order to evaluate the emissions and fuel consumption impacts of IVHS user services.

- The scope of IVHS field tests with environmental evaluation objectives in the United States, Europe, Japan, and Australia.

- The state-of-the-practice for appraising the environmental impacts of IVHS user services in field settings, including the use of experimental design, data collection, and analytical methods.

- Results on IVHS' environmental impacts available from completed field tests.

- The Volpe Center's efforts to develop a guidebook for conducting environmental evaluations within IVHS operational tests.

CONSIDERATIONS FOR ENVIRONMENTAL EVALUATIONS

The evaluation of emissions and energy impacts of IVHS technologies and services presents special challenges for operational tests. Not only are the processes that govern vehicular emissions and fuel consumption varied and complex, but IVHS user services can have multiple direct and indirect impacts on many parameters that affect these processes. In particular, operational tests cannot assess environmental impacts without first considering IVHS' impacts on travel behavior and traffic conditions in the context of site-specific conditions (fleet mix, temperature, etc.).

Emissions are a function of many factors that will likely not be affected by IVHS user services, including temperature, altitude, fuel type, road geometry, as well as vehicle class, maintenance and load. Air quality impacts are even more difficult to assess since they can result from reactions of pollutants from potentially varied and multiple sources, and are influenced by topography and meteorological conditions. Fuel economy is also a function of many parameters that will likely not be impacted by IVHS, including vehicle class and road geometry.

IVHS user services, however, can influence emissions and fuel consumption impacts by altering baseline levels of transportation supply and demand. In particular, emissions and fuel consumption are sensitive to changes in traffic flow pattern (e.g., the pattern and magnitude of cruise, acceleration, deceleration, and idle), the number of vehicle trips, vehicle miles traveled (VMT), and mode shifts (e.g., from cars to buses).

Traffic management user services, such as dynamic signal coordination, ramp metering and incident management, can directly alter traffic flow patterns. Traveler information user services, although they do not change transportation operations directly, increase travelers' knowledge of transportation options. In response to supply changes and new knowledge, individuals will make decisions regarding travel activity (e.g., trip-making, departure time, route, mode). The aggregate effect of individual responses could affect system-level supply or demand characteristics. Most of the operational tests as currently scaled, however, will likely not be large enough to measurably affect aggregate traffic operations or travel demand.

For environmental impact analysis, it is particularly important to distinguish the prospective impacts of pre-trip planning and en-route information. En-route information, provided by changeable message signs and on-board route guidance systems, can potentially affect route choice, which could indirectly impact VMT and travel speeds for individual motorists. Pre-trip information can potentially affect the full range of travel activity choices, most importantly trip-making and mode preference. In addition, the U.S. DOT and others are developing and supporting new user services that inform motorists of non-transportation related characteristics, such as their vehicles' emissions, in the hopes of more directly achieving environmental objectives.13

Because environmental impact assessment can follow only after IVHS' direct and indirect impacts on travel activity and traffic operations are appropriately appraised, this paper gauges the state-of-the-practice by addressing whether and how operational tests answer the following questions:

- How will the demonstrated IVHS user service(s) affect traveler behavior, particularly trip-making, departure time, mode choice, route choice, or other decisions that could impact environmental measures?

- What changes will the IVHS user service(s) produce on traffic operations, particularly VMT, speeds, and driving characteristics?

- How will changes in travel activity and traffic operations directly and indirectly impact emissions and fuel consumption, in the context of site-specific conditions?

To evaluate IVHS environmental impacts, operational tests must design discrete, but integrated, strategies that can measure changes in travel behavior, traffic operations, emissions, and fuel consumption. More specifically, the operational tests must develop resourceful experimental designs that delineate appropriate data collection and analytical techniques.14

THE SCOPE OF FIELD TESTS WITH ENVIRONMENTAL OBJECTIVES

To date, we have identified approximately forty field tests in the United States, Europe, Japan, and Australia, with environmental evaluation objectives. Tables 1 through 9 summarize the demonstrated IVHS user services, status, major goals, experimental designs, data collection, and analytical methods for each of these field tests. About a dozen of these tests have completed their analyses and published results. Because our investigations are still in progress, this paper's findings are preliminary and do not reflect a definitive accounting of tests planning to assess environmental impacts.

The Volpe Center obtained its information from draft and final evaluation plans, documents prepared by and for DOT and IVHS America, as well as the general body of IVHS literature. Whenever possible, the Volpe Center supplemented the written literature with telephone and in-person interviews with key participants of the operational tests.

The United States

We identified fifteen field tests in the United States with plans to evaluate the emissions and/or fuel consumption impacts of their IVHS user services. All but two of these tests are federally supported. The evaluation goals and objectives are summarized in Tables 1 through 4.

In the United States, operational tests develop autonomous evaluation plans, which address particular site-specific system designs and particular interests of the test partners.

For the most part, the operational tests demonstrate IVHS user services, where environmental concerns are secondary to other objectives, such as congestion reduction. The range of IVHS user services include dynamic signal coordination, ramp metering, pre-trip planning services for transit users and private motorists, and en-route information via dynamic route guidance and changeable message signs.

The DOT and the IVHS community have been especially cognizant of the need to demonstrate IVHS user services that can be proactively deployed to satisfy air quality objectives. In 1994, the DOT identified three new operational tests, which will implement travel demand and traffic management strategies in response to real-time pollution monitoring.[15] In addition, two Southern California counties plan to demonstrate a real-time data collection system designed to facilitate transportation and air quality planning. Although these field tests may show that certain technologies are environmentally beneficial, they will not obviate the need to evaluate the environmental impacts of more conventional traffic management, traveler information, and public transit user services, which metropolitan areas may wish to adopt to mitigate congestion or influence travel demand.

The range of field tests with environmental objectives is summarized below by IVHS user service:

- **Traffic Management Systems**

The Volpe Center identified three tests, ATSAC, FAST-TRAC and Smart Corridor,[16] which demonstrate dynamic signal coordination and its impacts on arterial traffic flow. Smart Corridor is also field testing dynamic ramp metering. ATSAC, a non-federally funded project that concluded in 1987, has the only published evaluation of the environmental impacts of dynamic signal coordination in the United States.” The study indicated that the ATSAC system reduced vehicular emissions and fuel consumption in the control area.

Traveler Information Systems

The Volpe Center identified seven operational tests, which demonstrate the feasibility of traveler information systems. Three of these tests, ADVANCE, TravTek, and FAST-TRAC, will provide en-route information to motorists equipped with dynamic route guidance systems while two other tests, Guidestar Genesis and SmarTraveler, provide pre-trip and en-route information through personal communication devices and telephone, respectively. Smart Corridor also considers the diversion impacts of changeable message signs. Of these tests, only SmarTraveler has completed an environmental evaluation, which indicated favorable air quality impacts. TravTek's evaluation will be completed within the next few months.

Environmental Management Systems

As mentioned previously, the U.S. DOT identified three projects that will demonstrate IVHS user services with primary environmental objectives. In addition, Southern California counties plan to implement a real-time data collection system to support transportation and air quality planning.

The first test ("Evaluating Environmental Impacts of IVHS using LIDAR") will control traffic around a sports arena in Blaine, Minnesota in response to area-wide particulate emissions monitoring using Light Detection and Ranging (LIDAR) technology and infrared remote sensing of roadside emissions. Air quality data will be correlated to traffic volume data, superimposed over a Geographic Information System (GIS) base map of the project area, and provided to the Minnesota DOT's portable traffic management system (PTMS), which will optimize traffic flow to minimize local pollution.

The objectives of the second test ("IVHS for Voluntary Emissions Reductions") are to identify super-emitting vehicles through infrared remote sensing and inform drivers of their vehicles' emissions output via a variable message sign. The field test may also include a highway advisory radio message at the site, a telephone information hotline, and educational materials at local service stations that would provide additional information on the environmental benefits of keeping vehicles well-tuned.

The third federal test (“Travel Demand Management Emissions Detection”) also uses infrared remote sensing to determine the relative contributions of in-county and out-of-county vehicles to mobile source emissions within Ada County, Idaho. The information will be provided to motorists, recommending voluntary or potentially subsidized vehicle repair for high-emitters.

PLANMODE (Planning and Modeling Data Environment) is a non-federally funded project that will collect real-time data from three components: AutoProbe, which uses GPS-equipped vehicles to collect trip-related data (e.g., speeds, VMT), AutoCensus, which collects traffic census data through a network of call boxes, and DriveCLEAN, which consists of call boxes and mobile source emissions sensors that measure point source air quality. The PLANMODE system will eventually link the collected data to a GIS system. The information would be provided to transportation and air quality planners.[18]

Public Transit System

The general evaluation guidelines for advanced public transportation systems identify air quality and energy measures of effectiveness, including perceptions of riders regarding transit use and air quality as well as impacts on CO, NOx, and fuel use.[19] To date, we identified one public transit system user service, Guidestar Travlink, which may qualitatively estimate emissions and fuel consumption impacts as a function of changes in trips and mode. Travlink will provide real-time transit and traffic information through videotex terminals, electronic signs, smart kiosks, and transit station displays.

Commercial Vehicle Operations

The Volpe Center identified one commercial vehicle operational test, ADVANTAGE I-75, which plans to evaluate the emissions and fuel consumption impacts of weigh-in-motion technologies. ADVANTAGE I-75 expects to improve the efficiency of commercial vehicle operations by allowing 4,500 transponder-equipped trucks to travel at freeway speeds with minimal stopping at roughly 30 weigh and inspections stations. The test is considering measuring emissions and fuel consumption through empirical methods that have not yet been identified.

In addition, Latshaw and Nutly have documented eight case studies of the effectiveness of scheduling and route optimization of commercial vehicles in the private sector. The study indicates that, in general, scheduling and route optimization systems reduced trips, VMT, and stops as well as vehicular emissions.[20]

Europe

The European focus has been on the development and evaluation of diverse IVHS technologies and services.[21] The two largest IVHS European programs are PROMETHEUS (Program for European Traffic with Highest Efficiency and Unprecedented Safety) and DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe). Additional European IVHS programs include POLIS and CORRIDOR, which support urban field tests, and CARMINAT, DEMETER, ERTIS, and EUROPOLIS.[22]

PROMETHEUS was initiated in 1987 by a consortium of European automobile manufacturers and later supported by national governments and research agencies. The program, which will conclude in 1994, originally allocated $770 million for 1986 through 1993.[23] PROMETHEUS' goals are to advance real-time information and vehicle control systems that can improve traffic flow and safety.

In parallel, the DRIVE program, which is coordinated by the European Community, focuses on developing a pan-European infrastructure. DRIVE's goal are to improve transportation efficiency and safety by implementing an Integrated Road Transport Environment (IRTE), which will provide real-time information on traffic conditions. The original 71 DRIVE projects were conducted from 1980 to late 1991. A second series of nearly 70 projects, DRIVE II, focus on field operational tests, which address both technical feasibility and benefit evaluation. From 1988 through 1994, the combined DRIVE I and DRIVE II budget totaled roughly $460 million, half of this provided by the public sector.[24]

Europe has been particularly aggressive in developing field test programs to assess environmental impacts. These programs not only evaluate impacts of conventional IVHS user services, but seek to demonstrate unique systems that can be proactively employed to meet environmental objectives. The Volpe Center identified sixteen field tests with environmental evaluation objectives, which are summarized in Tables 5 through 7.

PREDICT, funded by DRIVE I, was one of the first European field tests with an environmental focus. The other field tests are supported by four programs, QUARTET, SCOPE, THERMIE, and KITE. These programs provide resources to ensure that consistent, comprehensive, and credible methods are used to assess environmental impacts of IVHS technologies and services.

PREDICT

PREDICT (Pollution Reduction by Information and Control Techniques) assessed the emissions and air quality impacts of environmental traffic management systems, including environmental optimization of traffic signals, pollution-sensitive rerouting, and environmental area licensing.25 The project, which was based in Athens, Greece, developed a modeling suite to predict the pollution impacts of various traffic management and control strategies. In addition, PREDICT evaluated ambient air quality monitoring systems and developed plans for several European cities.

QUARTET

QUARTET (Quadrilateral Advanced Research on Telematics for Environment and Transport) supports field tests in four cities, who each take the lead in implementing one or two specific IVHS elements, called modules.26 The participating cities and their modules are Athens, Greece (environmental module), Birmingham, U.K. (public transportation systems module), Stuttgart, Germany (route guidance and the emergency call systems modules), and Torino, Italy (IVHS architecture and the management and coordination modules). Each of the cities considers integration of its IVHS module with other modules and collaborate on tasks of common interest.

APOLLON, located in Athens, is QUARTET's environmental module and is a follow-up to PREDICT. The field test evaluates the effectiveness of deploying real-time traffic control strategies in response to expected high pollution episodes. APOLLON, which is expected to begin testing in mid-l 994, consists of environmental monitoring, continuous monitoring of traffic flows, traffic rerouting, shdrt-term meteorological forecasts, restrictions on high emitting vehicles, and air quality models to estimate expected traffic pollution 1evels.27

SCOPE

SCOPE (Southampton, Cologne, and PiraEus), which is funded by DRIVE II; encompasses three projects: ROMANSE (Southampton, England), VICTORIA (Cologne, Germany), and PORTS (Piraeus, Greece).[28] Two of these projects, ROMANSE and VICTORIA, plan to evaluate both vehicular emissions and air quality impacts. ROMANSE consists of variable message signs, dynamic traffic guidance, high occupancy vehicle priority lanes, environmental traffic control, and various public transportation systems. The project emphasizes the use of a multi-modal information system, which will collect, evaluate, and disseminate real-time and forecast data on traffic conditions and transit schedules. VICTORIA also integrates traveler information and traffic management user services.

THERMIE

The goal of THERMIE, which began in 1990, is to promote improved energy efficiency using existing and new technologies.[29] THERMIE has allocated nearly $20 million to support transportation projects, including two IVHS programs, JUPITER (Joint Urban Project In Transport Energy Reduction) and ENTRANCE (ENergy savings in TRANsport through innovation in the Cities of Europe).[30]

JUPITER is a three-year project designed to field test public transportation technologies and services that "save energy and improve the urban environment."[31] The field tests will demonstrate passenger information services, public vehicle priority lanes, traffic restrictions, and new public transit vehicles, some of which will use alternative fuels. Tests are planned for Aalborg, Denmark;. Bilbao, Spain; Florence, Italy; Ghent, Belgium; Liverpool, U.K. and Patras, Greece.

ENTRANCE, a three-year project with a budget of nearly $12 million, promotes public transportation systems as well as some dynamic route guidance in seven "core" cities: Southampton and Portsmouth, U.K.; Cologne, Germany; Piraeus, Greece; Evora, Portugal; Rotterdam, the Netherlands; and Santiago, Spain. In addition, ENTRANCE shares knowledge gained from these field tests with three 'dissemination' cities: Caen, France; Cork, Ireland; and Dresden, Germany. These cities develop plans for deploying the technologies tested in the seven core cities.[32] One of the primary goals of the

ENTRANCE program is to shift single occupancy vehicle travel to public transportation systems by promoting park-and-ride, passenger information, and overall public transit efficiency. In addition, the program is evaluating the use of alternative fuels, such as compressed natural gas (CNG), for public transit buses.

KITE

The members of QUARTET and SCOPE received funding from DRIVE II to create KITE (Kernel project on Impacts of Transport telematics on the Environment), which aims to develop a standard "modeling suite" for assessing the environmental impacts of IVHS user services. KITE, which is led by Cologne, Germany, consists of twenty partners and has a budget of a little over $550 thousand.[33] KITE will use its modeling standard to perform a number of case studies on the environmental impacts of IVHS user services in several European cities, including the three SCOPE cities and four QUARTET cities. RITE convened an expert panel in late 1993 and is in the process of assessing current models and analytical techniques.

Japan

Japan's IVHS program has emphasized the development and deployment of advanced traffic management systems for arterial streets and in-vehicle navigation systems.[34]

Japan had 74 advanced traffic management centers and 87 sub-centers in operation by 1988-l 990. During this same period, Nissan and Mazda marketed automobiles equipped with navigation systems. The Tokyo Metropolitan Police Department also established a pilot Advanced Traffic Information Supply Service (ATISS).[35]

The Volpe Center identified two field tests of dynamic signal coordination, both with published results on emissions and fuel consumption impacts: the Comprehensive Automobile Traffic Control System, which was completed in Tokyo in 1979,[36] and a field evaluation conducted by the National Police Agency in 1993.[37] Both field tests, whose evaluation plans are summarized in Table 8, indicated positive environmental benefits of dynamic traffic control over fixed-time signalization.

Australia

Australia developed the adaptive traffic control system, SCATS (Sydney Coordinated Adaptive Traffic System), which is installed in more than thirty cities world-wide. During the 1980s, several Australian organizations evaluated SCATS relative to no traffic control and simple fixed-time signal control systems in Sydney and Melbourne Australia; Conventry, U.K.; and Glasgow, Scotland. Table 9 outlines the evaluation proposals and results. The studies indicate that SCATS reduced travel times, number of stops, and total fuel consumption relative to no traffic control and conventional fixed-time control systems.38

STATE-OF-THE-PRACTICE FOR ENVIRONMENTAL EVALUATION

This section assesses the state-of-the-practice for conducting environmental evaluations in operational tests. Because our investigations are still ongoing, the content is more descriptive than evaluative. In addition, we do not attempt to describe the evaluation strategies of every test shown in the attached tables, but instead present a cross-section of methods to show the breadth and diversity of approaches.

In general, we found that the operational tests are employing diverse techniques to evaluate travel behavior, traffic operations, emissions, and fuel consumption. For the most part, these strategies weigh heavily toward assessment of user response and travel behavior. In particular, several of the U.S. operational tests investigated so far have not yet identified the analytical methods to calculate emissions and fuel consumption impacts.

Most of the tests favor models over strictly empirical methods to assess emissions and fuel use impacts, particularly since the relatively small scale of most of the tests prohibit measurement of system-wide impacts?’ In addition, changes in emissions and air quality resulting from the implementation of IVHS user services will be difficult to measure directly because of confounding influences of stationary sources and fleet variability. State-of-the-art models, however, are not sufficiently developed to estimate the environmental impacts of traffic and travel demand projects. In addition, conventional travel demand and traffic simulation models cannot adequately estimate real-time impacts on traffic operations and consider differences in travelers' knowledge of transportation operations and travel choices.

Because both empirical methods and models have inherent biases, a few operational tests plan to use multiple methods to obtain ranges of results. For example, INFORM used three different methods to collect data on traffic operations for its statistical evaluation of ramp metering and signal coordination[40,41] while TravTek designed ten different evaluation methods for assessing the effectiveness of its dynamic route guidance vehicles.[42]

The analytical methods for estimating IVHS impacts on travel behavior, traffic operations, emissions, and fuel consumption are discussed below:

Travel Behavior

For the most part, operational tests demonstrating traffic control strategies, such as dynamic signalization and ramp metering, do not address travel behavior while the evaluation plans of traveler information user services emphasize travel behavior impacts.

With one exception, the operational tests investigated so far do not plan to use models to evaluate travel activity impacts, but instead will rely on a variety of surveying techniques. In addition, based on the written evaluation plans, the tests do not appear to consider potential latent demand resulting from improved mobility. One of the exceptions, TravTek, plans to perform parametric analyses by varying market penetration and travel demand variables provided to a traffic simulation model, INTEGRATION.

Empirical Analysis

For the most part, operational tests will use surveys, interviews, panels, and other empirical methods to obtain a wide range of information on travel behavior, including trip origin-destination, departure times, routes taken, and mode preferences. However, for the most part, the tests plan to structure these methods to assess user response and not explicitly to estimate emissions and fuel consumption impacts. For example, SmarTraveler, in its assessment of response to real-time traffic information, asked users if they changed route, mode, or departure time as a block of choices rather than discrete choices. The survey also qualitatively assessed the amplitude of travel behavior changes (e.g., “frequently”, “occasionally”, “never”). As a result, SmartRoute System’s later environmental evaluation inferred specific travel activity changes from the survey’s more aggregate information, which introduced additional uncertainty in the results.

Some tests, most notably FAST-TRAC, SmarTraveler and TravTek, plan to develop baseline measures of origin-destination travel demand. FAST-TRAC is pursuing baseline data through the Southeastern Michigan Council of Governments, the local metropolitan planning organization, while SmartRoute Systems obtained baseline travel demand data from Boston’s Central Transportation Planning staff in order to evaluate emissions impacts. TravTek developed origin-destination demand using a model, QUEENSOD, which infers origin-destination from actual traffic flow counts.

Models

With the exception of the ROMANSE project in Southampton, England, the use of regional planning (travel demand) models to assess travel activity impacts is notably absent. Travel demand models predict travel activity as a function of socioeconomic characteristics, land use patterns, and the transportation infrastructure. The models typically use a four step process of trip generation, trip distribution, mode split, and route assignment to characterize travel activity. Two projects, PREDICT and APOLLON, use a route assignment model, PDIAL, to evaluate environmental rerouting strategies.

ROMANSE, a demonstration of public transit systems, will use a travel demand model, EMME2, which is described as a “strategic model, capable of representing modes such as bus and rail, as well as the private car."[43] ROMANSE uses EMME2 to quantify the impacts of park-and-ride and priority bus measures on person and traffic movements. The evaluators will calibrate the model using stated preference surveys and other observed data. The Transportation Research Group at the University of Southampton, a test partner, is also developing a car park occupancy prediction model to evaluate parking strategies.

Traffic Operations

Nearly all of the operational tests plan to collect field data and conduct some combination of empirical analysis and modeling to ascertain impacts on traffic operations.

Empirical Analysis

Operational tests are employing various methods to measure travel times, speeds, VMT, stops, and other traffic characteristics, including the use of 'floating' cars, instrumented vehicles, loop detectors, video surveillance systems, and automated data via control centers. The data are being used to perform both statistical analyses of impacts and to calibrate traffic simulation models. In particular, INFORM and Smart Corridor have developed detailed plans to evaluate impacts on traffic operations using multivariate analyses of data collected before, during, and after the implementation of signal coordination, ramp metering, and changeable message signs.

In contrast to direct measurements, SmarTraveler inferred impacts on traffic operations based on expected changes in travel behavior and mean travel times, distance, and speeds obtained from the local transportation planning agency. Guidestar Travlink, which plans to evaluate the impact of real-time public transit information, indicated that it may survey users to determine changes in trip lengths and VMT.

Models

The field tests plan to employ a variety of traffic simulation models, which are described below:

- TRANSYT (ATSAC, PREDICT, APOLLON): TRANSYT is a well-known macroscopic traffic model, which simulates traffic flows through arterial networks and can be used to optimize signal timing plans. The model provides information on delays, average speed, number of stops, and queue lengths at links and intersections.44

- INTEGRATION (TravTek, FAST-TRAC): INTEGRATION was developed to analyze the operation and optimization of integrated freeway/arterial traffic management, dynamic traffic control, and route guidance systems. TravTek used the model to evaluate the potential system-wide impacts of dynamic route guidance vehicles. The evaluators calibrated the model using actual traffic counts. FAST-TRAC recently used INTEGRATION to determine the number of probe vehicles required to effectively support ALI-SCOUT's (a dynamic traffic control system) vehicle-to-center communications capabilities.45

- TRAF-NETSIM, THOREAU: FAST-TRAC's original evaluation plan considered INTEGRATION, TRAF-NETSIM or THOREAU to simulate areawide traffic operations impacts. The latter two models are microscopic models, which simulate each vehicle's distinct speed-time profile. FHWA developed TRAF-NETSIM while the IVHS System Architecture teams are using THOREAU, developed by MITRE, to design and evaluate their user services.

- RGCONTRAM (ROMANSE, Southampton, U.K.): RGCONTRAM is a microscopic model, enhanced by the Transportation Research Group at the University of Southampton. The model can simulate vehicles equipped with route guidance systems and distinguish between drivers who respond to information and those who ignore information or don't have access to it. The model can also produce incidents and estimate impacts of diversion strategies on traffic parameters.

- VISUM (VICTORIA, Cologne, Germany): At the time of writing, the Volpe Center did not have enough information to describe this model's capabilities.

Emissions/Air Quality

Most of the operational tests, with the exception of a few European projects, plan to evaluate IVHS' impacts on vehicular emissions rather than air quality. In addition, the majority of tests lean toward model-based analytical tools rather than empirical methods to assess emissions impacts. The state-of-the-practice for empirical procedures and models is highlighted below:

Empirical methods

- Infrared remote sensing (Environmental traffic control systems described in Table 2, ADVANTAGE I-75): The University of Denver developed infrared remote sensing devices, which can measure concentrations of CO and HC in tailpipe vehicle exhaust. Typically, the device directs an infrared beam across a single lane of roadway to distinguish an individual vehicle's exhaust emissions. Remote sensing has been used in a number of cities to determine the percentage of high emitting vehicles and their disproportionately high contribution to mobile source emissions.

- LIDAR (First entry in Table 2): LIDAR is a laser based system that can be used to locate pollution sources and track the movements of plumes within a range of roughly ten kilometers. The systems are relatively new to transportation applications, although LIDAR has been used to track aerosol plumes in traffic environments in Albuquerque, Barcelona, and Mexico City.[46]

- Unspecified pollution monitoring (PREDICT, APOLLON): The PREDICT project, which demonstrated environmental management strategies in Athens, evaluated various pollution monitoring systems that could be used to ensure compliance with air quality standards, validate model predictions, and evaluate the effectiveness of traffic control and travel demand strategies.[47] PREDICT also developed pollution monitoring plans for several European cities.

Models

- MOBILE (ATSAC, SmarTraveler): EPA developed MOBILE to prepare mobile source emissions inventories for the State Implementation Plans. MOBILE provides emissions factors (grams per mile) for a vehicle fleet for any calendar year between 1960 and 2020. The model can evaluate impacts due to changes in number of trips and average speed as well as changes in a wide variety of external factors, such as temperature, altitude, fuels, inspection/maintenance programs, and emissions tailpipe standards. MOBILE is based on fixed driving cycles, most prominently the Federal Test Procedure. As a result, the model cannot predict the impacts on emissions caused by changes in traffic flow.

- INTEGRATION (TravTek): For the TravTek evaluation, Michel Van Aerde developed emissions factors that could be coupled with the output of his INTEGRATION traffic simulation model. The model predicts CO, HC, and NO, emissions as a function of fuel consumption and is calibrated to a vehicle fleet using MOBILE5a. The model also incorporates procedures to account for changes in ambient temperature and cold starts. Van Aerde did not directly measure emissions to develop the model.[48]

- PREMIT (PREDICT, APOLLGN): PREMIT is a European modal emissions model that estimates CO, HC, and NO, emissions as a function of cruise, acceleration, deceleration, and idling for different vehicle classes. The model is integrated with a route assignment model (PDIAL), a traffic simulation model (TRANSYT), as well as an air dispersion model. APOLLON plans to adapt the model to estimate carbon dioxide emissions.

- Unspecified developmental model (Smart Corridor): Smart Corridor plans to use an as yet undeveloped model that will predict emissions as a function of average speed, travel time, number of stops, total stopped time, and VMT.

- Ford Corporate Vehicle Simulation Programme (ROMANSE, Southampton; VICTORIA, Cologne): The CVSP model, developed by Ford (U.K.), predicts modal emissions factors for new, well-tuned, gasoline passenger cars. The model appears to predict emissions as a function of cruise, deceleration, acceleration, and idle based on detailed vehicle engine maps that relate tailpipe emissions to engine load. The emissions model is integrated with a traffic queuing model (RGCONTRAM or VISUM) and an air dispersion model (UROPOL).

- UROPOL (SCOPE, Cologne and Southampton): UROPOL is an air quality dispersion model used by the European SCOPE field tests. The model does not consider secondary reactions, but instead tracks plumes of pollutants based on meteorology and topology. Two other European projects, PREDICT and APOLLON, plan to use air dispersion models (which are unidentified) in their analyses.

Fuel Consumption

Strategies for evaluating fuel consumption impacts are less defined than for other impacts.

Empirical Analysis

- Fuel logs (ADVANTAGE I-75): ADVANTAGE I-75 plans to assess energy impacts by comparing fuel use between trucks with and without weigh-in-motion transponders. The test may accomplish this by having drivers keep fuel logs, although the results may be confounded by differences in driving behavior. The evaluators may also compare the truck average fuel economy to that of trucks with weigh-in-motion systems.

Models

- TRANSYT-7F (ATSAC): TRANSYT-7F predicts fuel consumption as a function of cruise speed, delay time, and number of stops. The latest version of the model calculates fuel factors for a 1983 average fleet mix.

- INTEGRATION (TravTek): Michel Van Aerde calculated fuel consumption as a function of constant speed, idle, and velocity changes for use with the INTEGRATION model. The evaluators obtained actual fuel consumption data from a TravTek vehicle, a 1992 Oldsmobile Toronados, and planned to extrapolate results to a vehicle fleet using EPA's Highway and City fuel economy ratings.

- Unspecified developmental model (Smart Corridor): Smart Corridor's evaluation plan states that it will use an as yet undeveloped model that will predict fuel consumption as a function of average speed, travel time, number of stops, total stopped time, and VMT.

- Unspecified developmental model (APOLLON): APOLLON plans to adapt the PREMIT emissions model to estimate fuel consumption as a function of cruise, deceleration, acceleration, and idle.

ENVIRONMENTAL IMPACTS: RESULTS FROM FIELD TESTS

The Volpe Center identified a dozen field studies of IVHS user services, which have published their conclusions of environmental impacts. In general, the studies favorably view the potential benefits of IVHS technologies and strategies. The majority of studies evaluate well-known traffic technologies, particularly signal optimization. A description of the tests, evaluation methods, and results are summarized below by IVHS user service:

Dynamic signal control

The Volpe Center found nine studies that evaluate the environmental impacts of dynamic signal control. All of the studies show favorable impacts over conventional fixed-time traffic systems.

Automated Traffic Surveillance and Control Evaluation Study

Description: The Los Angeles Department of Transportation evaluated the Automated Traffic Surveillance and Control System (ATSAC) in 1987, three years after it was installed in the Coliseum area in June 1984. The ATSAC system included 118 signalized intersections and 396 detectors encompassing a four square mile area.[49]

The purpose of the ATSAC system was to reduce congestion, travel times, energy use, and air pollution during the 1984 Olympic Games. The system incorporated 64 separate signal timing plans and optimized traffic flow with computer controlled signals by selecting the timing plan that best matched real-time surveillance data.

Evaluation: Because of resource constraints, the ATSAC evaluation limited its scope to a northwestern quadrant of 28 signals and 80 system detectors. The evaluators extrapolated results to the entire area under ATSAC control because “a large sample size was used and travel in the network [was] fairly consistent and uniform.“[50] The ATSAC evaluators did not collect data before the ATSAC system went into effect. Instead, the experiment simulated “before” conditions by temporarily implementing the timing plan that was used prior to ATSAC’s implementation.[51]

The evaluators of ATSAC employed three distinct and independent procedures to measure traffic operation performance. The first involved a travel time study, where several drivers traveled over prescribed routes and measured both travel times and number of stops. In the second method, the evaluators equipped a vehicle with an automated data collection device, which measured stops, travel times, and average speed. The third method obtained data directly from the ATSAC system. The ATSAC evaluators collected data during morning and evening peak periods during typical weekdays and daylight hours. In addition, the evaluators were careful not to collect data during bad weather days. The evaluators used the field data to calibrate a signal optimization model, TRANSYT-7F, which estimated system-wide impacts on traffic operations and fuel consumption.

Conclusions: The study concludes that ATSAC reduced HC, CO, and fuel consumption by 10.2, 10.3, and 12.5 percent, respectively.52 The evaluators calculated emissions impacts using factors obtained from EPA's MOBILE1 . Fuel consumption results were obtained from TRANSYT-7F. In general, the emissions and fuel estimation procedures are appropriate, given the date of the study. However, the MOBILE model is not sensitive to traffic flow changes, but instead predicts emissions as a function of average speed for a fixed driving cycle. In addition, MOBILE's absolute emissions factors have increased significantly since the time of the study.

Australian Field Evaluations

Description: More than thirty cities world-wide have installed the Sydney Coordinated Adaptive Traffic System (SCATS) and similar systems. During the 1980s, several Australian organizations evaluated SCATS in a number of cities. The Volpe Center obtained information on seven of these studies, which were performed in Sydney and Melbourne, Australia; Coventry, U.K., and Glasgow, Scotland.

Evaluation: The evaluators compared SCATS performance relative to no area traffic control and conventional fixed-time signal systems. At the time of writing, we had not obtained information on the experimental design, data collection process, and analytical methods employed for these studies.

Conclusions: The studies indicate that, on average, SCATS reduced travel times by 20 percent, number of stops by 93 percent, and aggregate fuel consumption by 14 percent compared to no area traffic control. Relative to fixed-time traffic control systems, SCATS reduced travel times by 4 to 8 percent, number of stops by 9 to 25 percent, and total fuel consumption by 6 percent relative to fixed-time signal control systems.[53]

National Police Agency

Description: The National Police Agency is one of two agencies that have primary responsibility for implementing traffic safety systems in several Japanese cities. In 1993, the National Police Agency evaluated a traffic signal management system, which controlled timing for 80 streets. The system's goals were to improve traffic flows and "environmental quality."[54]

Evaluation : The evaluation compared dynamic signal coordination with conventional fixed-time signal control systems at three different levels: regional area control, street control, and isolated intersection control. To accomplish this, the evaluators collected field data before and after installing the dynamic control system, including traffic volumes (for 60 streets), travel time, queuing time, number of stops, and average travel speed.

Conclusions: The Volpe Center had access only to a summary of results for total area control. The study showed the following improvements: travel times (16 percent), queuing times (16 to 3 1 percent), number of stops (37 to 40 percent), and travel speed (20 percent). The evaluators estimated total annual fuel savings per intersection of 28 thousand liters. Fuel consumption impacts were calculated based on a linear relationship between fuel savings and average travel time. The study does not elaborate on the development of this algorithm or provide supporting references.

Traveler Information Services

SmarTraveler

Description: SmarTraveler, located in the Boston Area, provides commuters with real-time, location-specific traffic and transit information by telephone. The test has been operational since January 1993. The project. encompasses 1,400 square miles, reaching

122 cities and towns around Boston in eastern Massachusetts. SmarTraveler's goals are to demonstrate public acceptance of real-time traveler and transit information, reduce congestion, increase mobility, and improve environmental quality.

Evaluation: SmartRoute Systems, the operator of SmarTraveler, commissioned a study of projected emissions impacts of the service in 1999. The study used a six step approach: (1) projected the use of SmarTraveler in 1999, (2) determined what percent of users will make changes in their trips, (3) determined how those trips will change, (4) determined the frequency of incidents that cause delay, (5) for a given changed trip, calculated the effects on VMT and speed, and (6) calculated resulting impacts on emissions."

SmarTraveler had previously surveyed users to ascertain response to the service. The survey revealed that 96 percent of users changed the time, route, or mode of their travel at least occasionally, while 30 percent of the users changed the time, route or mode of their travel frequently. Because the survey was not designed for emissions evaluation, it did not disaggregate mode, route, or travel time changes. As a result, the evaluators inferred that 50 percent of users changed route, 45 percent changed time of travel, and 5 percent changed mode of travel based on a study of a similar traveler information service in Seattle.[56] The study used 1990 statewide census data to determine the VMT and average speed characteristics of morning commutes by single occupancy vehicles to the Boston Central Business District. The study obtained data on accidents, breakdowns, and roadway construction from the SmarTraveler system. The study calculated absolute impacts of the SmarTraveler project in 1999 on total volatile organic compounds (VOC), CO, and NO, by predicting impacts on VMT and speed resulting from expected changes in travel behavior and avoided delay.

Conclusions: The study estimates that SmarTraveler could reduce summertime CO, VOCs, and NO, in 1999 by an average of 5032,498, and 25 kilograms (kg) per day, respectively. The range of calculated emission reductions in 1999 were estimated at 2,726 to 7,338 kg/day for CO, 270 to 726 kg/day for VOC, and 14 to 36 kg/day for NO,. Emissions impacts were calculated using EPA's MOBILE5a emissions model.[57]

Vehicle Route Guidance

Comprehensive Automobile Traffic Control System

Description: The Comprehensive Automobile Traffic Control System (CACS) was completed in Tokyo in 1979 at the conclusion of a large scale field experiment of in-vehicle dynamic route guidance, which was conducted from 1977 to 1979.[58]

Evaluation: The experiment was conducted in a 30 square-kilometer area in southwest Tokyo, which included 103 intersections. Route guidance information was provided to 300 vehicles, which had two-way communication capability. The literature does not elaborate on the specific experimental design, data collection, and modeling methods.

Conclusions: The feasibility study on the guidance systems concludes that CACS reduced CO, HC, and NO, emissions by 6.5, 6.2, and 0.4 percent, respectively. The evaluators also estimated 3 to 7 percent improvements in fuel economy. The literature states that emissions estimates were calculated using simulation models, but does not name or describe the models while fuel savings were calculated using "the relationship between gasoline consumption and vehicle speed", which again is unspecified. The study provides very limited information about data, assumptions, and methodologies for estimating emissions and fuel impacts.

Environmental Management Systems

PREDICT

Description: PREDICT was a field demonstration of environmental optimization of traffic signal timings, pollution-sensitive traffic rerouting, "clean" cars, and environmental area licensing in Athens, Greece. The goal of the project was to improve air quality while optimizing traffic flow.

Evaluation: PREDICT used a four-element "model suite" consisting of a traffic assignment model (PDIAL), a traffic model (TRANSYT), an emissions model (PREMIT), and an air dispersion model (unnamed) to evaluate air quality impacts. The

PREDICT suite modeled traffic activity at the microscopic level and accounted for changes in traffic flow patterns as well as fleet composition. In addition, the project developed an additional module that predicts the human health effects of different ambient air pollution concentrations. PREDICT also evaluated the appropriate use of air pollution monitoring in traffic control operations.

Conclusions: The evaluators concluded that the demonstrated technologies could reduce vehicular emissions by 4 to 50 percent. The Volpe Center has not yet obtained information to differentiate impacts of each user service.

Routing and Scheduling Optimization Systems

Case Studies of Commercial Operations

Description: Latshaw and Nulty performed eight case studies of routing and scheduling optimization used in diverse commercial operations, including newspaper delivery, warehouses, dairy distribution, mail delivery, farm product shipment, consolidation of a utility cooperative, beverage products distribution, and grocery delivery.[59]

Evaluation: The case studies evaluated the affect of routing and scheduling optimization on trips, VMT, travel times, number of stops, and resulting impacts on emissions. The study concluded that optimization technologies reduced VMT by 5 to ***20*** percent, although for one warehouse consolidation case study, VMT increased as did emissions.

Conclusions: The study extrapolated case study results to the national level to conclude that the techniques could “reduce the National mobile source oxides of nitrogen emissions by 250 to 1000 tons/day along with reduction in other types of pollutants.“[60] At the time of writing, the Volpe Center did not have access to information describing the techniques used to obtain either traffic data or emissions estimates.

CONCLUSIONS

Implications of Operational Tests

The field tests with published results indicate favorable environmental impacts of IVHS user services. Most of these tests address more conventional traffic management user services, particularly dynamic signal coordination. However, tests demonstrating traveler information and, especially, public transportation user services are not well represented.

The evaluation plans for most of the field tests investigated to date focus on technical feasibility and, to a lesser extent, user response. Because most of the tests have multiple objectives. environmental evaluations are subject to the optimization of other evaluation strategies. In addition, in the United States, a number of the tests are struggling to identify appropriate data collection and analytical techniques to estimate emissions and fuel consumption impacts. Those operational tests that are evaluating environmental impacts have employed or will use dissimilar methods, which will make it difficult to compare IVHS user services. However, given the infancy of the national IVHS operational test program, a standard may naturally evolve as more field tests, such as TravTek, complete and publish their evaluations.

In contrast to the United States’ emphasis on individual, autonomous projects, Europe is developing programs to steward the environmental evaluations of IVHS field tests and to facilitate sharing of knowledge and experiences among tests. These programs also ensure that resources are dedicated to assess energy and air quality impacts of diverse IVHS user services. The European programs, upon closer scrutiny, may provide an alternative paradigm for evaluating the environmental implications of operational tests.

Future Work

The Volpe Center will complete its investigation of the environmental practices of the operational tests in early summer 1994. In conjunction with this work, we are developing a guidebook that will attempt to reduce the complexities of emissions and fuel consumption evaluation into manageable components that address exogenous variables, travel activity, traffic operations, and emissions and fuel use dynamics. The guidebook will propose experimental designs that capture, as much as possible, the causal relationships between these components. The intent of the guidebook is to recommend flexible, best practice options to accommodate pragmatic concerns of time and resources.

Table 1

OPERATIONAL TESTS WITH ENVIRONMENTAL OBJECTIVES

United States - Travel and Traffic Management

PROJECT TITLE (LOCATION)	IVHS USER SERVICES	STATUS	EVAL PLAN	MAJOR GOALS	EXPERIMENTAL DESIGN	DATA COLLECTION AND ANALYSIS			
						Travel Behavior	Traffic Operations	Emissions/ Air Quality	Fuel Use
ADVANCE* **(Chicago, IL)**	• Dynamic route guidance	I	Yes	• Improve travel times • Assist travelers • Reduce congestion	Compare "before" and "after" Compare "with" and "without" IVHS Time series analyses	Survey traveler behavior: trips and frequency, departure times, mode, user satisfaction	Link travel times, VMT through probe vehicles, surveillance. Calibrate traffic simulation model (undetermined)	Model HC, CO, NOx (undetermined)	Model undetermined
ATSAC (Los Angeles, LA)	• Dynamic signal coordination	C	Yes	• Reduce congestion • Improve travel times • Reduce energy use • Reduce air pollution	Compare "before" and "after" Simulated "before" by changing to previous signal timings. Multiple runs	None	Data collected on travel times, number of stops through moving car, system data, instrumented vehicle Calibrated TRANSYT-7F	Model HC, CO using MOBILE1 emissions factors HC, CO reduced by 10.2% and 10.3% respectively.	Model fuel use with TRANSYT-7F Fuel use reduced by 12.5%.
FAST-TRAC* (Oakland Co, MI)	• Dynamic signal control (SCATS) • Dynamic route guidance (ALI-SCOUT)	I T	Yes	• Integrate ATIS and ATMS • Improve mobility • Improve safety • Evaluate general benefits	SCATS: Compare "before" and "after" ALI-SCOUT: Natural use study Compare "with" and "without" with yoked drivers ALI-SCOUT driven on SCATS (adaptive and non-adaptive modes)	O & D demand data from South Eastern Michigan Council of Governments	Data collected on average travel times, lengths, and speeds, speed variance, number of stops, incidents, and turns. Calibrate traffic model (considering INTEGRATION, THOREAU, TRAF-NETSIM) with field data	Model HC, NOx, and CO (undetermined)	Model undetermined

KEY for all tables, which are adapted from Burt Stephens, "An Overview of Evaluation Plans for IVHS Operational Tests," p. 351:

PROJECTILE *Denotes U.S. DOT support; STATUS: complete, Tests Underway, Installation of Equipment/Procedures, Design State, Planning Stage, Not Started

Table 1 (cont.)

PROJECT TITLE (LOCATION)	IVHS USER SERVICES	STATUS	EVAL PLAN	MAJOR GOALS	EXPERIMENTAL DESIGN	DATA COLLECTION AND ANALYSIS			
						Travel Behavior	Traffic Operations	Emissions/ Air Quality	Fuel Use
GUIDESTAR-(GENESIS* (Minneapolis-St. Paul, MN)	• Real-time information on travel times and transit through personal communication devices (PCDs)	D	No	• Reduce congestion • Increase mobility • Improve environmental quality • improve energy efficiency • Increase transit use	Compare "with" and "without" PCDs	Trip O-Ds, actual departure and arrival times (PCDs and surveys)	Traffic simulation model (undetermined)	Model HC, NOx, and CO (undetermined)	Model undetermined
INFORM* (Long Island, NY)	• Dynamic ramp meters • Dynamic signal coordination • Changeable message signs (info on delay and diversion)	C	Yes	• Improve volumes • Reduce travel times • Reduce response times for assistance • Reduce accidents • Reduce air pollution • Reduce energy usage • Increase user satisfaction	Time-series study of seven two-week duration periods collected from 1987-1990	Home based survey of travel habits (VMT, departure time, route) and expectations of CMS info.	Collected data on volumes, occupancy, speed, travel times, incident data, other using moving car runs, commuter travel logs, and field count techniques. Perform statistical analyses.	Not performed, although stated as goal	Not performed, although stated as goal
Smart Corridor* (Los Angeles CA)	• Dynamic ramp metering • Dynamic signal coordination • Traveler information via changeable signs, radio, and telephone	I	Yes	• Improve throughput • Decreased travel time • Improved traffic distribution • Improved air quality • Reduced energy use	Series of evaluations including "before-during-after" analyses of new features Samples over several time intervals	O-D, trip purpose, departure and arrival times, routes taken, travel info (before and en-route) through surveys (broad and panel) of motorists.	Traffic volumes, occupancy, VMT, VHT, average speed, number of stops, and travel times from loop detectors, control system. Perform multivariate analyses.	Model undetermined Model function of some or all: average speed, travel time, number of stops, total stopped time, VMT	Model undetermined Model function of some or all: average speed, travel time, number of stops, total stopped time, VMT

Table 1 (cont.)

PROJECT TITLE (LOCATION)	IVHS USER SERVICES	STATUS	EVAL PLAN	MAJOR GOALS	EXPERIMENTAL DESIGN	DATA COLLECTION AND ANALYSIS			
						Travel Behavior	Traffic Operations	Emissions/ Air Quality	Fuel Use
SmarTraveler* (Boston, MA)	• Real-time information on traffic and transit via telephone service	T	Yes	• Increase mobility • Improve safety • Increase transit ridership • Improve air quality and energy efficiency	Randomized surveys of users	Survey on changes in travel behavior: departure time, route, trips, mode. Estimated through induction for user behavior: 50% change route, 45% change time of travel, 5% change mode.	Used CTPS 1990 census data to determine mean travel times, trip distances for cities/towns in Eastern Mass traveling to Boston CBD. Estimated percent of trips affected by user changes. Then, estimated impact on VMT and mean speed.	Calculated impacts on emissions based on changes in VMT and average speed using MOBILE5a Concluded that SmarTraveler would reduce average summertime emissions in 1999 for VOC, NOx, and CO by 498, 25, and 5,032 kg/day, respectively.	Not calculated
TravTek* (Orlando FL)	• Dynamic route guidance	C	Yes	• Assist drivers • Reduce delay and congestion • Reduce accident risk • Reduce fuel consumption • Reduce emissions • Evaluate display alternatives	Defined ten experimental approaches to compare "with" and "without": I field study with rental users 2. field study with local users 3. yoked drivers 4. Orlando test network study 5. camera car study 6. questionnaires 7. debriefings 8. TMC/traffic probe 9. modeling IO. global evaluation.	Data collected on user response, route through surveys, system. O-D travel demand for all links in study area obtained from model, QUEENSOD (O-D inferred from actual traffic flow counts) Parametric analyses of market penetration and travel demand	Field data collected on differences in travel time, mean speed, number of stops, time at idle, speed variance, trip distance using data logged in vehicle. INTEGRATION traffic model, calibrated with field data	Model HC, CO, and NOx in terms of grams per liter of fuel consumed using fuel consumption model and EPA's MOBILE5a.	Empirical measurement of TravTek vehicle (1992 Olds Toronados) extrapolated to fleet with EPA data.

Table 2

OPERATIONAL TESTS WITH ENVIRONMENTAL OBJECTIVES

United States - Environmental Traffic Management

PROJECT TITLE (LOCATION)	IVHS USER SERVICES	STATUS	EVAL PLAN	MAJOR GOALS	EXPERIMENTAL DESIGN	DATA COLLECTION AND ANALYSIS			
						Travel Behavior	Traffic Operations	Emissions/ Air Quality	Fuel Use
Evaluating Environmental Impacts of IVHS using LIDAR* **(Blaine, MN)**	• Dynamic implementation of real-time traffic control in response to air quality monitoring (LIDAR and infrared technology).	N	No	• Improve local air quality • Evaluate LIDAR feasibility • Evaluate traffic management system's effectiveness	Unknown	Unknown	Unknown	Unknown, but empirical measurements with LIDAR and active infrared technology	Unknown
IVHS for Voluntary Emissions Reduction* **(Colorado)**	• Real-time emissions readings to motorists using infrared remote sensing and variable message sign	N	No	• Reduce number of high-emitting vehicles • Evaluate user response and acceptance	Unknown, but possible time series evaluation of emissions and number of high emitting vehicles	Survey willingness of motorists to repair cars	Unknown	Unknown, but empirical measurements of identified high emitters over time.	Unknown
Travel Demand Management Emissions Detection* (Idaho)	• Identify high emitting vehicles through real-time use of infrared remote sensing	N	No	• Determine relative contributions of in-county and out-county high emitters • Evaluate infrared sensing feasibility and use in I/M program	Unknown	Unknown. but O-D determined from surveys (possibly using remote sensing technology)	Unknown	Unknown, but empirical measurement using infrared remote sensing.	Unknown

Table 2 (cont.)

PROJECT TITLE (LOCATION)	IVHS USER SERVICES	STATUS	EVAL PLAN	MAJOR GOALS	EXPERIMENTAL DESIGN	DATA COLLECTION AND ANALYSIS			
						Travel Behavior	Traffic Operations	Emissions/ Air Quality	Fuel Use
Planning and Modeling Data Environment (Riverside and San Bernardino, Co., CA)	• Real-time remote transportation data collection via probe vehicles, call boxes, and emission sensors	PD	N/A	• Demonstrate real-time data collection • Improve transportation and air quality planning	Unknown	Collect data on trip 0-Ds by trip type, direction of travel and speed, vehicle trips by time of day, average vehicle ridershipl occupancy via probe vehicles equipped with GPS Compatible with TRANPLAN model	Collect data on average daily counts, turning movements, peak hour volumes and times, average/ max/min speeds, vehicle class, directional splits, number of high emitter vehicles, VMT, VHT.	Empirical measurements to ascertain number of high emitters. Travel demand/ traffic data compatible with California's regulatory emissions and air quality models	Unknown

Table 3

OPERATIONAL TESTS WITH ENVIRONMENTAL OBJECTIVES

United States Public Transportation System

PROJECT TITLE (LOCATION)	IVHS USER SERVICES	STATUS	EVAL PLAN	MAJOR GOALS	EXPERIMENTAL DESIGN	DATA COLLECTION AND ANALYSIS			
						Travel Behavior	Traffic Operations	Emissions/ Air Quality	Fuel Use
GUIDESTAR-TRAVLINK+ (Minneapolis-St. Paul, MN)	• Real-time transit and traffic information through videotex terminals, electronic signs, smart kiosks, transit station displays	7= D	No	• Increase transit users • Improve transit efficiency	No formal design as yet, probably "with" and "without" comparisons using control group	Survey changes in number of trips, mode, route.	Survey changes in trip length, VMT	May or may not consider air quality impacts	May or may not consider energy impacts

Table 4

OPERATIONAL TESTS WITH ENVIRONMENTAL OBJECTIVES

United States Commercial Vehicle Operations

PROJECT TITLE (LOCATION)	IVHS USER SERVICES	STATUS	EVAL PLAN	MAJOR GOALS	EXPERIMENTAL DESIGN	DATA COLLECTION AND ANALYSIS			
						Travel Behavior	Traffic Operations	Emissions/ Air Quality	Fuel Use
ADVANTAGE I-75* ((I-75 Corridor)	• Weigh-in-motion	I	Yes	• Increase efficiency • Enhance motorist safety • Reduce congestion	Compare "before" and "after" Compare "with" and "without", with possible yoked drivers	None	Data collected on stop times, travel	Empirical measurements of HC, NOx, and particulate matter (method undetermined)	Empirical measurement (method undetermined)
Private Sector (CVO) Case Studies (United States and Canada)	• Routing and scheduling optimization	C	N/A	• Increase productivity • Increase customer satisfaction • Decrease energy use • Decrease vehicular emissions	Unknown, but appear to be comparisons of "before" and "after"	Unknown	Unknown. Results: 1. Newspaper Delivery: (VMT reduced by 3500) 2. Commodities delivery: Florida -VMT reduced by 30%, # of trucks reduced by 40%); Kentucky - VMT reduced by 5%) 3. Dairy Distributor: VMT reduced by 9%, VHT by 4%) 4. Mail Delivery: (VMT reduced by 2680 km/day) 5. Farm Products: VMT reduced by 15%/year 6. Beverage Distribution: (# of stops reduced by 5%, number of vehicles and VMT reduced) 7. Consolidation: no reductions in VMT, stops	Unknown, but uses methodology adopted for California emissions inventory. Extrapolates from case studies to nation, using unknown method. Predicts NOx reductions of 250 to 1000 tons/day	Unknown

Table 5

OPERATIONAL TESTS WITH ENVIRONMENTAL OBJECTIVES

Europe - Travel and Traffic Management

PROJECT TITLE (LOCATION)	IVHS USER SERVICES	STATUS	EVAL PLAN	MAJOR GOALS	EXPERIMENTAL DESIGN	DATA COLLECTION AND ANALYSIS			
						Travel Behavior	**Traffic Operations**	Emissions/ **Air Quality**	**Fuel Use**
KITE (Kernel Project on Impacts of Transport Telematics on the Environment) (European cities, **lead by Cologne, Germany)**	• Recommend standard methods of monitoring environmental impacts of IVHS • Assess air quality impacts of IVHS	P	N/A	• Provide a "suite of models" and tools to assess air pollution impacts • Assess air quality impacts of IVHS	Formal design unknown Case studies of SCOPE (Colgne; Piraeus, Greece and Southampton, UK) and QUARTET (Athens; Birmingham, UK, and Turin, Italy)	Unknown	Unknown	Currently assessing existing emissions and dispersion models	Unknown
DRIVE II - SCOPE (Southampton, England; Cologne, Germany; Port of Piraeus, Greece)	• Provision of real-time pre-trip and en-route data on traffic and transit via radio, TV, message signs, station kiosks • Dynamic signal coordination • Real-time transit info and priority bus	I	N/A	• Improve air quality • Optimize urban networks on environmental criteria	Formal design unknown. Evaluate environmental impacts of modal shift and traffic smoothing.	Use travel demand model, EMME2 to mdel mode choice options. Calibrate model based on stated preference surveys. Develop parking prediction model	Field data collection unknown. Calculate speed-time profiles using microscopic models RGCONTRAM (Route Guidance Continuous Traffic Assignment Model) for Cologne and VISUM for Southampton.	Model CO, HC, NOx and lead emissions using Ford Corporate Vehicle Simulation Programme for well-turned gasoline passenger cars. Provides modal emissions rates (cruise, accel, decel, idle) Model air quality using UROPOL (Urban Road Pollution) dispersion model. Plans to develop more complex emissions data, add buses, improve dispersion models.	Unknown

Table 6
OPERATIONAL TESTS WITH ENVIRONMENTAL OBJECTIVES
Europe - Environmental Traffic Management

PROJECT TITLE (LOCATION)	IVHS USER SERVICES	STATUS	EVAL PLAN	MAJOR GOALS	EXPERIMENTAL DESIGN	DATA COLLECTION AND ANALYSIS			
						Travel Behavior	**Traffic Operations**	**Emissions/ Air Quality**	**Fuel Use**
DRIVE 1 - PREDICT (Athens, Greece)	• Environmental optimization of signals • Pollution sensitive re-routing • "Clean" vehicles • Environmental area liscensing	C	N/A	• Assess feasibility of real-time air pollution monitoring integrated with traffic management	Formal design unknown	Field data collection unknown. O-D trip matrix obtained from unknown source.	Field data collection unknown. Modeling using TRANSYT, which provides avg. speed, delays, stops, queue lengths. Model integrated with emissions/ dispersion models	Modeled HC, CO, and NOx using PREMIT. Estimates emissions as function of acceleration, cruise, deceleration, and idling. Model represents different vehicle classes Link emissions rates provided to air dispersion model	Unknown
DRIVE II/POLIS (QUARTET) - APOLLON (Athens, Greece)	• Pollution-sensitive re-routing via in-vehicle route guidance	I	Yes	• Improve local air quality • Evaluate technical feasibility	Compare "with" and "without" route guidance	Collect real-time traffic flow data from system, loop detectors, and on-site observations to reconstruct O-D matrix for PREDICT modeling suite. Surveys also with travelers, residents and participating drivers.	Field data collection unknown. Modeling using TRANSYT, which provides avg. speed, delays, stops, queue lengths Model integrated with emissions/ dispersion models	Modeled HC, CO, and NOx using PREMIT. Estimates emissions as function of acceleration, cruise, deceleration, and idling. Model represents different vehicle classes Link emissions rates provided to air dispersion model Plans to expand model for carbon dioxide.	Plans to adapt PREMIT, emissions model to evaluate fuel consumption

Table 7

OPERATIONAL TESTS WITH ENVIRONMENTAL OBJECTIVES

Europe - Public Transportation Systems

PROJECT TITLE (LOCATION)	IVHS USER SERVICES	STATUS	EVAL PLAN	MAJOR GOALS	EXPERIMENTAL DESIGN	DATA COLLECTION AND ANALYSIS			
						Travel Behavior	Traffic Operations	Emissions/ Air Quality	Fuel Use
THERMIE - JUPITER (Joint Urban Project in **Transport Energy Reduction)** **(Aalborg, Denmark; Bilbao, Spain; Florence, Italy;** Chent, Belgium; Liverpool, UK; Patras, Greece)	• Real-time passenger info, public vehicle priority lanes. • Traffic restrictions • New public transit vehicles, some with alternative fuels.	P	N/A	• Reduce energy consumption • Improve air quality • Increase ridership of public transportation and carpools	Formal design unknown	Unknown	Unknown	Unknown	Unknown
THERMIE - ENTRANCE (Energy Savings in Transportation through Innovation in the Cities of **Europe)** (Southampton and Portsmouth, UK; Cologne, Germany; Piraeus, Greece; Evora, Portugal; Rotterdam, the Netherlands; Santiago, Spain)	• Real-time transit and priority bus lanes • Park-and-ride guidance via changeable message signs. • Environmental traffic control • Vehicle restrictions using advanced vehicle identification • Cycling promotion. priority bus	D P	N/A	• Reduce energy consumption • Improve air quality • Increase ridership of public transportation and carpools	Formal design unknown.	Unknown	Unknown	Unknown	Unknown

Table 8
OPERATIONAL TESTS WITH ENVIRONMENTAL OBJECTIVES
Japan

PROJECT TITLE (LOCATION)	IVHS USER SERVICES	STATUS	EVAL PLAN	MAJOR GOALS	EXPERIMENTAL DESIGN	DATA COLLECTION AND ANALYSIS			
						Travel Behavior	Traffic Operations	Emissions/ Air Quality	Fuel Use
Comprehensive Traffic Control System (Tokyo, Japan)	• On-board route guidance	C	N/A	• Improve traffic flow • Reduce navigational waste • Improve air quality	Formal design is unknown, but appears to compare "with" and "without". Extrapolates field results for small test area to all of Tokyo.	Unknown	Methodology unknown, but appears, at a minimum, travel times, speed, and VMT were collected or modeled.	Modeled CO, HC, and NO emissions using unspecified model. Concluded that system would reduce average CO, HC, and NO emissions by 6.5, 6.2, and 0.4%, respectively.	Modeled fuel usage through unspecified model that uses a "relationship between gasoline consumption and vehicle speed." Concluded that system would reduce average daily fuel savings by 5%.
National Police Agency **(Japan)**	• Dynamic signal coordination	C	NIA	• Reduce traffic accidents • Improve traffic flow • Reduce pollution	Compare traffic responsive control with fixed-time control system for various time periods and for regional area, street, and intersections.	Unknown, but appears not to have been estimated. May have obtained vehicle occupancy data from census statistics.	Field data of traffic flow collected before and after for 80 streets. Measures include travel time, queuing time, number of stops, and travel speed. Estimated improvements of 16%, 16-31%, 37-40%, and 20% for travel lime, queuing time, # of stops, and travel speed, respectively.	Unknown if estimated. May use fuel consumption to qualify pollution impacts.	Estimated fuel savings using algorithm where fuel use is linearly proportional lo travel time. Estimated annual fuel savings of 28 k liters per intersection

Table 9

OPERATIONAL TESTS WITH ENVIRONMENTAL OBJECTIVES

Australia

PROJECT TITLE (LOCATION)	IVHS USER SERVICES	STATUS	EVAL PLAN	MAJOR GOALS	EXPERIMENTAL DESIGN	DATA COLLECTION AND ANALYSIS			
						Travel Behavior	Traffic Operations	Emissions/ Air Quality	Fuel Use
Evaluations of Seven Sydney Coordinated Adaptive Traffic Systems (SCATS) in Several Cities (Sydney and Melbourne, Australia; Coventry, UK, Glasgow, Scotland)	- Dynamic signal coordination - HOV lanes	C	N/A	- Reduce travel times - Reduce fuel usage - Reduce number of stops	Compare SCATS to networks with no trafiic control Compare SCATS to tixed time traffic signal systems.	Unknown	Methodology unknown. Evaluation criteria: network travel time, stops SCATS compared to networks without traffic control: network travel times reduced by 20%; # of stops reduced by 93%. SCATS compared to simple fixed-time systems: network travel times reduced 4-8%; # of stops reduced 9-25% SCATS with priority lanes: travel time for public transit vehicles reduced 6-10%.	Unknown if calculated	Methodology unknown. SCATS compared to networks without traffic control: total fuel consumption reduced by 14% SCATS compared to simple tixed-time systems: total fuel consumption reduced by 6%.

ENDNOTES

---

1 The minimum number of nationally funded operational tests is 400. This figure is a composite estimate derived from several sources. The estimate, therefore, is not exact, but does suggest the scope of IVHS field tests.

2 The US. DOT funded 59 operational tests in FY93 and earlier and identified 17 operational tests in FY94. U.S. DOT, ***Intelligent Vehicle Highway Systems Projects,*** Washington, D.C., March 1994 and FHWA, Intelligent Vehicle Highway Systems: Operational Tests Program, announcement, undated.

3 Steven Underwood and Fredric Streff, "Avoiding Delay, Death, and Dirty Air: Framework for Evaluation of Intelligent Vehicle-Highway Systems, ***Proceedings of the IVHS America*** 1992 ***Annual Meeting,*** Vol. 1, IVHS America, Washington, D.C., May 17-20, 1992, p. 365. Underwood and Streff emphasize the difference between demonstration and evaluation: "Where a demonstration is designed to show that a system can be developed and made operational, which is an important aspect of any operational field test, an evaluation is designed to show that implementation of the system has led to some nonrandom and measurable changes in select target populations."

4 U.S. Department of Transportation, ***IVHS Strategic Plan: Report to Congress,*** Publication No. FHWA-SA-93-009, December 18, 1992, p. 28.

5 U.S. Department of Transportation, IVHS ***National Program Plan: Implementation Report*** to ***Congress,*** Draft, January 28, 1994, p. 8.

6 Federal Highway Administration, ***The Intelligent Vehicle Highway Systems Program in the United States,*** Washington, D.C., April 1994, p. 6.

7 U.S. Department of Transportation, ***IVHS National Program Plan: Implementation Report to Congress,*** Draft, January 28,1994, p. 10.

8 Federal Highway Administration, ***The intelligent Vehicle Highway Systems Program in the United States,*** p. 5.

9 Intermodal Surface Transportation and Efficiency Act, Title VI, Part B, Section 6053(c) and Section 6055 (d).

10 Federal Highway Administration, ***Intelligent Vehicle Highway Systems Operational Test Evaluation Guidelines,*** Washington, D.C., November 1993.

11 U.S. Department of Transportation, ***intelligent Vehicle Highway Systems Projects,*** "Evaluation Support for Operational Tests", March 1994, p. 306.

12 U.S. Department of Transportation, ***IVHS Strategic Plan: Report to Congress,*** p. 63.

---

[13] Federal Highway Administration, Intelligent Vehicle Highway Systems: Operational Tests Program, announcement, undated.

[14] For detailed discussions of experimental design and evaluation criteria in the context of IVHS operational tests refer to Daniel Brand, "Criteria and Methods for Evaluating IVHS Plans and Operational Tests," Preprint ***No. 940989, Transportation Research Board 73rd Annual Meeting,*** Washington, DC., January 9-13, 1994. Also Steven Underwood and Fredrick Streff, "Avoiding Delay, Death and Dirty Air: Framework for the Evaluation of Intelligent Vehicle-Highway Systems," ***Proceedings of the IVHS America 1992 Annual Meeting,*** Newport Beach, California, May 17-20, 1992, Vol. 1, p. 358-381.

[15] Federal Highway Administration, Intelligent Vehicle Highway Systems: Operational Tests Program, announcement, undated. The operational tests are three "travel demand management" operational tests identified by the DOT's September 8, 1993 Federal Register requests for solicitations. The tests make use of infrared remote sensing and Light Detection and Ranging (LIDAR) technologies.

[16] The INFORM field test carried out detailed data collection and field studies to determine impacts on traveler behavior and traffic operations of ramp metering and signal coordination. However, the evaluators stopped short of estimating emissions and fuel consumption impacts, although environmental objectives are stated in the project's evaluation plan. JHK & Associates, ***INFORM Evaluation, Volume I: Technical Report,*** prepared for FHWA, Publication No. 1 FHWA-RD-91-075, McLean, Virginia, January ***1992,*** p. 29.

[17] Los Angeles Department of Transportation, ***Automated Traffic Surveillance and Control: Evaluation Study,*** Los Angeles, California, July 1987.

[18] Bruce Churchill, et al., "Planning and Modeling Data Environment," Preprint No. 94102, IVHS America 1994 Annual Meeting, Atlanta, Georgia, April 17-20,1994.

[19] Volpe National Transportation Systems Center, ***Advanced Public Transportation Systems: Evaluation Guidelines,*** FTA-MA-26-0007-94-2, prepared for Federal Transit Administration, Cambridge, Mass., January 1994, p. 33.

[20] Gary L. Latshaw and William G. Nutly, "Improving Energy Efficiency and Air Quality," Preprint No. 94005, IVHS America 1994 Annual Meeting, Atlanta, Georgia, April 17-20, 1994.

[21] R. L. French, et al., ***A Comparison of IVHS Progress in the United States, Europe, and Japan.*** Approval Draft, February 18, 1994, p. ES-2,

[22] Summary of European IVHS Efforts, briefing for IVHS America Management Review Committee, lQ1993, unpublished, unnumbered.

---

23 R.L. French, et ***al., A Comparison of IVHS Progress in the United States, Europe, and Japan,*** p. ES-2..

24 ***Ibid.,*** p. ES-2.

25 PREDICT, informational brochure, Castle Rock Consultants, Nottingham, England. undated.

26 Quartet Apollon: A Technological Challenge. Public information brochure, prepared by Apollon Tower, 64 Louise Riencourt Str., 115 23 Athens, Greece. QUARTET is part of the European POLIS program and co-financed under DRIVE II

27 Fra.ser Sommervile and Adam Bostock, "Environment Traffic Control, Paper No. 94124, IVHS America 1994 Annual Meeting, Atlanta, Georgia, April 17-20, 1994.

28 Paul J. Taylor and Bob McQueen, "Assessment of Air Quality Impacts - IVHS Implementation in Sourthampton & Cologne," Preprint No. 94118, IVHS America 1994 Annual Meeting, Atlanta, Georgia, April 17-20, 1994.

29 "Passenger Info Set as THERMIE Priority for New RTI Energy Projects." ***The Intelligent Vehicle Highway,*** October 29, p. 6.

30 ***Ibid.,*** p. 6-8.

31 ***Ibid.,*** p. 6-8.

32 "Entrance Participants Set Out THERMIE Plans with Reduced Funding." ***The Intelligent Highway,*** November 12, 1993, p. 6.

33 "DRIVE Approves Project to Assess Pollution Impact of RTI Trials," ***The Intelligent Highway,*** December 10, 1993, p. 4.

34 R. L. French, et al., ***A Comparison of IVHS Progress in the United States, Europe, and Japan,***

35 ***Ibid.,*** p ES-2, ES-5, 5-10

36 The results for CACS were obtained from secondary sources. Adolf May, ***The Highway Congestion Problem and the Role of In- Vehicle Information Systems,*** Institute of Transportation Studies, University of California, Berkeley, April 1992 and Fumihiko Kobayashi, "Feasibility Study of Route Guidance System", ***Transportation Research Record 737,*** Traffic Control Devices, Geometrics, Visibility, and Route Guidance, 1979.

37 Kentaro Sakamoto, "Benefit of Traffic Signal Management System of the National Police Agency (NPA) in Japan, ***Summary*** from ***The Report on the Effectiveness of the***

Traffic Safety System** of **the National Police Agency in Japan, March 1993, by Japan Traffic Management Technology Association (JTMTA), p.3-4.

38 Doug Quail, RTA (Roads and Traffic Authority, New South Wales, Australia) fax to John O'Donnell (the Volpe Center), May 4, 1994.

39 For example, a study for the ADVANCE project, which expects to deploy up to 5,000 vehicles in a 300 square-mile area, indicated that, given the area's historical accident rate, at least 10,000 probe driver years would be required to statistically detect a roughly 20 percent difference between baseline and post-IVHS accident levels. Volpe National Transportation Systems Center, ***Sample Size and Other Calculations for the ADVANCE Operational Test Evaluation,*** prepared for NHTSA Technical Information Exchange, January 28, 1993, unpublished for internal distribution only.

40 JHK & Associates, ***INFORM Evaluation, Volume I: Technical Report,*** prepared for FHWA, Publication No. FHWA-RD-9 l-075, January 1992.

41 JHK & Associates, ***INFORM Evaluation, Volume II: Executive Summary,*** prepared for FHWA, Publication No. FHWA-RD-9 l-076, January 1992.

42 Rebecca Fleischman, "Research and Evaluation Plans for the TravTek IVHS Operational Field Test," ***SAE Paper*** No. 912831, October 1991.

43 "The ROMANSE Project," ***Traffic Technology International*** 94, undated, unnumbered.

44 The Volpe Center also incorporated TRANSYT-7F in a model-based framework, which evaluates arterial-based dynamic traffic control strategies.

45 Steve Underwood, "FAST-TRAC as an Integrated System: Evaluation Plans and Preliminary Findings," Preprint No. 94123, IVHS America 1994 Annual Meeting, Atlanta, Georgia, April 17-20, 1994, unnumbered.

46 Information based on literature obtained from Sante Fe Technologies and Los Alamos National Laboratory.

47 PREDICT, informational brochure, Castle Rock Consultants, Nottingham, England, undated.

48 Michel Van Aerde and Mark Baker, "Modeling Fuel Consumption and Vehicle Emissions for the TravTek System, ***Proceedings** of **the IEEE-IEE Vehicle Navigation & Information Systems Conference,*** Ottawa, October 1993, p. 126-129.

49 Los Angeles Department of Transportation, ***Automated Traffic Surveillance and Control Evaluation Study,*** p. 1,

"Ibid., p. 8.

---

[51] Los Angeles Department of Transportation, ATSAC Evaluation Study, July 1987, p. 5. The evaluators noted that the procedure “had a very important advantage over traditional studies where often one or more years separated the “before” and “after” periods, thereby introducing the possibility of extraneous factors such as changes in traffic volume and street geometrics, which could account for some of the variation in key performance measures.”

[52] ***Ibid.,*** p. 11.

[53] Doug Quail, ***op. cit.***

[54] Kentaro Sakamoto, ***op. cit.,*** p. 3-4.

[55] Tech Environmental, Inc, ***Air Quality Benefits Study*** *of* ***the SmarTraveler Advanced Traveler Information*** Service. prepared for SmartRoute Systems, July 1993, p. 3.

[56] Smart Route Systems, ***The SmarTraveler Operational Test Early Findings October 30, I992-March*** 30, 1993, SmartRoute Systems, Cambridge Massachusetts, May 4, 1993, p. 1.

[57] Tech Environmental, ***Air Quality Benefits Study*** *of* ***the SmarTraveler Advanced Traveler Information Service,*** prepared for SmartRoutes Systems, Cambridge, Mass., July 1993, p. 9.

[58] Adolf Mav ***The Highway Congestion Problem and the Role*** *of* ***In-Vehicle Information Systems,*** Institute of Transportation Studies, University of California, Berkeley, April 1992 and Fumihiko Kobayashi, “Feasibility Study of Route Guidance System”, ***Transportation Research Record*** 73 7, Traffic Control Devices, Geometrics, Visibility, and Route Guidance, 1979.

[59] Gary L. Latshaw and William G. Nutly, “Improving Energy Efficiency and Air Quality,” Preprint ***No. 94005, IVHS America 1994 Annual Meeting,*** Atlanta, Georgia, April 17-20, 1994.

[60] Latshaw and Nutly, ***op. cit.,*** unnumbered.

REFERENCES

ADVANCE News. ADVANCE Project, Schaurnburg, IL, initial newsletter (undated), April 1994.

"Athens Pollution Trial Prepares for May Start with Cut Down System." The ***Intelligent Highway,*** Volume 5, Issue 1, April 1, 1994, p. 12.

"AVL/CAD Installations for Travlink Field Test to Begin Next Month." ***Inside IVHS,*** March 28, 1994, p. 8.

Barbaresso, James C. "Preliminary Findings and Lessons Learned from the FAST-TRAC IVHS Program," Preprint No. 94030, IVHS America 1994 Annual Meeting, Atlanta, Georgia, April 17-20, 1994.

Barbaresso, James C. and Terry L. Kemp. "FAST-TRAC Program System Integration Plans," IVHS America 1994 Annual Meeting, Atlanta, Georgia, April 17-20, 1994.

Bonsignore, Ruth M. ***A Comparative Evaluation of the Benefits*** *of* ***Advanced Traveler Information System (ATIS) Operational Tests,*** Master's thesis, Massachusetts Institute of Technology, 1994, unpublished.

Brand, Daniel. "Criteria and Methods for Evaluating IVHS Plans and Operational Tests," Preprint ***No. 940989, Transportation Research Board 73rd Annual Meeting,*** Washington, D.C., January 9-13, 1994.

Brand, Daniel. "An IVHS Benefits Assessment Framework," Presented at the 1993 ***Transportation Research Board Annual Meeting,*** Washington, D.C., January 12, 1993.

BRW. ***Genesis: A Summary*** *of* ***the Detailed System Design,*** prepared for Guidestar Program, Minnesota DOT, March 1994.

California PATH. ***Smart Corridor Evaluation Plan: Conception Design,*** prepared for Santa Monica Freeway Smart Corridor Technical Committee/Caltrans, UCB-ITS-PRR-94-01, Institute of Transportation Studies, University of California, Berkeley, February 1994.

Churchill, Bruce, et. al. "Planning and Modeling Data Environment," Preprint No. 94102, IVHS America 1994 Annual Meeting, Atlanta, Georgia, April 17-20,1994.

The Development of IVHS in Japan, briefing for IVHS America Management Review Committee, 1 Q1993, unpublished.

"DRIVE Approves Project to Assess Pollution Impact of RTI Trials." ***The Intelligent Highway,*** December 10, 1993, p. 4.

Federal Highway Administration. ***intelligent Vehicle Highway Systems Operational Test Evaluation Guidelines,*** Washington, D.C., November 1993.

Federal Highway Administration. Intelligent Vehicle Highway Systems: Operational Tests Program, announcement, Washington, D.C., undated.

Federal Highway Administration. The Intelligent Vehicle Highway Systems Program in the United States, April 1994.

Federal Highway Administration. 16 New Projects - FY 1993 IVHS Operational Tests Program, announcement, undated.

Feradyne Systems and The Center for Applied Research. ***TravTek Evaluation Plan - Final,*** prepared for FHWA, Contract No. DTFH61-90-C-00063, April 4, 1991.

Fleischman, Rebecca N. "Research and Evaluation Plans for the TravTek IVHS Operational Field Test," ***SAE Paper No. 912831,*** October 1991.

French, R. L., et. ***al. A Comparison*** *of* ***IVHS Progress in the United States, Europe, and Japan,*** Approval Draft, prepared for IVHS America, February 18, 1994.

Horan, Thomas A., ed. ***Proceedings*** *of* ***National IVHS and Air Quality Workshop,*** Diamond Bar, California, March 29-30, 1993, George Mason University, Fairfax, Virginia, 1993.

Horan, Thomas A. and Jonathan L. Gifford. "Determining Congestion and Air Quality Effects: The Need for Field and Forecast Data on IVHS Technologies," Modeling and Simulation, Vol. 23, part ***3, Proceedings*** *of* ***the Twenty-Third Annual Pittsburgh Conference,*** April 30-May 1, 1993, p. 1319-1325.

Inn-ran, Vaughan, et. al. "Contribution of Controlled Field Experiments to the Evaluation of TravTek," draft, undated, unpublished.

The Intelligent Highway. European Transport Telematics Update, THERMIE, undated.

IVHS America. ***Strategic Plan*** *for* ***Intelligent Vehicle Highway Systems in the United States,*** Washington, DC., May 20, 1992.

JHK & Associates. ***INFORM Evaluation, Volume I: Technical Report,*** prepared for FHWA, Publication No. 1 FHWA-RD-9 l-075, McLean, Virginia, January 1992.

JHK & Associates. ***INFORM Evaluation, Volume II: Executive Summary,*** prepared for FHWA, Publication No. 1 FHWA-RD-9 l-076, McLean, Virginia, January 1992.

Juster, Richard D., et. al. "An Evaluation of the SMARTRAVLER ATIS Operational Test," Preprint No. 94106, IVHS America 1994 Annual Meeting, Atlanta, Georgia, April 17-20, 1994.

Kobayashi, Furnihiko, "Feasibility Study of Route Guidance System," ***Transportation Research Record*** 73 7, Traffic Control Devices, Geometrics, Visibility, and Route Guidance, 1979.

Latshaw, Gary L. and William G. Nutly. "Improving Energy Efficiency and Air Quality," Preprint No. 94005, IVHS America 1994 Annual Meeting, Atlanta, Georgia, April 17-20, 1994.

Little, Cheryl, et. al. "Development of a Model-Based Framework for IVHS Benefit Analysis," ***Proceedings*** *of* ***the IVHS America 1993 Annual Meeting,*** Washington, DC., April 1994, p. 213-225.

Los Angeles Department of Transportation. ***Automated Traffic Surveillance and Control: Evaluation Study,*** Los Angeles, California, July 1987.

May, Adolf. ***The Highway Congestion Problem and the Role*** *of* ***In-Vehicle Information Systems,*** Institute of Transportation Studies, University of California, Berkeley, April 1992.

MITRE. Evaluation Plan *for* ***the ADVANCE Project,*** prepared for FHWA, McLean, Virginia, April 1992.

MITRE. "Generic IVHS Operational Test Evaluation Guidelines", working paper, prepared for FHWA, October 1993.

Multisystems, ***Evaluation*** *of* ***the SmarTraveler Advanced Traveler Information System Operational Test: A Proposal - Part*** II, submitted to Metropolitan Area Planning Council, January 19, 1993.

Munnich, Lee W. Jr, et. al. "IVHS and the Environment: New Models for Federal, State and Local Cooperation in the Application of Advanced Transportation Systems for Environmental Improvement in Urban Areas," Preprint No. 94070, IVHS America 1994 Annual Meeting, Atlanta, Georgia, April 17-20, 1994.

PREDICT informational brochure. Castle Rock Consultants, Nottingham, England, undated.

Quail, Doug (Road and Traffic Authority, New South Wales, Australia). Fax to John O'Donnell (Volpe Center, Cambridge, Mass.), May 4, 1994, unpublished.

Sakamoto, Kentaro. "Benefit of Traffic Signal Management System of the National Police Agency (NPA) in Japan," ***Summary*** from ***The Report on the Effectiveness of the Traffic Safety System of the National Police Agency in Japan,*** prepared by Japan Traffic Management Technology Association (JTMA), March 1993.

SmartRoute Systems, ***The SmarTraveler Operational Test: Early Findings, October 30, 1992 - March 30, 1993,*** Cambridge, Mass., May 4, 1993.

Sommervile, Fraser and Adam Bostock. "Environmental Traffic Control," Preprint No. 94 124, IVHS America 1994 Annual Meeting, Atlanta, Georgia, April 17-20, 1994.

Starr, Ray A. et. al. "GENESIS: Project Design and Pilot Test," Preprint No. 94040, IVHS America 1994 Annual Meeting, Atlanta, Georgia, April 17-20, 1994.

"State Funds Extend SmarTraveler Test in Greater Boston." ***Inside IVHS,*** February 28, 1994, p. 4-6.

Stephens, Burton. "An Overview of Evaluation Plans for Intelligent Vehicle-Highway Systems Operational Tests," ***Proceedings of the IVHS America I992 Annual Meeting, Newport*** Beach, California, May 17-20, 1992, Vol 1, p. 349-357.

Summary of European IVHS Efforts, briefing for IVHS America Management Review Committee, 141993, unpublished.

Tax-rant, David. E. "ROMANSE - A Road Management System for Europe," Preprint No. 94066, IVHS America 1994 Annual Meeting, Atlanta, Georgia, April 17-20, 1994.

Taylor, Paul J. and Bob McQueen "Assessment of Air Quality Impacts - IVHS Implementations in Southampton & Cologne," Preprint No. 94118, IVHS America 1994 Annual Meeting, Atlanta, Georgia, April 17-20, 1994.

Tech Environmental, Inc. ***Air Quality Benefits Study of the SmarTraveler Advanced Traveler Information Service,*** prepared for SmartRoute Systems, Cambridge, Mass, July 1993.

Underwood, Steve. "FAST-TRAC as an Integrated System: Evaluation Plans and Preliminary Findings," Preprint No. 94123, IVHS America 1994 Annual Meeting. Atlanta, Georgia, April 17-20, 1994.

Underwood, Steven E. and Fredrick M. Streff. "Avoiding Delay, Death and Dirty Air Framework for the Evaluation of Intelligent Vehicle-Highway Systems,"

Proceedings of the IVHS America 1992 Annual Meeting, Newport Beach, California, May 17-20, 1992, Vol. 1, p. 358-381.

U.S. Department of Transportation. The Intelligent Vehicle Highway System (IVHS) Progress Report, January 1994.

U.S. Department of Transportation. ***Intelligent Vehicle Highway Systems Projects,*** Washington, DC., March 1994.

U.S. Department of Transportation. ***IVHS National Program Plan: Implementation Report to Congress,*** Appendices, Draft, Washington, DC., January 28, 1994.

U.S. Department of Transportation. ***IVHS Strategic Plan: Report to Congress,*** Washington, DC., December 18, 1992.

U.S. Department of Transportation. ***National Program Plan for Intelligent Vehicle-Highway Systems (IVHS),*** Draft, Washington, DC., October 15, 1993.

Van Aerde, Michel and Mark Baker. "Modeling Fuel Consumption and Vehicle Emissions for the TravTek System," ***Proceedings of the Vehicle Navigation and Information Systems Conference,*** Institute of Electrical Engineers, Ottawa, Canada, October 12-15, 1993, p. 126-129.

Van Aerde, Michel and L. Rilett. ***TravTek Evaluation: Detailed Test Plan, Task E1-Traffic Simulation Studies,*** prepared for SAIC, February 24, 1993.

Volpe National Transportation Systems Center. ***Analysis of IVHS Benefits/Costs Studies,*** prepared for OST, PM-42-93-ER2, Cambridge, Mass., September 1993.

Volpe National Transportation Systems Center. ***Advanced Public Transportation Systems: Evaluation Guidelines,*** prepared for FTA, DOT-VNTSC-FTA-93-9, Cambridge, Mass., January 1994.

Volpe National Transportation Systems Center. ***IVHS Institutional Issues and Case Studies: ADVANCE Case Study,*** prepared for FHWA, DOT-VNTSC-FHWA-94-9, Cambridge, Mass., March 1994.

Volpe National Transportation Systems Center. ***IVHS Institutional Issues and Case Studies: Advantage I-75 Case Study,*** prepared for FHWA, DOT-VNTSC-FHWA-94-l 0, Cambridge, Mass., December 1993.

Volpe National Transportation Systems Center. ***IVHS Institutional Issues and Case Studies: TravTek Case Study,*** prepared for FHWA, DOT-VNTSC-FHWA-94-12, Cambridge, Mass., December 1993.

Volpe National Transportation Systems Center. ***ATIS Market Research: A Survey** of **Operational Tests and University and Government Research,*** prepared for FHWA, Cambridge, Mass., January 28, 1994.

Volpe National Transportation Systems Center. ***Public Acceptance and User Response to ATIS Products and Services: The Role** of **Operational Tests in Understanding User Response to ATIS,*** prepared for FHWA, Cambridge, Mass., December 1993.

Volpe National Transportation Systems Center. "Sample Size and Other Calculations for the ADVANCE Operational Test Evaluation," prepared for NHTSA Technical Information Exchange, January 28, 1993, unpublished for internal distribution only.

Volpe National Transportation Systems Center. "Sample Size and Other Calculations for the FAST-TRAC Dynamic Route Guidance Operational Test Evaluation," prepared for NHTSA Technical Information Exchange, May 14, 1993, unpublished for internal distribution only.

Wendtland, Michael 0. and Alan Clelland. "Evaluating Pathfinder," ***IVHS Review,*** Fall 1993, p. 87-94.

Westinghouse Electric Corporation, et. al. ***Travlink: Concept Definition and Preliminary System Design,*** prepared for Minnesota Guidestar et. al., April 1994.