

**A Comparative Evaluation of the Benefits of Advanced
Traveler Information System (ATIS) Operational Tests**

by

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B.S., Civil Engineering
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Submitted to the Department of Civil and Environmental Engineering
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Abstract

Little "real" evidence of the benefits of Advanced Traveler Information Systems (ATIS) are available. Different technologies are being applied through operational tests in the United States, Europe and Japan. Only recently, and especially in the United States, has the focus of the evaluation of operational tests been shifted to understanding and quantifying the benefits of ATIS.

This thesis examines ATIS applications from a public-sector perspective, focusing on three key questions: 1) Does government sponsorship of ATIS result in a better transportation system? 2) Which concept among the emerging ATIS technologies has the best long-term potential? and 3) What long-term challenges and opportunities will ATIS technology place on state and local governments?

To gain insight on these questions, the research utilizes five case studies of current operational tests, reviews evaluation practices and provides a summary of the early results of these efforts. These case studies focus on highway-related ATIS.

An analytical framework is then developed by which the costs and benefits of the various tests and their associated architecture can be compared. The long-term challenges and opportunities facing the public sector as a result of the deployment of ATIS are included in this comparison. The framework is tested, using the case studies, to identify its strengths and weaknesses and determine how well the operational test program is answering questions regarding the cost-effectiveness of ATIS. Finally, key issues and areas for further research are discussed.

Thesis Supervisor: Thomas F. Humphrey
Title: Senior Research Engineer and Lecturer

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1 INTRODUCTION

There have been several years of speculation concerning the potential benefits that Intelligent Vehicle-Highway Systems (IVHS) might have in alleviating traffic congestion and improving safety on our nation's highways and improving operations of our public transportation systems. An important component of the IVHS program is Advanced Traveler Information Systems (ATIS).

ATIS is new terminology for a practice which began several decades ago. Traffic reports through commercial radio stations were the first widespread application of advanced traveler information. With enhancements to computer and communications technologies came highway advisory radio (HAR) and variable message signs (VMS). The evolution of these information technologies continues today with the development, testing and deployment of in-vehicle navigation systems; audio, and video text systems; transportation information kiosks; and personal digital assistants (PDAs), as examples.

Little "real" evidence of the benefits of ATIS are available. Different technologies are being applied through operational tests in the United States, Europe and Japan. The evaluations of these systems have varied tremendously, with many focusing purely on the functionality of the technology. Only recently, and especially in the United States, has the focus of the evaluation of operational tests been shifted to understanding and quantifying the benefits of ATIS.

1.1 Scope and Objective of the Thesis

Advanced Traveler Information Systems are intended to provide travelers with real-time information regarding traffic conditions, roadway congestion, delays, alternate routes, incidents, parking and other dynamic situations. It is envisioned that motorists will then use this information to make decisions about when (or if) to travel, what mode to use and what routes to take. In-vehicle navigational instruments, which represent one element of the ATIS architecture, could also help direct motorists through unfamiliar areas. The general goals of ATIS are to improve system efficiency, increase safety and enhance traveler comfort (through the knowledge of what lies ahead). These can be accomplished primarily by eliminating vehicle trips, reducing unnecessary vehicle miles traveled and delays, and improving the balance between demand and the available capacity.

This thesis examines ATIS applications from a public-sector perspective, focusing on three key questions:

- Does government sponsorship of ATIS result in a better transportation system?
- Which concept among the emerging ATIS technologies has the best long-term potential?
- What long-term challenges and opportunities will ATIS technology place on state and local governments?

To gain insight on the first two questions, the research focuses on case studies of current tests. The U.S. Department of Transportation (U.S.DOT) embarked on a

formal program of operational tests in 1990 to evaluate the effectiveness of ATIS in "real" applications. Public officials need to know whether the benefits of these systems justify the expenditures and which systems offer the greatest returns for the least costs. Humphrey [1992] emphasizes the need to identify some early IVHS winners in his research. A primary purpose of this thesis is to review current evaluation practices and provide a summary of the early results of ATIS operational tests.

Focusing on the second question, an analytical framework is then developed by which the costs and benefits of the various tests and their associated architecture can be compared. This evaluation framework focuses on highway-related ATIS and is, again, developed from the perspective of the public-sector transportation professional or policy maker, whose primary interest is in maintaining cost-effective mobility and safety on the transportation network. Since transportation infrastructure needs always exceed annual appropriations, the job of the transportation professional is successfully completed when the cost effectiveness of their programming decisions are maximized. (This objective applies to both traditional transportation improvements, such as roadway widening, and to the deployment of new transportation technologies, a.k.a. IVHS).

The long-term challenges and opportunities facing the public sector as a result of the deployment of ATIS will, in large part, depend on the eventual role of government in ATIS and the technology(ies) that are pursued. Through the various public/private approaches to ATIS and the lessons learned in the case studies, this thesis will examine some of the issues associated with public-sector involvement in the planning, deployment and operation of advanced traveler information systems.

1.2 Outline of the Thesis

The thesis is organized into seven chapters. This chapter (1) provides an introduction to the research topic and describes the structure of the thesis. Chapter 2 presents background on the U.S. Department of Transportation's goals, objectives and the anticipated benefits of the ATIS and brings the reader up to date on the status of existing ATIS operational tests in the United States. Chapter 3 describes the unique requirements of evaluating advanced traveler information systems including the elements of a "comprehensive" evaluation plan and applicable methods for the conduct of such an evaluation. Chapter 4 focuses on case studies to provide: an understanding of the types of technologies being deployed to disseminate advance travel information; a description of public and private sector responsibilities, details on the methods being used to conduct multi-dimensional evaluations of these systems; and insight on the quantitative benefits of ATIS. Each case study describes the project and the evaluation methodology used to assess its performance. For those evaluations that have been completed or are well underway, the findings of the evaluation and lessons learned from the experience are also reported.

Chapter 5 develops a framework for the comparison of the case study evaluations by identifying key measures of effectiveness (MOEs) and long-term planning considerations. Chapter 6 tests this framework using the case studies to identify its strengths and weaknesses and determine how well the operational test program is answering key questions regarding the cost-effectiveness of ATIS. And, finally, Chapter 7 reports on the results of this research including key findings, issues, and areas for further research.

2 IVHS AND ADVANCED TRAVELER INFORMATION SYSTEMS

As background to this thesis, it is helpful to understand the recent history of IVHS in the United States and the legislation and key organizations that have provided the impetus for this growing transportation field.

2.1 The IVHS Movement

For more than two decades, long before the term IVHS was coined, transportation engineers have been applying new communication and control technologies to transportation projects. This program was very informal; as new technologies evolved, they were slowly adapted to transportation applications.

By the mid-1980's, with the burgeoning progress of the communications industry, professionals began to envision radical changes in transportation operations through new communications and computer technologies which could greatly enhance the safety and efficiency of the transportation network. Individuals from the public and private sectors and academia informally organized Mobility 2000 in 1986 and worked over the next four years toward a national vision for applying new technologies to transportation--intelligent vehicles and intelligent highway systems. [Mobility 2000, 1990] Their document contained the first published estimates of the potential costs and benefits of the IVHS program.

Several catalysts have more recently propelled Intelligent Vehicle-Highway Systems into the mainstream of transportation planning in the United States: increased congestion on our roadways; unmitigated highway safety issues; an underutilized public transportation system; heightened concern for air quality; and, finally, the need to convert our traditional defense industries with the end of the Cold War. Efforts to develop a national IVHS program were significantly buoyed by the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 which authorized \$659 million in spending on IVHS over a six-year period. Since that legislative mandate, the U.S. Department of Transportation and IVHS AMERICA, a non-profit professional association incorporated in 1990, have taken the lead in shaping the IVHS program in the United States.

2.1.1 ISTEA's Role

The passage of the Intermodal Surface Transportation Efficiency Act of 1991 ushered in a new era in transportation planning and programming. The transportation policy defined by ISTEA is "to develop a National Intermodal Transportation System that is economically efficient, environmentally sound, provides the foundation for the Nation to compete in the global economy and will move people and goods in an energy efficient manner".¹ The policy emphasizes intermodalism and calls for significant improvements in public transportation, improved access to ports and airports, and better management of the overall system. The ISTEA also makes an unprecedented linkage between transportation programming and the need to achieve the national goals for improved air quality (the Clean Air Act Amendments of 1990).

¹Congressional Record - House - Intermodal Surface Transportation Efficiency Act. Washington, D.C. November 26, 1991,. p. H11517.

The Declaration of Policy concludes with: "The National Intermodal Transportation System shall be adapted to 'Intelligent Vehicles,' 'magnetic levitation systems' and other new technologies wherever feasible and economical, with benefit cost estimates given special emphasis concerning safety considerations and techniques for cost allocation."² This component of the Act consists of a program to research, develop, operationally test, and eventually promote implementation of intelligent vehicle-highway systems.

The broad-reaching goals of the program, as defined by the Act, include:

- The widespread implementation of intelligent vehicle-highway systems to enhance the capacity, efficiency, and safety of the Federal-aid highway system and to serve as an alternative to additional physical capacity of the Federal-aid highway system;
- The enhancement, through more efficient use of the Federal-aid highway system, of the efforts of the several States to attain air quality goals established pursuant to the Clean Air Act;
- The enhancement of safe and efficient operation of the Nation's highway systems with a particular emphasis on aspects of systems that will increase safety and identification of aspects of the system that may degrade safety;

²Ibid, p. H11518.

- The development and promotion of intelligent vehicle-highway systems and an intelligent vehicle-highway systems industry in the United States using authority provided under section 307 of title 23, United States Code;
- The reduction of societal, economic, and environmental costs associated with traffic congestion; and
- The enhancement of United States industrial and economic competitiveness and productivity by improving the free flow of people and commerce and by establishing a significant United States presence in an emerging field of technology;
- The development of a technology base for intelligent vehicle-highway systems and the establishment of the capability to perform demonstration experiments, using existing national laboratory capabilities where appropriate; and
- The facilitation of the transfer of transportation technology from national laboratories to the private sector."³

To measure progress in the program, the legislation mandates that all field tests be evaluated to determine how they contribute to these goals.

³Ibid, p. H11605.

2.1.2 The U.S. DOT's Role

The United States Department of Transportation is charged with implementation of ISTEA and, as such, leads the U.S. IVHS program. The U.S. DOT published a Strategic Plan for IVHS in December of 1992, as mandated by the ISTEA. This plan was largely adapted from an earlier plan developed by IVHS AMERICA. [IVHS AMERICA , 1992]

The purpose of the U.S. DOT Strategic Plan is threefold:

- To clarify the role of the federal government in the development of the national IVHS program;
- To define discrete milestones for the next five years of the IVHS program (1993 to 1997); and
- To demonstrate how the IVHS program is compatible with other federal policies and regulations.

The focus on five-year milestones is to demonstrate some early winners to lawmakers who are funding the program. This objective has placed an emphasis on the evaluation of benefits from the operational tests. The overall goals for IVHS, as defined by the U.S. DOT [1992] are:

- Improved safety
- Reduced congestion

- Increased and higher quality mobility
- Reduced environmental impact
- Improved energy efficiency
- Improved economic productivity
- A viable U.S. IVHS industry

The U.S. DOT is responsible for the operational test program, including selection of each project, overseeing its design and testing, and evaluation of its performance.

2.1.3 IVHS AMERICA's Role

IVHS AMERICA is a non-profit educational and scientific association comprised of over 500 members from the public and private sectors and academia. The purpose of IVHS AMERICA is to plan and promote the development of IVHS in the United States. The organization is a key policy advisor to the U.S. DOT. IVHS AMERICA's most ambitious project to date, was the preparation of a Strategic Plan for IVHS in the United States issued in May of 1992. This document was the underpinnings of the (later) U.S. DOT plan.

The IVHS AMERICA plan details the wide array of potential IVHS applications, divided into five functional areas: Advanced Traffic Management Systems (ATMS); Advanced Traveler Information Systems; Advanced Vehicle Control Systems (AVCS); Commercial Vehicle Operations (CVO); and Advanced

Public Transportation Systems (APTS)⁴. The strategic plan discusses the integration of these IVHS technologies and the key institutional and legal issues associated with them. It also estimates the cost of implementation, including public and private participation, and (boldly) quantifies potential benefits to the transportation network (a 20 percent reduction in congestion and an eight percent reduction in traffic fatalities by the year 2011).

The IVHS AMERICA Strategic Plan continues the theme initiated by the ISTEA of the importance of evaluation, through operational tests, to determine the measurable benefits of IVHS deployment. The plan calls for "uniform evaluation criteria that can be applied to all operational tests." These criteria should provide accurate estimates of the benefits and would allow a comparison among tests. A more detailed discussion of the evaluation guidelines developed by IVHS AMERICA and others, as they pertain to ATIS, is provided in Chapter 3.

2.2 Advanced Traveler Information Systems

Advanced Traveler Information Systems represent a wide array of different applications. Many ATIS are technically components of larger ATMS, which provide the information source and subsequent control functions (i.e., vehicle detection, incident management, signal control, ramp metering, etc.). The formal definition is: "Advanced Traveler Information Systems (ATIS) acquire, analyze, communicate, and present information to assist surface transportation travelers in moving from a starting location (origin) to their desired destination. The systems provide such assistance in a

⁴A sixth area, Advanced Rural Transportation Systems (ARTS) was added after publication of this document. The movement today is away from these six broad functional areas and toward more detailed service oriented descriptions.

manner that best satisfies the travelers' needs for safety, efficiency, and comfort. The travel may involve a single mode of transportation, or it may link multiple modes together during various parts of the trip."⁵

2.2.1 ATIS Characteristics

ATIS utilize a variety of technologies and communication links. As previously mentioned, these range from in-vehicle navigation systems to commercial radio traffic reports. They also vary from low-cost, fairly autonomous systems to more expensive, infrastructure-intensive systems.

In-vehicle systems are navigation aids that provide text, auditory or digital map presentations to the driver. These systems can function on their own (autonomously) or can communicate with the infrastructure (vehicle to roadside communications). One benefit of vehicle to roadside communications is the ability to capture real-time information on traffic conditions and other factors which may affect trip planning.

Another range of ATIS applications involve the transmission of travel information from a central control center directly to the user via a variety of communications links and transceivers. Examples of transceivers include in-vehicle devices (radio, cellular telephone), home or office computers, transportation kiosks, cable television, personal communication devices or variable message signs. Methods of communication between the control center and user might include area or local radio broadcasting, mobile two-way radio communication, land-line or cellular telephone, coaxial or fiber optic cable.

⁵Strategic Plan for Intelligent Vehicle - Highway Systems in the United States. IVHS AMERICA. Washington, D.C. May 20, 1992. p. III-21.

The operational tests reviewed as case studies in Chapter 4 of this thesis represent several different ATIS architecture. An update of current or recent tests undertaken in the United States is provided in the next section of this report.

2.2.2 Update on ATIS Operational Tests

The ATIS operational tests in the United States are in various stages of design, deployment and evaluation. The most interesting aspect of ATIS operational tests is the broad range of architecture currently being evaluated. As data on the successes and failures of these tests become available, it will be essential to make comparisons among the system designs to determine which are most feasible and beneficial to the overall transportation system. Those tests of most importance to this research effort are the ones that have been completed, are actively being evaluated, or for which evaluation plans have been developed. These criteria narrow the eligible field of case studies considerably. Although ATIS can apply to both highway and public transportation, this thesis focuses on those systems which are predominantly highway oriented.

Three operational tests have been completed to date in the United States: INFORM on Long Island, New York; Pathfinder in Los Angeles, California; and, TravTek in Orlando, Florida. INFORM was a variable message sign based information system while Pathfinder and TravTek were in-vehicle information systems. The evaluations of INFORM and Pathfinder are complete. The TravTek evaluation is in progress and is scheduled to be complete by June of 1994. Five additional ATIS operational tests are in various stages of development:

SmarTraveler is fully operational and consists of a telephone-based information test located in Boston, Massachusetts. The demonstration is scheduled to be concluded at the end of 1993 and the evaluation is underway and is expected to be complete by March of 1994. (However, a current proposal to extend each by 3 months is likely to be approved).

Phase I of the ADVANCE in-vehicle operational test, sited in the metropolitan Chicago area, is scheduled to be operational by the end of 1993 with full deployment of a 5,000 vehicle fleet by 1994. A draft evaluation plan has been completed.

The Minnesota Guidestar Program, with several traveler information components, is expected to be operational beginning in late 1993.

FAST-TRAC, located in Oakland County, Michigan, involves a test of the Ali-Scout navigation and route guidance system. The test currently consists of 30 beacons, 60 vehicles and 95 intersections in Troy. A draft evaluation plan has been completed, and the evaluation of the project is underway.

DIRECT consists of 21 miles of interstate between Detroit, Michigan and the Metro Airport, where various ATIS communications technologies are being tested. Implementation of the project and the draft evaluation plan are currently underway.

A review of INFORM, Pathfinder, TravTek and SmarTraveler are included in Chapter 4 of this thesis. These case studies, and a case drawn from the United Kingdom, include a project description, an overview of the evaluation methodology, and a summary of the findings and lessons learned (where results are available).

3 EVALUATING THE BENEFITS OF ATIS

The first major step in this research effort involved gaining a better understanding of the state-of-the-practice of ATIS evaluations. Understanding ATIS evaluation procedures was achieved by talking to experts in IVHS, as well as those directly involved in current operational tests, and reviewing the literature. This chapter introduces the requirements of evaluating advanced traveler information systems. Project-specific evaluation objectives and methodology are discussed further in the case studies.

The mandate for comprehensive evaluation of operational tests of IVHS is made clear in the ISTEA. The U.S. DOT, with the help of academia and the consulting community, has made significant progress in developing a consensus on the goals and objectives of ATIS operational tests, identifying candidate measures of effectiveness (MOEs) and discussing of appropriate methods to quantify these MOEs.

Bolczak [1992] authored guidelines for ATIS evaluations on behalf of the U.S. DOT which provide an overview of the evaluation process. The report identifies five phases of an evaluation effort:

- Operational test definition
- Evaluation definition
- Evaluation plan design
- Evaluation plan performance
- Reporting

A concise schematic of these phases and their components is provided in Figure 3-1.

3.1 Evaluation Objectives

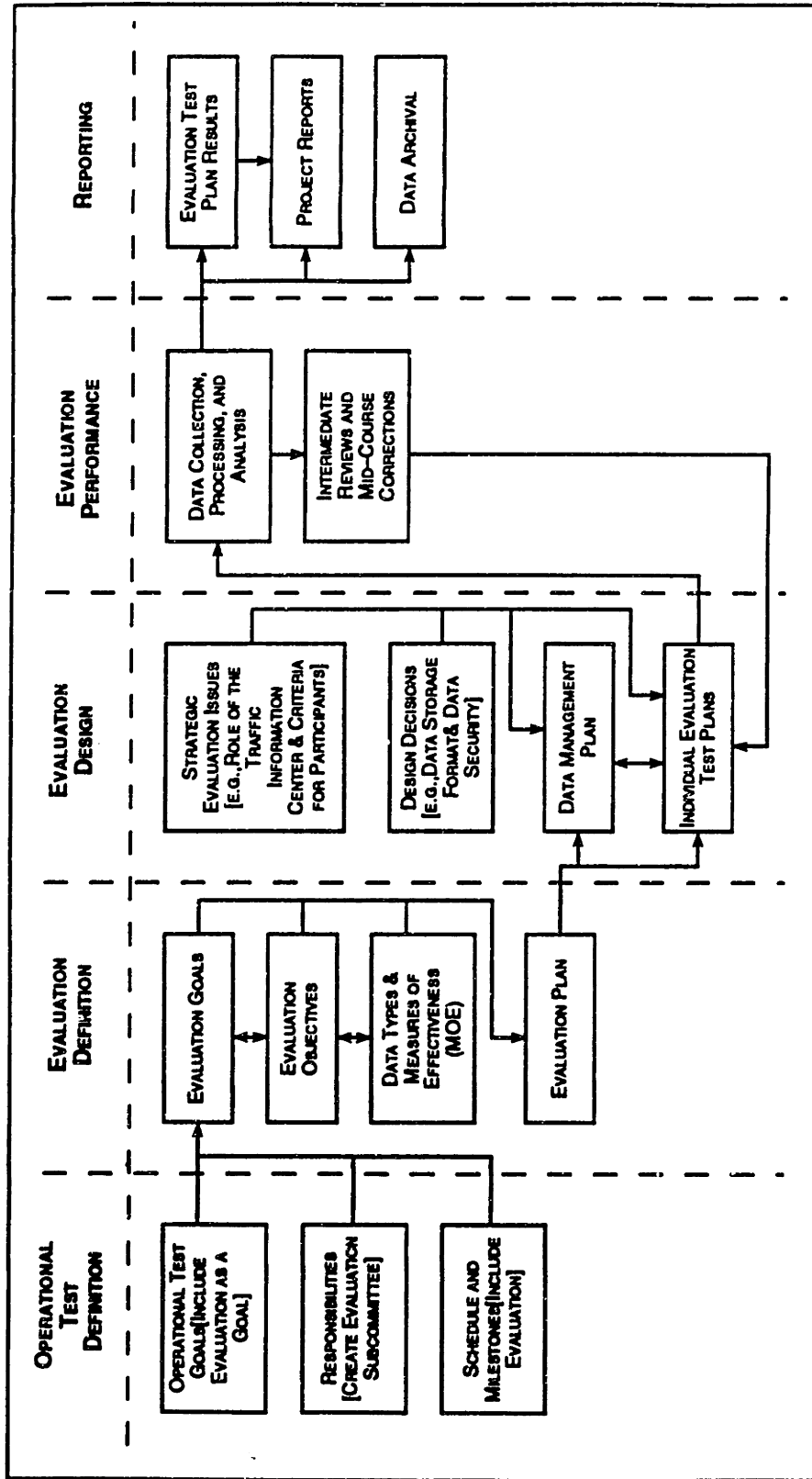
Evaluating ATIS projects offers many challenges beyond those encountered in evaluating conventional transportation improvements. ATIS applications are intended to improve transportation system safety and efficiency by providing real-time information. Given the issues of market penetration, the various responses that the user might have to this information, and the availability of alternate routes or modes, the potential impacts of ATIS are complex. The effectiveness of any system actually depends on a wide range of factors, which may include:

- Market penetration
- Public acceptance
- Driver behavior/response
- Level of congestion
- Availability of alternatives
- Reliability of the technology
- Accuracy of the information

These evaluation efforts are further complicated by the wide range of ATIS technologies and approaches, as discussed in the previous two chapters.

Bonsall and May [1989] outlined, in more detail, ten major aspects of in-vehicle ATIS evaluation to consider:

Figure 3-1 ATIS Evaluation Methodology



Source: Bolczak, 1992.

- Costs (fixed and variable)
- Consumer response (market)
- Value of any byproducts
- Perceived quality of advice
- True quality of advice
- Technical performance of the system
- Ergonomic aspects
- Safety aspects
- Behavioral responses
- Effects on non-users

Quite obviously, from the perspective of quantifying societal benefits and costs, some of these aspects are more important than others.

Bolczak simplifies these aspects into five more general evaluation goals: institutional issues; performance of the system and its impact on the transportation system; performance of the individual functional areas; costs; and user acceptance. Using these goals, he elaborates extensively on possible evaluation objectives in Appendix A of this thesis.

As observed by Stephens [1992], there is no scarcity of ideas about what to evaluate; the difficulty lies in determining operational objectives, practically measuring the impacts, and projecting small operational test results to larger deployment scenarios.

3.2 Evaluation Methodology

Underwood and Streff [1992] present a framework for evaluating IVHS, divided into three forms--field test, comparative, and projective. Underwood and Gehring [1992, 1993] further the discussion of methods used to conduct these evaluations. Their work draws from traditional transportation methods, as well as the work of others on recent operational tests, including INFORM, Pathfinder, TravTek, and ADVANCE.

Although methodological gaps exist in IVHS evaluation (e.g., dynamic travel demand modelling), Underwood and Gehring write: "It has been our experience in planning several IVHS evaluations that most of the evaluation questions can be addressed through the clever adaptation of the traditional methods and procedures found in areas such as human factors, social psychology, traffic engineering, transportation planning, marketing, environmental impact assessment, program evaluation, technology forecasting and assessment, and the like."⁶

Of course, the integration and coordination of these many disciplines is, in and of itself, a unique challenge for the evaluation team.

3.2.1 Evaluation Framework

Underwood and Streff [1992] define the formal IVHS evaluation framework as consisting of three major components:

⁶Will IVHS Transform Transportation System Effectiveness? - Draft - Benefits and Costs Committee Workshop-Proceedings. "Evaluating Intelligent Vehicle-Highway Systems: A Perspective on Methodological Development," December 1992. p B-11.

Field test evaluation, used to assess the technology, define institutional issues associated with implementation, evaluate user behavior/response, and measure benefits and costs.

Comparative evaluation, to determine the most cost-effective alternative among candidate architectures. A comparative evaluation may be conducted in the field, laboratory or modeled.

Prospective evaluation, a model-based evaluation used to estimate future benefits and costs.

This three-tier framework appropriately addresses the range of questions and issues associated with the deployment of IVHS. It also provides a structure by which all evaluation efforts can be organized and synthesized.

Field test methods are discussed in the next section of this thesis. Comparative evaluation is elaborated on in Chapter 5.

Prospective evaluation is not specifically focused on in this research, although it is equally important and is included in some of the evaluation plans considered in the case studies. It involves forecasting demographics, technology diffusion, market penetration and social benefits and costs to predict a future net value of the IVHS technology. Prospective model-based evaluation methods are elaborated on by Underwood and Gehring [1993].

It should be noted that field test results can generate input for the comparative and prospective analyses. Data needs for these efforts should be understood early and incorporated into the field test and evaluation design.

3.2.2 Field Test Evaluation Methods

A wide range of studies might be incorporated into the operational field test evaluation, drawn from multiple disciplines. Most literature advocate a matrix planning procedure to sort out the evaluation objectives and applicable methods. This process also facilitates the consolidation of evaluation exercises to measure multiple objectives with, ideally, the assignment of more than one method to each objective.

Underwood and Streff [1992] provide a concise summary of the appropriateness of various methodologies to seven general field test objectives, shown in Figure 3-2. The methods examined include: field experiment; quasi-field experiment; surveys; subject debriefing; cost analysis; extrapolated impact assessment; and, narrative case studies.

System technical performance and user interface are most appropriately evaluated through field experiments. Individual driver behavior and traffic impacts are best evaluated through quasi-field experiments (e.g. yoked driving experiments) and extrapolated impact assessment (e.g. models). Similar approaches can be used to quantify environmental and energy impacts. Surveys and subject debriefing are appropriate methods to reveal user attitude and preferences. Institutional issues can be identified and understood through narrative case studies. Cost analysis is especially important to system performance, traffic impact and environmental impact assessments.

Specific evaluation plans are reviewed as part of the five case studies presented in the next chapter. The case studies developed in this thesis are: INFORM, Pathfinder, TravTek, SmarTraveler, and Trafficmaster (U.K.)

Figure 3-2 Appropriateness of Methodologies in Evaluating an Operational Field Test

	A	B	C	D	E	F	G
	System Technical Performance	Safe and Efficient User Interface	Individual Driver Behavior and Impact	User Attitudes and Preferences	Traffic Behavior and Impacts	Environmental and Energy Impacts	Institutional and Socio-economic
1 Field Experiment	●	●	◐	◐	◐	◐	○
2 Field Quasi Experiment	◐	◐	●	◐	●	●	○
3 Surveys	○	◐	◐	●	○	○	◐
4 Subject Debriefing	◐	◐	◐	●	○	○	◐
5 Cost Analysis	●	○	◐	○	●	●	○
6 Extrap. Impact Assessment	○	○	●	○	●	●	○
7 Narrative Case Studies	◐	◐	◐	◐	◐	◐	●

Key

●	Most Appropriate
◐	Often Appropriate
◑	Occasionally Appropriate
○	Least Appropriate

Source: Underwood and Sireff [1992]

4.0 ATIS OPERATIONAL TESTS

Five case studies are presented in this chapter: **INFORM, Pathfinder, TravTek, SmarTraveler and Trafficmaster**. The first four are U.S. operational tests, the last is from the United Kingdom.

Each case study describes the project, its public and private participants, the evaluation methodology used to assess its performance, the findings of the evaluation and lessons learned (to date) from the experience.

4.1 The INFORM System

4.1.1 Project Description

Overview

The Information for Motorists (INFORM) project is a traffic management and motorist information system located in a heavily traveled corridor on Long Island, New York. This project is a wholly public sector application of ATIS. The project was implemented as a cooperative effort among the Federal Highway Administration (FHWA), the New York State Department of Transportation (NYSDOT) and local transportation agencies.

The project consists of integrated electronic traffic monitoring, variable message signing, ramp metering and traffic control systems. The system controls a 40-mile corridor which includes two major freeways, the Long Island Expressway (LIE - Interstate 495) and the Northern State Parkway/Grand Central Parkway (NSP/GCP),

as well as a number of crossing arterials and freeways. In total, approximately 128 miles of roads are controlled by the system.

Information presented in this case study is principally drawn from the INFORM Evaluation: Volume I: Technical Report and Volume II: Executive Summary [Smith, 1992].

System Configuration

The INFORM system is infrastructure intensive. It is a variable message sign (VMS)-based motorist information system that relies heavily on electronic traffic surveillance. Other traffic control mechanisms include ramp metering and traffic signal coordination. The infrastructure of the project includes:

- Traffic Surveillance:
 - 2,100 in-roadway vehicle detectors;
 - 21 roadside citizens band radios;
 - Several closed circuit television cameras;
 - Approximately 160 miles of coaxial cable.

- Traffic Control:
 - Variable message signs at 72 locations;
 - 50 ramp metering signals;
 - 104 arterial traffic signals.

The overall system is controlled by an operations center located in the State Office Building in Hauppauge, located at the western limits of the project area. Incoming and outgoing information at the control center is processed with the assistance of 3 minicomputers.

The capital costs for the project were approximately \$35 million. Day-to-day operational responsibilities and the maintenance of field equipment for INFORM were contracted out. These efforts are overseen by NYSDOT staff. The annual operations and maintenance costs, including the NYSDOT staff dedicated to the project, are approximately \$4.5 million.

4.1.2 Project Evaluation

Goals and Objectives

The initial evaluation plan for the INFORM (MIS) project was written in 1980 with minor revisions occurring in 1988. The evaluation plan was based on the goals of the project and a defined set of measures of effectiveness (MOE's). The goals and objectives of the INFORM project, as defined very early in the planning process, are summarized in Table 4-1. The actual evaluation of the INFORM system, completed in 1991, focused on six major areas:

- Motorist information;
- Ramp metering;
- Public perception;
- Design and construction issues;
- General operational issues;
- Evaluation methodology.

Certain elements of the evaluation were quantitative while others were qualitative. The evaluation also documented "lessons learned" from the project. The last task of the evaluation effort provided a (sketchy) cost-benefit assessment of the project.

TABLE 4-1

INFORM: System Goals and Objectives⁷

GOALS	OBJECTIVES
1. Improved throughput	1. Increase corridor throughput during peak periods 2. Increase person travel
2. Decreased and more predictable travel time	1. Decrease average travel time 2. Reduce variability of average travel time
3. Rapid detection and removal of capacity reducing incidents	1. Reduce incident detection time 2. Reduce incident response time 3. Reduce incident clearance time
4. Timely assistance to stranded motorists	1. Reduce time between breakdown or stop and contact with authorities 2. Decrease response time to provide assistance
5. Reduction in accidents and incidents	1. Reduce number of accidents 2. Reduce number of secondary accidents 3. Reduce severity of accidents
6. Reduced air pollution	1. Reduce undesirable vehicle emissions 2. Reduce corridor CO hot spots
7. Reduced energy consumption	1. Reduce fuel usage
8. Reduced vehicle operating costs	1. Reduce average vehicle operating cost
9. Improved trip information	1. Increase number of motorists given advisory information 2. Reduce number of lost motorists 3. Increase accuracy and timeliness of advisory information
10. Improved comfort and security of motorists	1. Improve comfort and convenience of system 2. Improve security within the system
11. Improved management of highway facilities	1. Increase effectiveness of highway system
12. Increased knowledge and experience with IMIS projects	1. Assess total system and subsystems

⁷Source: Smith, 1992.

Much of the data used in the evaluation was collected by the system. These data were supplemented by surveys and field observations. The evaluation methodology, data collection process, and findings are summarized in subsequent sections.

Evaluation Methodology

The evaluation methodology used to assess each defined measure of effectiveness is summarized in Table 4-2. The quantitative evaluation tried to address four general issues: the value of motorist information; the effectiveness of variable message signing; the effectiveness of ramp metering; and, the public perception and response to INFORM.

Table 4-2 demonstrates the breadth of analyses necessary to evaluate ATIS applications. While this effort is more complex than most conventional traffic engineering exercises, the methods employed in the INFORM evaluation were fairly straightforward.

In addition to the quantitative component of the evaluation plan, considerable thought went into identifying and documenting design and construction issues, general operational issues, and the intricacies of the evaluation methodology. These details are not reviewed as part of this summary discussion; however, the key findings of the quantitative evaluation and the general lessons learned from the project are reported.

TABLE 4-2

INFORM: Measures of Effectiveness (MOE's) and Evaluation Methodology for Key Quantitative Analyses⁸

MEASURES OF EFFECTIVENESS

EVALUATION METHODOLOGY

Motorist Information

Travel/Delay:

Vehicle Miles Traveled (VMT)

Vehicle Hours Traveled (VHT)

Average Speeds (VMT/VHT)

Safety:

Derived from detector data

Derived from detector data

Derived from detector data

Comparison of before/after

Accident Reduction statistics

Variable Message Signing

Information:

Frequency of VMS Displays

Accuracy of VMS Displays

Public Perception Response

System generated report

Comparison with travel time runs

Home-based survey

Travel/Delay:

Diverted Traffic

Reduced Delays

Analysis of traffic data and incident

case studies (recreation of an incident)

Derived from detector data and case study

Ramp Metering

Operational:

Performance

Motorist Compliance

System generated report

Analysis of input/output detectors

Travel/Delay:

Changes in Throughput

Changes in Freeway Speeds

Delays at Ramps

Derived from detector data

Derived from detector data

Calculated and supplemented by field observations

Public Perception

User Perceptions:

Perception of Information

Perception of Ramp Metering

Overall Perception of INFORM

Home-based survey

Home-based survey

Home-based survey

⁸Summarized from "INFORM Evaluation Volume 1: Technical Report", FHWA, January 1992.

Data Collection Program

The types and sources of the data collected as part of the evaluation are summarized in Table 4-3. The method of time-series data collection was utilized to account for the (extended) phased implementation of the project and to filter out construction or other "external" factors that potentially could influence the evaluation results. (Originally, a simpler before/after analysis was planned). A total of seven 2-week samples were conducted between March of 1987 and March of 1990.

TABLE 4-3
 INFORM: Data Collection Program⁹

<u>SYSTEM GENERATED DATA</u>	<u>SOURCE</u>
<u>Traffic Data</u> - Traffic Volumes - Traffic Occupancy - Traffic Speed	Freeway, Ramp, and Arterial Detectors Freeway, Ramp, and Arterial Detectors Freeway, Ramp, and Arterial Detectors
<u>Performance Data</u> - Sign and Detector Failures - Changes in VMS Displays - Ramp Metering Status/Rates	System Generated Report System Generated Report System Generated Report
 <u>OPERATOR DATA</u>	
<u>Incident-Related Data</u> - Incident Occurrences - Incident Details (Detection time, Location, Source, Duration, etc.)	INFORM Operator Records INFORM Operator Records
 <u>FIELD COLLECTED DATA</u>	
<u>Traffic Data</u> - Travel Time Runs - Ramp Delay Counts - Vehicle Occupancy Counts - Off-Freeway Automatic Traffic Counts - Travel Time Logging	Evaluation Contractor Evaluation Contractor Evaluation Contractor Evaluation Contractor Regular Commuters
<u>Incident Data</u> - Supplemental Incident Reports	Various Long Island Police Agencies
<u>Accident Data</u> - Project Area Accident Statistics	NYSDOT Computer Files
<u>Attitudinal Data</u> - Travel Habits and Opinions	Home-Based Survey

⁹ Extracted from "INFORM Evaluation Volume 1: Technical Report", FHWA, January 1992.

4.1.3 Evaluation Results

Key results of the evaluation of the INFORM operational test [Smith, 1992] include:

Motorist Information Benefits

- Delay savings associated with incidents were estimated at up to 1,900 vehicle hours per day with a yearly savings of 300,000 hours.
- Delay savings from better management of recurring traffic congestion, construction activity and special events were difficult to (reliably) quantify.
- Overall, average peak directional speeds on the freeways increased slightly (1.5 to 5 miles per hour). Most of this change is attributed to the ramp metering program.
- Limited accident analysis revealed a 5 percent reduction in accidents since implementation of the INFORM project. (More recent data should be reviewed to verify this finding.)

Variable Message Signs Effectiveness

- INFORM produces 14,000 sign messages per month. Despite an automated sign selection algorithm, 80 percent of the operation staff time is spent monitoring and controlling the VMS displays.

- There can be short periods of time when the sign display does not characterize actual conditions due to the necessary smoothing/filtering of detector data and the decision algorithm for sign selection.
- For a typical incident, 5 to 10 percent of mainline traffic diverted in response to a passive VMS (without a recommended alternate route).
- Displaying an alternate route recommendation resulted in higher diversions, but also left the system vulnerable to off-freeway, and potentially worse, congestion.
- In general, the level of diversion varied significantly with the severity and location of the incident, and motorists' confidence in the information they were receiving.

Ramp Metering Effectiveness

- The effectiveness of ramp metering was limited by the number of ramps actively being controlled.
- High volume ramps were either not metered or turned off due to queues impacting sidestreets or adjacent arterials.
- As previously mentioned, average freeway speeds increased 1 to 5 mph, largely attributable to the ramp metering component of the project.

- This improvement in speed resulted in a 25 to 50 percent reduction in the congestion index (portion of detectors with speeds less than or equal to 30 mph) during the morning peak period and a 0 to 35 percent decrease during the evening peak period.
- Marginal increases (2 to 3 percent) in throughput at bottleneck locations were realized.
- Average queues at the metered ramps ranged from 1.2 to 3.4 vehicles. These data are skewed because they include few (if any) high volume ramps.

Public Perceptions

The home-based survey measured the characteristics of Long Island drivers and their perceptions about the INFORM project. In general, the survey showed that:

- Residents were very aware (96 percent) of the VMS's in the INFORM.
- The majority of residents (73 percent) felt the information displayed by the signs was moderately to very useful.
- Approximately 45 percent of the drivers sometimes change their routes in response to the signs. Another 25 percent said they never changed their routes on the basis of the signs.
- Reaction to ramp metering was mixed.

- The overall perception of drivers was that INFORM was quite useful (25 percent of the responses) or helpful once in awhile (40 percent of the responses). Interestingly, when asked what the best source of traffic information was, the majority of INFORM drivers (57 to 64 percent) responded the radio.

Benefit-Cost (B/C) Analysis

The last task of the INFORM evaluation was a benefit-cost analysis. Details of this analysis in the technical report are sketchy and it appears as if this exercise was done largely as an afterthought to provide some measure of economic worth to the project.

The analysis was done for two time periods. March of 1990 (compared with and without metering); and March of 1990 (with metering) compared to the spring of 1987. Annualized costs were estimated at approximately \$10 million (over a 10 year life with a 10 percent discount rate). Benefits were computed by multiplying the vehicle delay savings by \$8.00 per hour. From this assessment, the B/C rates ranged from 1.8 to 8.3. No details were provided on how the vehicle hours of delay saved was calculated.

Lessons Learned

Key lessons learned from the INFORM operational test includes:

- The system needs to be flexible to adapt to new technologies and address problems as they arise.

- Ongoing traffic engineering and management commitment to the project is necessary for success.
- Traffic surveillance and control on adjacent facilities is critical to the traffic management plan (INFORM did not have sufficient control on adjacent arterial systems).
- Maintaining communications, both technically from a hardware perspective and personally among people and agencies is crucial.
- Operations and maintenance issues should be incorporated into the design process.
- And finally, that the direct benefits of such a program are difficult to measure.

4.2 The Pathfinder Project

4.2.1 Project Description

Overview

The Pathfinder project involved testing the viability of in-vehicle navigation and information systems on a 13-mile section of the Santa Monica Freeway in Los Angeles, California. This test represents a public/private application of ATIS, where the public sector assumes the responsibility for the infrastructure and the private sector is responsible for the in-vehicle system. The project represented a cooperative venture by the FHWA, General Motors, and Caltrans (the California Department of Transportation). Other participants in the project included the City of Los Angeles Department of Transportation (LADOT), the California Highway Patrol (CHP), and the City of Los Angeles Bureau of Engineering.

The Pathfinder project consisted of equipping 25 automobiles with on-board computers to provide real-time navigation and traffic information to the driver. The system took advantage of a traffic management infrastructure which already existed in the Santa Monica "Smart Corridor". This corridor includes a section of the Santa Monica Freeway (Interstate 10) and a network of parallel arterials.

The traffic management infrastructure within the corridor consists of traffic detectors, a freeway Traffic Operations Center, and a centralized traffic signal control system. The availability of this information database was instrumental in the selection of this corridor for the in-vehicle navigation test. This corridor was also targeted because it is heavily traveled (about 325,000 vehicles per day travel through it) and because of the availability of alternate routes. Much of the information presented in

this case study is taken from the Pathfinder Evaluation Report [JHK Associates, 1993].

System Configuration

Pathfinder consists of three major components: the in-vehicle system, the central control system, and the communications system. The in-vehicle component featured off-the-shelf hardware and customized software. Navigational functions, including vehicle location processes, were handled by ETAK. A video display terminal and sensors were installed in the passenger compartment of the vehicle with the balance of the hardware placed in the trunk. Real-time traffic information was conveyed to the driver via text messages and graphics on the terminal and through voice messages.

Centralized control of the Pathfinder experiment was achieved by an integrated system which included a Pathfinder Workstation, an ETAK Workstation, with radio communications to and from the vehicles and a computer communication link to other external information sources. A consulting firm operated Pathfinder Central under contract to Caltrans.

The Pathfinder field test cost \$2.4 million and took advantage of surveillance, information, and control systems provided by the \$48 million Smart Corridor project.

4.2.2 Project Evaluation

Goals and Objectives

The evaluation plan developed for the Pathfinder project was structured to address three key issues:

- Whether real-time information combined with an in-vehicle navigation system can improve the efficiency of motorist routing
- The feasibility of combining real-time traffic information with in-vehicle navigation
- The feasibility of using vehicles as traffic probes

The plan was systematically carried out in four distinct stages with data collected over a period of almost two years:

Stage I - State employees tested the hardware and software performance.

Stage II - Hired drivers conducted a controlled experiment. Drivers traveled assigned routes and collected travel time data. One group operated with no information (Blank Mode), one group received navigational information (Map Mode), and the last group received real-time information on traffic conditions to supplement navigation information (Pathfinder Mode).

Stage III - Vehicles were used for normal commuting by Los Angeles city employees.

Stage IV - Similar to Stage II, hired drivers were utilized for a structured yoked driving study but in this case traveled to unfamiliar destinations.

Each stage was designated to address specific elements of the project including human factors, the value of travel time and navigation information for familiar and unfamiliar travel routes, and user perceptions.

Evaluation Methodology

Figure 4-1 describes in detail the analysis techniques used to quantify the system objectives and measures of effectiveness for the Pathfinder evaluation. Statistical analyses were used to filter out factors which could impact the test results such as variation in driver characteristics and the trip samples.

An extensive database was created, maintained and analyzed using Pathfinder Evaluation Software. This software was configured around an off-the-shelf database package, interfaced with statistical analysis software.

Data Collection Program

Unlike INFORM, the evaluation of Pathfinder focused on individual response to ATIS rather than overall system results. Accordingly, much of the data collected as part of the evaluation was based on individual travel logs, human factor surveys, operator surveys, driver debriefings, etc. These data were supplemented by system generated data. A comprehensive summary of the data collection methods used to qualify each measure of effectiveness is also provided in Figure 4-1.

Figure 4-1 Pathfinder: Objectives, MOEs, Data Collection Methods and Analysis Techniques

OBJECTIVES	MEASURES OF EFFECTIVENESS	DATA COLLECTION METHODS	ANALYSIS TECHNIQUE
Driver Objectives			
Minimize Travel Time	Mean Travel Time Savings by: TOD/TL	Paired Comparisons using Trip Logs	ANOVA & Fisher's LSD
Maximize Travel Speed	Change in Mean Speed by: TOD/TL	Paired Comparisons using Trip Logs	ANOVA & Fisher's LSD
Minimize Number of Stops	Change in Number of Stops/Trip by: TOD/TL	Paired Comparisons with Recording by Pathfinder	ANOVA & Fisher's LSD
Minimize Speed Variance (measures ride quality)	Change in Standard Deviation of One Minute Speeds/Trip	Paired Comparisons with Recording by Pathfinder	ANOVA & Fisher's LSD
Minimize Vehicle Operating Cost	Change in Annual Operating Cost for Typical Vehicle	Trip Log Data	Report
Increase Driver Confidence	Driver Perception of Usefulness by: DE/TL/TOD/LOI	Trip Log Data Weekly Surveys Human Factors Surveys	Histograms Binomial & Multinomial Experiments Chi-square test
Maintain Safety	Reason for Diverting by: TOD/TL Change in One Minute Speeds/Trip by: TL/TOD	Paired Comparisons with Recording by Pathfinder	ANOVA & Fisher's LSD
	Driver Perception of Distraction	Weekly Surveys Human Factors Surveys Driver Debriefing	Histograms Report
Minimize Trip Distance	Change in Distance Travelled by: OD Pair/TL/TOD	Paired Comparisons using Trip Logs	ANOVA & Fisher's LSD
Minimize Travel Time Variance	Change in Coefficient of Variation of Travel Time By: TL/TOD	Paired Comparisons using Trip Logs	Report

TOD = Time of Day

TL = Trip Length

CL = Congestion Level

LOI = Level of Information

DE = Driver Experience with System

Source: JHK & Associates, 1993.

Figure 4-1 (continued) Pathfinder: Objectives, MOEs, Data Collection Methods and Analysis Techniques

OBJECTIVES	MEASURES OF EFFECTIVENESS	DATA COLLECTION METHODS	ANALYSIS TECHNIQUE
Public Agency/System Operator Objectives			
Improve Demand/Capacity Balance Among Facilities	Percent of Trips Diverted by: TL/TOD	Trip Logs	Report Case Studies
Minimize Vehicle Time in System	Change in Corridor VHT by: TOD/TL	Corridor-wide Estimates Based on Pathfinder Trip Data	Separate Analysis
Provide Additional Traffic Information to System Operator	Validity of Data Provided	Comparison of Pathfinder Data to Field Observations	Report
Optimize Routing Efficiency	Mean Ratio of Roadway Distance/Linear Distance by O/D Pair	Paired Comparisons using Trip Logs	ANOVA & Fisher's LSD
Optimize Network Coverage	Percent of Network for Which Data is Provided	Analysis Based on Experience with Pathfinder	Report
Detect Incidents	Number and percent of incidents Identifiable by Pathfinder Vehicle Data	Analysis of Pathfinder Trip Data	Report
Minimize Work Load	Amount of Time Required by Operator to Monitor and Run System	Operator Time Logs	Report
Pathfinder System Objectives			
Provide Functional System	Percent Machine Up-Time	Operator Log	Report
	Percent Successful Transmissions	System Recording	Report
Provide Effective Visual Information	Driver Rating of Visual Characteristics by DE	Weekly Surveys	Report, Chi-square
	Driver Rating of Voice (Clarity, Tone, etc)	Human Factors Surveys	Histograms
Provide Effective Voice Information	Driver Evaluation of Information Adequacy (Numerical & Comments)	Weekly Surveys	Report, Chi-square
		Human Factors Surveys	Histograms
Provide Effective Information Content		Weekly Surveys	Report, Chi-square
		Human Factors Surveys	Histograms
		Debriefing	Report, Chi-square

Source: JHK & Associates, 1993.

4.2.3 Evaluation Results

Significant findings and the general lessons learned from the Pathfinder evaluation are summarized in the following paragraphs: [JHK & Associates, 1993].

Navigation Benefits

- A small reduction in the percentage of motorists getting lost was realized with Pathfinder.
- Drivers were found to be ten times more likely to get lost when they diverted off their standard route.
- Approximately one third of the drivers perceived travel time savings using Pathfinder during their commute trips.
- On trips to unfamiliar destinations, comparing Pathfinder with no information, 79 percent of drivers travel time savings. When comparing the Pathfinder Mode with the Map Mode, 56 percent indicated their trips were faster.
- About half of the drivers felt that Pathfinder reduced their stress while driving.

System Effects

- Drivers diverted 40 percent more often in the Pathfinder Mode than in the Blank Mode (no information) and 27 percent more often than in the Map Mode.

- Diversion percentages suggest that Pathfinder has the potential to redistribute travel demands across a network.
- Interestingly, driver diversions decreased with increased familiarity with Pathfinder.

Travel Benefits

- Extensive paired comparison showed no significant differences among the display modes (Blank vs. Map vs. Pathfinder) for any of the mobility MOE's--travel time, travel distance, travel speed, etc..
- Factors cited that limited the quantifiable benefits of Pathfinder included:
 - The limited size of the corridor, relatively short origin--destination pairs, and limited alternate routes.
 - The lack of "severe" incidents during the evaluation program.
 - Human factors affecting interpretation of the data provided and the driver's willingness to divert.
 - Problems associated with information quality, content, and timeliness.

Driver Perceptions/Human Factors

- Extensive surveys measured drivers' overall perception of Pathfinder as well as its utility, accuracy, and the presentation of the information. The surveys showed:
- The overall driver perception of Pathfinder was very positive ("good" to "excellent") with the map feature with congestion information rated highest for usefulness.
- The text messages got the least favorable rating. Complaints ranged from "the text is too small" to "it provides too much information to absorb."
- The information presented by the various components of Pathfinder were rated for accuracy. The map got the highest rating (75 percent) and the voice message got the lowest rating (37 percent). These compare with a 25 percent accuracy rating for radio traffic broadcasts.
- Drivers were asked to rank the motorist information source which most strongly influenced their decision to divert. The responses were: 1) Actual traffic conditions (a write-in category); 2) Pathfinder, 3) Other sources; and 4) Commercial broadcast radio.

- Drivers perceived the map and voice components of Pathfinder easiest to use with the text ranked hardest.
- The ambiguity of the messages was a factor in the limited effectiveness of the system. Problems cited included use of confusing terminology, poor location descriptions, link-based reporting, lack of directional information, and inadequate secondary route information.
- Despite these findings, approximately two thirds of the drivers said they would purchased a Pathfinder unit if it cost about the same as a radio.

Pathfinder as a Surveillance Tool

- The project demonstrated that Pathfinder has little potential as an automated vehicle identification (AVI) or automated vehicle location (AVL) tool, but could be useful for commercial vehicle operations.
- Little practical insight was gained on the use of in-vehicle information systems as traffic probes due to the limitations of the Pathfinder experiment.

Lessons Learned

- Pathfinder broke new ground in the development and testing of in-vehicle motorist information systems in the United States. Many lessons were learned through this process:
- The Pathfinder experiment uncovered many human factor issues, including human interaction with in-vehicle technology, that require further study.
- The study confirmed the need for flexibility in all system attributes to adapt to new technologies and address problems with system operations and human interface.
- The Pathfinder project also demonstrated the need for comprehensive documentation, better integration of data from multiple sources, and improved interagency coordination and communication.
- Finally, the study confirmed that good quality traffic data is essential to ATIS success.

4.3 TravTek

4.3.1 Project Description

Overview

The one year TravTek experiment was completed in March of 1993 and is currently undergoing evaluation. TravTek, similar to Pathfinder, tested the usefulness of in-vehicle navigation and real-time traffic information. Again, the project was a public (infrastructure) and private (in-vehicle) partnership involving FHWA, Florida DOT, the City of Orlando, General Motors, and the American Automobile Association (AAA).

The formal planning and design of the TravTek experiment began in 1989. The project drew from the Ali-scout work in Germany, the Advanced Mobile Traffic Information and Communication System (AMTICS) in Japan and Pathfinder [Rillings, 1992]. The operational test involved equipping vehicles with in-vehicle navigation and information systems. These devices were capable of providing the driver with routing advice using real-time information on traffic conditions, as well as tourist information on local attractions. Information was obtained from an extensive transportation infrastructure largely established for this project.

The study area for TravTek included a 1,200 square mile section of metropolitan Orlando, Florida. The Orlando road network was an ideal location for this test because of its mix of local residents, tourists, and business travelers.

Project Configuration

The TravTek operational test had three major components: the vehicle system; the Traffic Management Center (TMC); and the TravTek Information and Services Center (TISC). A number of technical papers have described the TravTek architecture [Fleischman 1991] and [Rillings, 1992]. A schematic of the system is provided in Figure 4-2 (a).

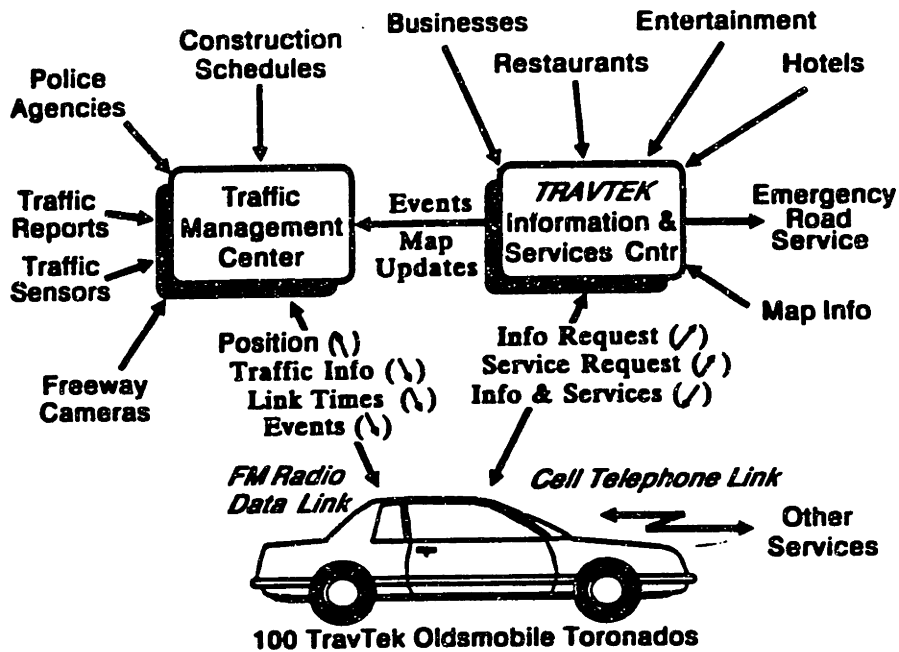
One hundred vehicles, including 75 rental cars and 25 vehicles for local drivers and specialized tests, were equipped with TravTek systems. The TravTek vehicle system consisted of the following key components:

- Navigation computer (80386-based)
- Routing Computer (80386-based)
- GPS receiver
- Voice synthesizer
- Traffic data transceiver
- Cellular telephone

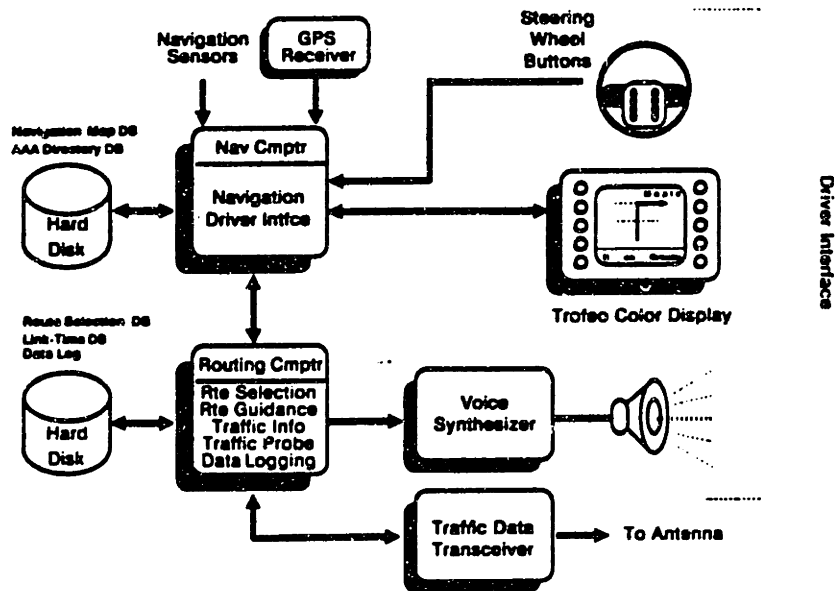
A simplified schematic of the TravTek vehicle architecture is depicted in Figure 4-2 (b). Information for the test was collected and distributed through a Traffic Management Center, under the control of the City of Orlando and the Florida DOT, and the TravTek Information and Services Center, operated by the AAA.

The TMC's collect function was to and process real-time traffic information for a network consisting of 822 one-way mile of roads. Traffic data is received from a

Figure 4-2 TravTek: System Architecture



(a) System



(b) Vehicle

Source: Rillings and Krage, 1992

variety of sources including: loop detectors at approximately 250 intersections; video surveillance, Metro Traffic Control, a commercial radio traffic-reporting company; local and state police; and the TravTek vehicles themselves. These data were processed by the TMC and transmitted to the vehicle every minute with adjusted travel time information and congestion advisories.

The TISC, located at the AAA regional headquarters in Heathrow, Florida, provided the TravTek system with information on attractions, lodging, restaurants, special events, and other local businesses and services. The TISC also served as an on-line help service to TravTek users for emergency road service or questions on the system. The TISC data bases were periodically updated, either through the TMC or by loading new files into the in-vehicle computer. The TravTek project cost a total of \$12 million. No further breakdown of these costs is currently available.

4.3.2 Project Evaluation

Goals and Objectives

The TravTek evaluation plan is the most extensive operation test evaluation plan, to date. Some elements of the evaluation were integrated into the system design to facilitate data collection and analysis. The plan was developed over a one year period by an Evaluation Working Group which was comprised of representatives from each partner organization.

The early tasks of the working group were focused on developing a consensus on the objectives and goals of TravTek among the different partners. Overlapping research interests among the parties involved can generally be broken down into five areas:

- Transportation/Network Effects
- Safety Effects
- Human Factors
- System Architecture Performance
- Market Research

The objectives and evaluation goals developed by the working group are summarized in Table 4-4. These objectives were then prioritized to assign appropriate levels of research funding.

TABLE 4-4

TravTek: Objectives and Evaluation Goals¹⁰

- A. Trip/Network Efficiency
 - 1. Congestion Avoidance
 - 2. Time Savings
 - 3. Pollution Reduction
 - 4. Fuel Savings
 - 5. Reduced Vehicle Operating Cost
- B. Benefits to Non-TravTek Users
- C. Driver Performance/Behavior/Satisfaction
 - 1. Driving/Navigation Behavior
 - 2. Perception of Congestion, Time, Safety
 - 3. Usability/Learnability
 - 4. Feature Use (Route guidance, voice guidance, phone, local info. etc.)
 - 5. User Friendliness/Driver Satisfaction
- D. Safety
- E. System and Subsystem Performance
 - 1. Hardware
 - a. Reliability
 - b. Compatibility
 - 2. Software
 - a. Reliability
 - b. Compatibility
 - 3. Data
 - a. Accuracy (map, local information, etc. databases)
 - b. Timeliness
 - 4. Operations/Procedures
 - a. Data Collection (map, traffic, events, local information)
 - b. Data Input-TMC, TISC
 - c. Driver Recruitment, Training, Debriefing
 - d. Helpline Management
 - e. Vehicle Management
 - f. Vehicle Maintenance
- F. Image
- G. Impact Future Transportation/Travel
 - 1. Generalizable/Transportable
 - 2. Technology Transfer
- H. Feature Preferences
- I. Price/Cost
 - 1. Willingness, personal vehicle
 - 2. Willingness, rental vehicle
 - 3. Infrastructure (TMC, TISC)
- J. Local Area Impact
 - 1. Improvements Beyond TravTek Operating Period
 - 2. Routing through Sensitive Areas (neighborhoods, hospitals, etc.)
 - 3. Local Driver Usage
 - 4. Local Jurisdiction, Policy Issues
 - 5. Macroeconomic Benefits

¹⁰Source: Fleischman, 1991.

Evaluation Methodology

The next phase in the development of the plan was to distill the long list of objectives and goals for the evaluation into a workable set of hypothesis and assign measures of effectiveness to each. Ten TravTek evaluation areas were flushed out through this process [Ferradyne Systems, 1991]:

- Trip/Network Efficiency
- Benefits to Non-TravTek Users
- Driver Performance/Behavior/Satisfaction
- Safety
- System and Subsystem Performance
- Image
- Impact on Future Transportation/Travel
- Feature Performance
- Price/Cost
- Local Area Impact

More than 60 MOE's were identified to assess the impacts of TravTek in each of these areas. A complete description of these MOEs is provided in Appendix B. The evaluation plan took extra care to ensure that a number of MOEs were defined for each TravTek objective.

To quantify the measures of effectiveness, a series of twelve studies [Peters, et al, 1993] were included in the scope of the evaluation plan.¹⁰ These included:

¹⁰The studies were reorganized slightly from the original evaluation plan during the course of the test.

- **Field Study with Rental Car Users**
- **Field Study with Local Users**
- **Yoked Driving Study**
- **Orlando Test Network Study**
- **Camera Car Study**
- **Debriefing and Interview Study**
- **Questionnaire Study**
- **Modeling Study**
- **Safety Study**
- **Architecture Evaluation Study**
- **Differential Global Positioning System Study**
- **Global Evaluation (integration of all studies)**

In most cases more than one study was used to quantify the defined MOEs
Appendix B lists how the various approaches were utilized.

Similar to the experimental design of Pathfinder, three configurations of the
TravTek vehicles were utilized for the rental car field study:

Services provide users with access to only the information and services
database (the control group);

Navigation includes services and autonomous navigation functions (routing
advice from a static data base); and

Navigation Plus which featured of all the functions of service and navigation with the addition of real-time traffic information and dynamic routing advice.

Two configurations (Navigation and Navigation Plus) were available for the local users field study.

Data Collection Program

A variety of data sources were available to the project evaluation team, many of which were generated by the system. Because the evaluation plan was developed so extensively before the operational test began, the format and content of the data maintained by the system could be tailored somewhat to meet the research needs. Sources of data include the in-vehicle log, the TMC log, the TISC log, the AVIS log, the driver fueling log, the Oldsmobile maintenance log, police and traffic departments logs, experimental logs, driver profiles, and questionnaire/interview data. The expected data source for each piece of the analysis is referenced to each MOE in Appendix B.

4.3.3 Evaluation Results

The TravTek evaluation is expected to be formally completed by June of 1994; however, the evaluation team has made several preliminary presentations of their findings at industry conferences and meetings. This section describes the limited results to date of the TravTek operational test.

Rental User Perceptions

The questionnaires and driver debriefings revealed user perceptions and opinion on TravTek [Perez, et al., 1993]:

- The system was generally perceived as easy to use.
- Drivers of the N and N+ configurations viewed the system as easy to understand and felt it helped them find their way, save time, and concentrate more on their driving.
- Drivers of the N and N+ configurations did not feel that TravTek interfered with their driving.
- Rental drivers were very positive about the system's visual displays and voice guidance.
- Drivers showed a preference for visual displays with voice augmentation.

Route Guidance Usage

An early component of the TravTek analysis of rental car and local users focused on how drivers use the route guidance function. Some preliminary results showed [Fleischman, et al, 1993]:

- Route guidance was used by both rental car drivers and local drivers for approximately half of their trips.
- Rental drivers most often selected a destination from the services/attractions directory. Local drivers most often selected a pre-set destination from the saved list.
- Drivers from all groups opted for the "fastest route" more than the "avoid tolls roads" and "avoid interstates" options.
- The Guidance Map display (a more detailed turn by turn map) was preferred over the more general Route Map. (The default display is the Guidance Map).
- Voice guidance was used 90 percent of the time by rental car users and just under 70 percent of the time by local users. (The default condition was with the voice guidance on).

Navigation

Controlled field experiments conducted as part of the TravTek evaluation offer insight on driver performance under different navigation displays. Preliminary results of the Orlando Test Network Study (OTNS) presented by Inman [1993] showed:

- The OTNS tested if TravTek saved time in trip planning when drivers were asked to navigate to unfamiliar destinations. Under this test, TravTek was shown to save 81 percent of the usual trip

planning time (using a traditional paper map or telephone assistance).

- With respect to time savings, route guidance saved upwards of 20 percent in travel time over the control case (no displays).
- In terms of navigational errors, there was no significant change in the rate of wrong turns taken with TravTek.

Willingness to Pay

The willingness of rental users to pay for the TravTek system was revealed through questionnaires, and driver debriefings. Preliminary results [Perez, et al, 1993] show:

- The average willingness to pay for the TravTek system was \$900.
- Drivers stated a willingness to pay approximately \$400 for navigation and route guidance features, \$200 for services and attractions, and \$300 for real-time traffic information.
- Perceived safety and driving benefits may be important factors in predicting ATIS product acceptances/willingness to pay.

Architecture Evaluation

Early work conducted as part of the System Architecture Evaluation examined the quality of the traffic information and the reliability of the subsystems. Preliminary findings were reported by Blumentritt, et al. [1993]:

- Approximately 12 megabytes of data were logged by the TMC everyday during the first 9 months of the TravTek experiment. Over the final 3 months of the project, 20 megabytes of data were logged daily.
- Only 90 miles of the 897 miles of roads included in the TravTek network were covered by real-time surveillance (detector and/or video).
- Other sources of travel time information included historical measurements, the TravTek vehicles themselves, model output and incident reports. More research is underway to determine the quality of these sources.
- Overall availability of the subsystems exceeded 96 percent over the course of the project.

Network and Safety Effects

Very little data have been released to date on the network and safety effects of TravTek. Analysis of network effects is underway at Queen's University [Van Aerde et al., 1993] on a simulation model suitable for predicting changes in travel times and the calibration of a fuel consumption and emissions model. The safety study is also on-going, coordinated by Perez and Van Aerde.

Results from these efforts will probably not be available until close to the end of the evaluation program, expected in June of 1994.

4.4 SmarTraveler

4.4.1 Project Description

Overview

The one year SmarTraveler operational test was officially launched in January of 1993. This advanced traveler information system utilizes telephone based technology to disseminate "real time", location specific, information on traffic and transit conditions. The system covers eastern Massachusetts (inside Interstate 495) and Cape Cod. SmarTraveler was the first ATIS demonstration in the United States to have a private company as the lead party. The project was implemented as a public-private partnership among the Federal Highway Administration, the Massachusetts Highway Department (MHD) and SmartRoute Systems.

SmarTraveler involves monitoring traffic and transit conditions within its operating area and disseminating this information to the traveler from an operations center in Cambridge. The system covers approximately 700 miles of major highways and arterials. Conditions on bus, commuter rail and rapid transit services operated by the Massachusetts Bay Transportation Authority are also maintained. Callers access specific route or mode information via a touch tone telephone.

System Configuration

The SmarTraveler uses a variety of information sources to maintain up-to-date status on roads and public transportation, including:

- Thirty-eight video cameras (13 live, 24 slow scan, and one pan zoom and tilt).

- Sixty contracted, scheduled mobile phone probes.
- One hundred informal mobile phone and two-way radio probes
- Two-way radio communication with Logan Express buses
- Monitoring 300+ public agency and emergency frequencies on eight electronic scanners.
- Two fixed-wing aircraft, operating a total of 15 hours daily
- Direct ring-down lines to the State Police, Massachusetts Highway Department, Amtrak, and the MBTA.

In addition, the SmarTraveler information center maintains a regular database on construction activities, special events, and alternate routes.

This information is stored and managed on computers by traffic managers and transferred regularly to an audiotext system. When the SmarTraveler user accesses the system, s/he simply presses the route number or location code (e.g. downtown Boston, Logan Airport) on a touch tone telephone. Up-to-date information on that route or mode is then provided to the listener.

The total capital cost of the SmarTraveler system is \$0.5 million. The annual operating budget for the test period is \$1.44 million. [SmartRoute Systems, 1993].

4.4.2 Project Evaluation

Goals and Objectives

In late 1992, the Massachusetts Highway Department issued a Request for Proposals (RFP) for the SmarTraveler operational test evaluation. A fairly detailed scope of work was developed by the MHD and reviewed and approved by the FHWA [Massachusetts Highway Department, 1992].

The objectives of the operational test as defined by the RFP are:

- To demonstrate public acceptance of real-time , location specific traveler information delivered by telephone;
- To assess the utility of this information;
- To evaluate the traffic impact of real-time information
- To test the viability of privatization of the delivery of travel information.

The evaluation effort was charged with the assessment of these objective as well as the identification of improvements to data collection practices and information dissemination.

Unlike the previously reviewed evaluation plans, neither the RFP nor the subsequent consultant contract utilized a typical planning matrix of objectives, MOEs, and analysis methods for evaluation design. Instead, the consultant contract, which follows closely the format of the RFP, identifies a series of analysis methods and questions about SmarTraveler that might be answered through these analyses. At this point, it can only be assumed that a more rigid structure with definitive MOEs might be revealed during the survey design phase of the evaluation.

The evaluation got underway in March of 1993 and is currently expected to be completed by March of 1994. (A proposal to extend the operational test until March of 1994 is being considered. This would also extend the evaluation deadline to June of 1994).

Evaluation Methodology

A summary of the SmarTraveler Evaluation Plan is provided in Table 4-5. [MHD, 1992; Multisystems, 1993]. For the purposes of this review, key components of the plan have been categorized as: market and behavior studies; market segmentation; profile of service consumed; assessment of traffic monitoring sources; institutional issues; and, synthesis and reporting. A separate component of the evaluation contract involves developing a privatization feasibility study and plan.

To gain an understanding of the characteristics and behavior of the probes used for data collection and the users (both present and former) of the system, a number of surveys will be conducted as part of the evaluation. These surveys include a mobile and two-way radio probe survey, a user survey and a non-repeat user survey. It is hoped that these surveys will reveal a range of insights on the project and its participants. The key information sought from these surveys is elaborated on in Table 4-5.

TABLE 4-5
SmarTraveler: Summary of Evaluation Plan¹¹

<u>Analysis/Methodology</u>	<u>Key Information</u>
1. Market and Behavior Studies	
Mobile and Two-way Radio Probe Survey:	<ul style="list-style-type: none"> • Reporting frequency • Travel characteristics • Information reported • Opinions/comments on system
User Survey:	<ul style="list-style-type: none"> • User profile • Frequency of usage • Trip characteristics • Information requested • User response to information • Perceived benefit • Timeliness and quality of information (Vis a vis radio) • Expected future usage
Non-repeat User Survey:	<ul style="list-style-type: none"> • Reasons why users elect not to call again
2. Market Segmentation	
Analysis of telephone call sources and usage rates	<ul style="list-style-type: none"> • Land-based vs. mobile source calls • Willingness to pay
3. Profile of Service Consumed	
Analysis of system utilization:	<ul style="list-style-type: none"> • Call counts • Time of day, day of week variations • Variation due to weather • Information sought by callers
4. Assessment of Traffic Monitoring Sources	
Analysis of each data source:	<ul style="list-style-type: none"> • A profile of data sources • Quality and timeliness of data • Coverage of data collection (to identify "blind spots")
5. Institutional Issues	
Participant Interviews:	<ul style="list-style-type: none"> • Institutional barriers • Jurisdictional issues • Probe turnover
6. Synthesis and Reporting	
Assess the quality of service and cost/benefit from a public sector perspective:	<ul style="list-style-type: none"> • Adequacy of data collection • Accuracy of information • Public acceptance • Profile of users • Impact on traffic congestion • Reliability of technology • Feasibility of privatization plan • Benefit/cost analysis

¹¹Summarized from Request for Proposals issued by the Massachusetts Highway Department in November of 1992 and Proposal submitted by MultiSystems in January of 1993.

Market segmentation and a profile of the services consumed will be analyzed to determine the source of calls and any unique locational or facility patterns of information requested.

A review of the adequacy of the traffic monitoring program will be conducted as one component of the plan. Although the plan is not specific as to how this analysis will be carried out, it is intended to provide an assessment of the quality and timeliness of the data sources, the appropriateness of this coverage, and areas for improvement.

Institutional and jurisdictional issues will be the focus of the fifth component of the plan. These issues will be uncovered through interviews with participants in the operational test.

The final task of the evaluation plan involves the synthesis of all previous reports and studies into a summary of the quality of service provided by SmarTraveler and its relative costs and benefits.

Data Collection Program

The vast majority of the data used for the SmarTraveler evaluation will be collected through surveys and participant debriefings. The data sought through these efforts were summarized previously in the Table 4-5.

The data used to evaluate market segmentation, usage and a profile of services consumed will be largely generated by the system. This data base has been adapted

somewhat during the course of the operational test period to meet the requirements of the evaluation plan.

4.4.3 Evaluation Results

There are no extensive results to be reported on SmarTraveler, as data collection and analysis is still in progress. SmartRoute Systems [1993] issued an informal report on early funding which overviews preliminary system statistics and market issues.

In a recent discussion, the Project Manager for the evaluation team [Juster, 1993] indicated that SmarTraveler receives approximately 8,000 calls per weekday. Approximately 58 percent of these calls are being made from mobile telephones, while 42 percent are being made from land-based telephones, prior to the trip. This represents a very small fraction of the total trips being made within the SmarTraveler market area. As such, the effect on network congestion and safety is expected to be neutral.

The evaluation underway is instead focusing on people's awareness of the system, how they utilize the information, the types of trips being affected, the effectiveness of the data collection, and the potential for privatization of the system.

4.5 Trafficmaster

4.5.1 Project Description

Overview

To supplement the limited early results of ATIS operational tests in the United States, a case study for this thesis of Traffic master was drawn from the United Kingdom (UK). Trafficmaster was also selected because it is an example of a wholly private sector ATIS initiative. The same technology used for Trafficmaster is expected to be demonstrated on the Washington, DC beltway in 1994.

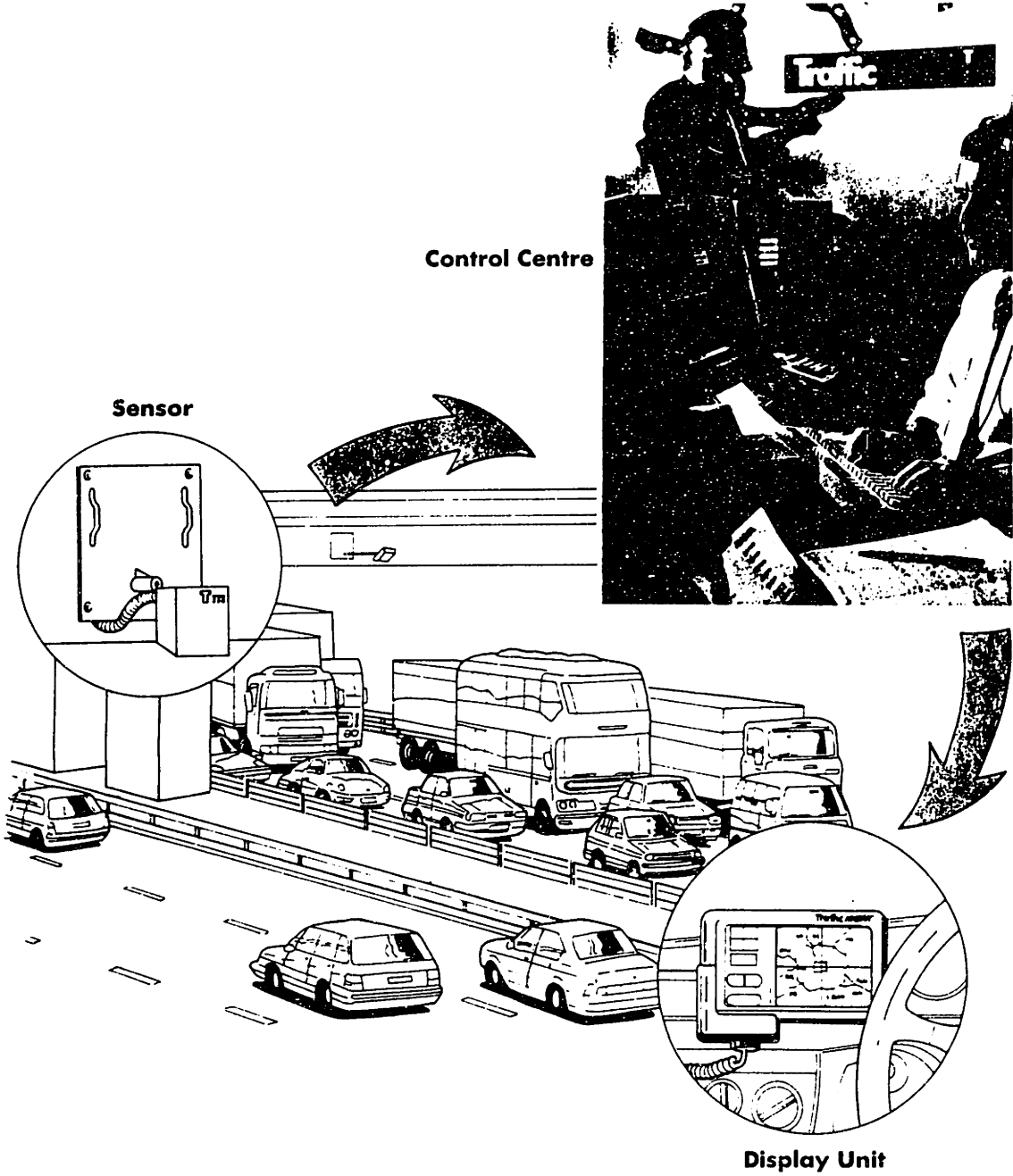
Trafficmaster is a commercially available in-vehicle ATIS that covers over 1,000 miles of motorway in the UK. Trafficmaster was developed and is operated by General Logistics PLC.

Trafficmaster started as a pilot program under the Department of Transport in September of 1990 and initially covered the M25 (a beltway around London) and a few nearby motorways. In February of 1992, Trafficmaster received a full 12-year license under the 1989 Road Traffic (Driving, Licensing and Information System) Act and launched its nationwide program in May of 1993.

System Configuration

There are three important components of the Trafficmaster system: the sensor, the control center, and the in-vehicle display. A schematic of the system is provided in Figure 4-3.

Figure 4-3 Trafficmaster: System Architecture



the system

- the sensor
- the control centre
- Trafficmaster[®] display unit

Source: General Logistics PLC

Trafficmaster relies on approximately 800 infra-red vehicle sensors mounted overhead along the various motorways it monitors. These sensors measure the volume and speed of traffic on the road. The data are microprocessed in the field every three minutes and when speeds drop below a preset threshold (usually 30 mph), are radio broadcast back to the Trafficmaster control center.

The control center collects sensor data and monitors several other sources:

- Police
- Motoring Clubs and Organizations
- Road Repair Contractors
- Local Governments

These data are analyzed by a central computer and translated into geographical and narrative text formats. This information, updated every three minutes, is then sent using a radio paging network to the in-vehicle unit. The control center is housed at the General Logistics PLC headquarters in Bedfordshire.

The Trafficmaster unit is a portable radio receiver that can be used in a vehicle, in the office or at home. The screen provides a map display with zoom capabilities and an accompanying narrative. Speeds (below the threshold) are shown at 5 mph intervals. Queue lengths are implied from the speed and map displays. The Trafficmaster unit also provides a message pager option.

Since Trafficmaster is a private sector initiative, detailed cost data are not readily available. It was estimated by TRRL [Stevens, 1993] that the sensors cost approximately \$1,000 each, installed. These sensors are owned and operated by General Logistic PLC. (They sell historical traffic data to the government for planning

purposes). The Trafficmaster unit costs approximately \$500 to purchase, including installation, delivery and connection. The user also pays approximately \$35 per month for the information subscription.

4.5.2 Project Evaluation

Goals and Objectives

The evaluation of Trafficmaster was conducted by the Transport Research Laboratory (TRL) during 1991 and 1992 for the UKDOT. This detailed assessment program was carried out to determine [Stevens and Martell, 1993]:

- Type and quality of information disseminated
- Public acceptance/response to information
- Safety implications of driver/in-vehicle unit interface
- Network traffic effects
- Network safety effects

The assessment was organized into six sub-assessments: day-file analysis; questionnaires and driver logs; modelling studies; reading and comprehension tests; driving simulator studies; and instrumented vehicle trials. Data and results from all six assessments were compared and synthesized to draw conclusions on the overall traffic and safety implications of the system.

Evaluation Methodology

The methods used in the six individual studies which comprise the overall Trafficmaster assessment are summarized in Table 4-6. Key information to be revealed by each study is also elaborated on in the table.

TABLE 4-6
Trafficmaster: Summary of the Evaluation Plan¹³

<u>STUDIES</u>	<u>METHODS</u>	<u>KEY INFORMATION</u>
1. "Day-file" Analysis	Six month monitoring of speeds and congestion information generated by the system	<ul style="list-style-type: none"> •Variation in speeds and congestion •Type and quality of information presented to drivers •Value of information for traffic management
2. Questionnaires and Driver Logs	Two postal questionnaires over six - month period Driver logs over two-week period from 25 participants	<ul style="list-style-type: none"> •Driver profile •Previous sources of traffic information •Trafficmaster usage •Response to information •Comments on display •Perceptions on benefits
3. Modelling Studies	Spread sheet analysis of traffic diversions using alternate route information and results of study 2 (above)	<ul style="list-style-type: none"> •Existing diversions attributable to Trafficmaster •Future diversions attributable to Trafficmaster •Safety implications
4. Reading and Comprehension Tests	Static laboratory tests of 24 subjects	<ul style="list-style-type: none"> •Average reading times per display •Average comprehensive •Complexity of message vs. reading time
5. Driving Simulator Studies	Dynamic simulation of difficult and critical driving conditions using 20 Trafficmaster users as subjects	<ul style="list-style-type: none"> •Attentional demand of Trafficmaster •Glance times and duration •Driver response to information
6. Instrumented Vehicle Trial	In-field testing of Trafficmaster attention requirements vs other during tasks using instrumented vehicle and 20 subjects	<ul style="list-style-type: none"> •Attentional demands of Trafficmaster •Driver response to information •Attentional demands of other tasks

¹³Extracted from "Assessment of the Trafficmaster driver information system: Summary and discussion of traffic and safety implications," A. Stevens, Transport Research Laboratory, 1992.

The "Day-File" Analysis investigated the variations in speeds and congestion on the network and the type and quantity of information disseminated to the drivers.

The Questionnaire and Driver Logs were used to learn about user characteristics, driving patterns, acceptance and response to information, opinions on the system, and perceptions of benefits. The Modelling studies then used some of this data to help quantify the traffic and safety effects of Trafficmaster on the network.

The last three studies (Reading and Comprehension Tests, Driving Simulator Studies, and Instrumented Vehicle Trials) were focused on the human-machine interface. The primary objective of these studies was to measure the safety implications of the driver distraction caused by Trafficmaster.

Data Collection Program

Data used for the TRL assessment were collected from a variety of sources including (as previously alluded to): computer generated files of speeds, congestion and information output; questionnaires; driver logs; person-machine laboratory tests; driving simulator studies and instrumented vehicle field trials. These observations and statistics are reported on in a series of internal documents and published technical papers by the TRRL.

4.5.3 Evaluation Results

Key results of the Trafficmaster pilot program assessment are summarized as follows:

System Effects [Royles and Stevens, 1992]

- On regular trips, 37 percent of motorists were found to divert less using Trafficmaster, while 47 percent were found to divert more.
- On less frequently made trips, TRL's research showed that 24 percent of motorists using Trafficmaster diverted less, while 39 percent diverted more.
- Overall, a slight increase in the number of mainline diversions was attributed to Trafficmaster.
- TRL estimated that the effects of additional diversions on the traffic network are insignificant at present levels of market penetration
- Under future conditions, it will be the density of actively used Trafficmaster units on a given link, not the overall number sold, that will affect network traffic operations.
- Given this condition, the TRL concludes that market penetration and system traffic effects will be diluted as the Trafficmaster market area grows and that the overall system effects will be "broadly neutral".
- For the isolated service area of M25 and several adjacent motorways (the original pilot area), TRL estimates that 50,000 units would have to be sold to affect a 1 percent diversion from the mainline.

- The safety implications of the diversions attributed to Trafficmaster showed a very small net increase in accident cost.
- TRL noted in their research that three more sophisticated modelling techniques could be supplied to the problem: Queues and Delays at Roadways (QUADRO); Motorway Continuous Traffic Assignment Model (MCONTRAM); and Route Guidance Simulator (ROGUS). However, each of these models requires significantly more data on Trafficmaster than is currently available.

Driver Interface [Stevens and Martell, 1993]

The man-machine interface analyses of Trafficmaster provided the following insights on the safety issues associated with its use:

- The reading and comprehension tests revealed that the average time required to read the in-vehicle display was 4 to 5 seconds with an average comprehension rate of 91 percent.
- As the message became more complex, the reading time increased.
- Driving simulator studies showed that drivers typically took two to four glances at the Trafficmaster display with average durations ranging from 1 to 2 seconds.

- Simulation and field trial results showed a decrease in vehicle control under Trafficmaster operation. No standards or thresholds by which to compare these results exist.
- When compared with other tasks conducted while driving, it was found that Trafficmaster offers slightly greater distraction than operating a cassette player or radio.

User Perceptions/Acceptance [Royles, 1992]

The user questionnaires and driver logs showed:

- Trafficmaster users were very satisfied with the service.
- Many users felt it reduced their stress and saved their time.
- Approximately 83 percent of drivers were using Trafficmaster 3 to 5 days per week and 27 percent reported using it 6 to 7 days per week.
- Prior to Trafficmaster, the most common source of pre-trip traffic information was the radio, used (at least sometimes) by 70 percent of the respondent. Approximately 78 percent of respondents said they also used the radio during this trip for traffic information.

- Of the 70 percent that used the radio for pre-trip information, only 10 percent thought it was an effective source. Of the 78 percent that used the radio during their trip, only 6 percent thought it was effective and timely.
- There was a measurable reduction (13 to 27 percent) in the use of other traffic information sources after implementation of Trafficmaster.
- With respect to the quality of the display, approximately one third of the users found it hard to read in daylight and 15 percent found it hard to read at night.
- Approximately 19 percent of users believed that Trafficmaster significantly distracted them from their driving.
- Overall, 55 percent of the users responded that Trafficmaster reduced the stress levels while driving. Only 3 percent felt that it had increased their stress level.

5 COMPARATIVE EVALUATION FRAMEWORK

5.1 Background

Underwood and Streff [1992] identified comparative evaluation as an important form in the overall IVHS evaluation process. This focus of evaluation involves comparing the costs and benefits of various system architecture to make a determination on the cost effectiveness and appropriateness of the various technological approaches.

Although Underwood argues that a meaningful (valid) comparison can only be made when these technologies are tested under identical conditions, it is unrealistic to think that policy makers will not try to compare the results and benefits of the various operational tests (even when it may be desirable to compare them under ideal settings). In fact, the ISTEA and the IVHS strategic plans developed by IVHS AMERICA and the U.S.DOT acknowledge this and have called for uniform evaluation guidelines to facilitate this comparison.

Underwood's case for a uniform test bed to compare architecture is perhaps most appropriate and easiest to implement when the systems being tested are closely related to one another, with only subtle differences (i.e. two in-vehicle navigation systems). But in the case of ATIS--that is the general dissemination of advanced travel information--there are a wide range of techniques and approaches that are being tested. It is difficult, perhaps even impossible, to develop consistent experiments by

which to compare, as examples, a variable message sign system with a telephone-delivered traffic information system.

As the operational test program is carried out and evaluation plans are designed and implemented, there will be increased opportunity to make comparison, or at least make judgment, on the relative merits of the various IVHS technologies. It is worthwhile at this early stage in the process to define an evaluation framework to provide some structure for the conduct of these comparisons.

The comparative evaluation framework proposed in this thesis focuses on two areas: 1) what ATIS concept has the best long-term potential; and 2) what are the operational and maintenance implications for the public sector-- the long-term planning issues-- associated with the ATIS deployment.

The first component of this comparative evaluation framework concentrates on the key benefits and costs that are expected from implementation of the ATIS concept. To accomplish this, the analyst must have at his/her disposal uniform measures of effectiveness that have been quantified using similar methodologies. This component of the thesis will define a number of MOEs for the purpose of quantifying and comparing the benefits and costs of ATIS tests. Chapter 6 will investigate how well the evaluations completed to date fit within this comparative structure and satisfy the evaluation guidelines defined by the U.S. DOT.

At the outset it should again be emphasized that this framework is being developed from the perspective of a transportation policy maker. A transportation policy maker will make decisions on whether or not to invest in advanced

information systems, or what type of system to invest in, based on the cost effectiveness of the system (i.e. the benefits accrued to the public vs. the costs to implement and operate the system). A "perceived" benefit of ATIS might translate into a willingness to pay for such a service but does not translate into a "real" public benefit. This distinction is important in sorting out the costs and benefits of such systems. Furthermore, a private benefit (i.e. an equipped vehicle user's saving of travel time) does not translate directly into a public benefit unless there is some measurable system effect--that is a marginal savings on the part of all users of the network. The comparative framework must be based on public costs and public benefits.

The second piece of the framework must set forth the long-term planning implications of ATIS strategies for the public sector; in other words, what is the legacy of the ATIS technology? Is operation and maintenance of the system overly burdensome, or not? Are there on-going public sector responsibilities inherent in the system? This component of the framework is more qualitative and speculative; however, it is important for public sector officials to think in these terms prior to committing to technology and systems which they may not be able to afford to operate and maintain.

5.2 A Comparative Evaluation Framework

There are broad goals established for the United States IVHS program in all of the planning documents that have been issued by the various public and private groups that have an interest in the field. These range from increased safety to improved economic productivity, as discussed in Chapter 2 of this thesis.

The goals and their associated benefits are complex. Some of the impacts resulting from the implementation of ATIS can be measured, some can be modeled, and some are intangibles. (This problem was made clear in the level of "inconclusive" results reported on in the case studies.) These impacts are further clouded by the issue of who pays and who benefits in the public/private make-up of the IVHS industry.

From the more pragmatic perspective of the transportation planner or policy maker, however; the goals of IVHS and, more specifically ATIS, are straightforward and fundamental: to improve the safety and efficiency of the operation of the transportation system. The objective of the comparative framework is to assess and compare how well the various approaches to ATIS are achieving these goals and for what costs.

The operational tests are intended to test the viability and robustness of the various ATIS technologies. This process may lead to technological enhancements and refinements to the systems. It may also eliminate some technologies that are obsolete or problematic. Any technology being considered for deployment by a public sector agency should "pass" certain pre-tests (or demonstrations) to be eligible. (The public sector confidence in technology is also strengthened if the manufacturer is required to operate and maintain the system.) Therefore, the evaluation framework will ignore the issue of technology performance and assume that the system being compared is "workable".

5.2.1 ATIS Benefits

There is a general consensus that the public benefits which might accrue from the development of ATIS strategies fall into four general categories; reduced congestion, enhanced safety, improved air quality, and lower energy use. There is no consensus (and much debate) over which measures of effectiveness most accurately quantify these benefits. A discussion of each category of impact and the approach prescribed in the comparative evaluation is provided in the following sections.

Reduced Congestion

Ideally, full implementation of ATIS should result in multi-modal network flow optimization--that is the optimal balance of demand and capacity to maximize the system's utility. In terms of the road network, ATIS could reduce overall congestion by effecting mode shifts, time of day shifts, diversions to alternate routes, and the elimination of some more discretionary, low valued trips altogether.

Research on user behavior should provide some information on the potential for mode shifts, time of day travel shifts, motorists' tendency to divert from major routes and decisions not to travel. Understanding and quantifying these isolated components of ATIS's potential traffic impact is not complicated. The difficulty arises in aggregating market penetration and user response into a reasonable estimate of system effects.

The spatial and temporal factors which affect system impacts adds more complexity to the problem. Significant mainline diversions, for example, can quickly over-saturate alternate routes, impact local streets, and, in the overall system, cause

more delays and social disbenefits. Network optimization is a delicate and dynamic balancing act.

In the aggregate, the most effective measure of road system performance is travel time or average travel speed. This is true because time savings or higher speeds always indicate higher service quality; unlike the more ambiguous measure of vehicle miles traveled (VMT), which in the case of diversions to alternate routes, may *increase* while the origin to destination travel time *decreases*.

To translate travel time or speed improvements into benefits, one must consider reduced vehicle delays and the value motorists place on their time. Vehicle delays can be calculated using congested and free-flow speeds, distance and volume data, for conditions before and after ATIS implementation. This infers, of course, that all else is equal and, in fact, the analyst must take great care to ensure that abnormalities (i.e. weather, major incidents, etc.) are filtered out of the analysis so that "typical" conditions are compared.

Enhanced Safety

Systems safety effects of ATIS deployment are equally complicated. Driver control might be negatively impacted by the en-route distractions caused by in-vehicle devices or variable message signs. Conversely, system safety might be enhanced through ATIS deployment by increasing the driver's knowledge of what lies ahead, by the reduction of delays and queues, or by less variable traffic conditions. Again, it is necessary to study the aggregate system safety effects. This requires a thorough understanding of accident and traffic volume patterns by location, accident severity, and reported accident causes. It is much easier to establish a cause and effect

relationship in a safety analysis because of the institution of accident reporting and insurance claims.

Improved traveler information can affect system safety in unexpected ways. If motorists are advised to divert from a mainline to avoid congestion, the probability of an accident on the mainline decreases while the probability of an accident on the alternate route increases. In general, freeway accident rates are lower than arterial accident rates; hence, the total number of accidents might actually increase with ATIS deployment. To counter this, the severity of accidents (personal injury or fatalities) on arterials is generally lower than on freeways, so the total accident costs might go down or remain unchanged. Therefore, a reduction in the total number of accidents is not an appropriate safety measure of effectiveness for ATIS deployment. Nor is it sufficient to simply study accident statistics on the mainline.

For the purposes of developing this comparative evaluation framework, accident cost savings was selected as the measure to quantify the safety benefits of ATIS. These savings are calculated by a time series comparison of total accidents by severity for the entire study area. Again, this assumes that factors which invalidate the before and after comparison are isolated or adjusted for in the analysis. Furthermore, this MOE does not try to account for the delay characteristics of different types of accidents on different types of facilities. These delay costs and benefits are far too speculative to be reliably used for a broad comparison of system effects.

Improved Air Quality

The measure of effectiveness used to quantify system benefits for air quality is straightforward: reduced emissions (HC, CO, NO_x). However, the methodologies

available to quantify such benefits are the subject of enormous technical debate, heightened by the new demands placed on states to comply with the Clean Air Act Amendments of 1990.

In addition to the standard parameters of fleet mix, age and atmospheric conditions, it has been shown that mobile emissions may vary according to a number of travel characteristics: distance traveled; the length (idling time) and number of stops; the vehicle speed profile; the level of congestion; and the number of cold starts and hot soaks.

Existing air quality models lack the sensitivity to account for these more subtle shifts in travel characteristics. As a result, many local and state agencies, as well as academic institutions, are devoting significant efforts toward developing more sophisticated models. As an example, a combined air quality and fuel consumption model is being developed specifically for use in the TravTek evaluation [Van Aerde and Baker, 1993] to define the fuel consumption and emission indications of the TravTek technology.

Lower Energy Use

Measuring the impact on energy use of ATIS deployment is similar to air quality in that the measure of effectiveness is obvious (reduced fuel consumption) but the methodology necessary to quantify the benefit is complicated.

Fuel usage depends on many of the same factors which affect emission rates. In fact, the two are closely related. And again, standardized models are not sensitive enough to subtle shifts in travel characteristics that may result from ATIS deployment.

It is also unclear as to whether or not fuel savings represents a public or private good. The users of the system will capture the savings of any reduction in fuel usage. And, aside from reduced emissions, it is hard to quantify any other public benefit that would accrue. For these reasons, fuel consumption was not included in the comparative evaluation framework.

5.2.2 ATIS Costs

There may be public and private costs associated with the deployment of advanced traveler information systems. The public sector has, almost exclusively, assumed responsibility for infrastructure surveillance costs in the past. In the cases of variable message signs and highway advisory radio, the public sector has also carried the costs of disseminating information to the traveler.

In many ATIS applications, however, the private sector will take the lead in disseminating the travel information. Their return on investment will be the price that users of the system are willing to pay for the information and the various products associated with it. In some cases, the private sector will also assume responsibility for the infrastructure costs. All private sector costs should not be factored out of the public sector economic analysis.

Costs are generally broken down in two categories: capital, and operating and maintenance (or, fixed and variable). For ATIS deployment, capital costs usually include system design, detector installation, the communications system, and construction and start-up of the operations control center. For the purpose of this

evaluation, these initial costs should be amortized over the life of the project to develop annualized capital costs.

Operating and maintenance (or variable) costs for ATIS may include maintenance of the detectors, maintenance and user fees associated with the communications system, and operation of the traffic control center. These costs should be estimated for each year over the life of the project.

5.2.3 Long-Term Planning Issues

There are a number of long-term planning implications associated with advanced traveler information systems that public sector officials should consider prior to committing to a technology. These issues vary depending on the technology and the level of private sector involvement and should be included in the comparative evaluation framework.

As seen by the case studies, approaches to ATIS have ranged from wholly public sector initiatives, such as INFORM, to wholly private sector efforts like Trafficmaster. The level of public infrastructure required for surveillance also varied significantly, from what one might call an infrastructure "intensive" project like INFORM, to an infrastructure "light" project such as SmarTraveler. These very important factors will affect the long-term role and responsibilities of the public sector in ATIS.

A comparison of the long-term public sector issues inherent in each of the various ATIS technologies and approaches is proposed in this thesis. This comparison would consider:

- Operation and maintenance plans
- Technical and educational requirements for public sector personnel
- Staff / resource commitments
- Institutional issues and arrangements
- Public/private partnerships

Chapter 6 summarizes the comparative framework and tests its applicability using the case studies presented in Chapter 4 of this thesis.

6 TESTING THE COMPARATIVE FRAMEWORK

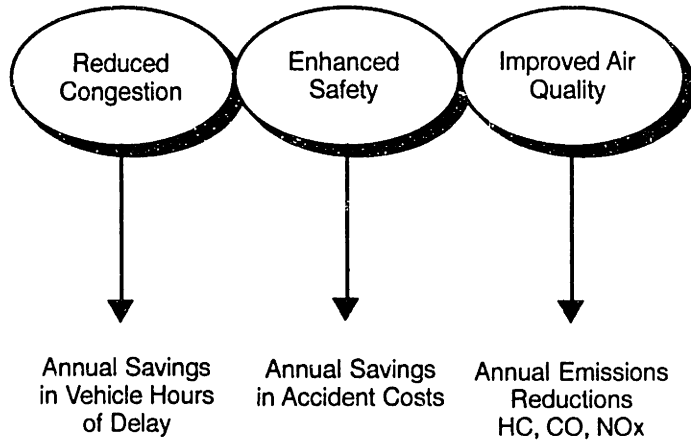
The previous chapter describe a simplified structure for a comparison of the public sector benefits, costs, and planning issues associated with ATIS technologies and system approaches. Applying this framework to the ATIS operational tests should demonstrate the cost effectiveness and inherent public sector responsibilities applicable to the various systems. Many industry experts believe that if the public sector benefits from ATIS are large, then the government should be a significant participant in the deployment of ATIS; however, if the benefits of ATIS are largely private benefits accrued by the individual users, then ATIS should be left primarily to the private sector [Whitworth, 1993].

The comparative cost-effectiveness evaluation framework is summarized in Figure 6-1. The cost effectiveness comparison focuses on only three measures of benefits: savings in vehicle hours of delay; savings in accident costs; and reductions in emissions. (While only 3 MOEs may appear to over-simplify the problem, the analyses required to reliably estimate these measures are the most difficult aspects of the evaluation process. And, indeed, other measures of effectiveness may be inherent in these analyses). These three measures capture the primary system benefits expected from ATIS deployment and represent the key issues of concern to the public sector transportation professional:

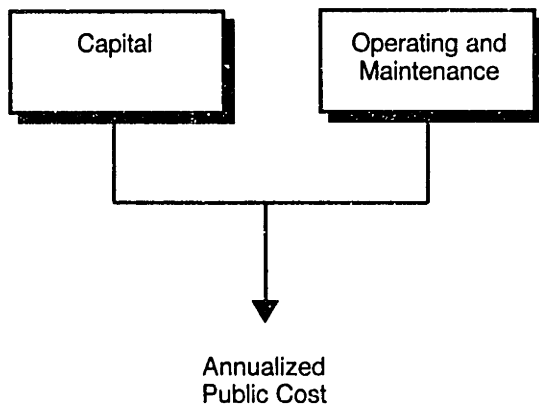
- How effective is ATIS in reducing transportation system delays?
- How effective is ATIS in lowering the costs of accidents?
- How effective is ATIS in reducing mobile source emissions?

Figure 6-1 Comparative Cost-Effectiveness Framework

Potential Benefits



Potential Costs



Testing the comparative cost effectiveness framework using the case studies examined in Chapter 4 will offer insight on how well the operational tests are answering these critical questions.

6.1 Cost Effectiveness

The evaluation plans completed were reviewed to determine if they adequately quantify these benefits. The evaluation plans in progress were also reviewed to determine whether or not they are leading toward results which will fit within this framework. To test the cost effectiveness evaluation framework, one would ideally like to set up a matrix with projects listed in the left-hand column and benefits, costs, and the benefit/cost ratio listed across the top. Then one could starkly compare the investment implications of all of the tested ATIS strategies. Unfortunately, due to the embryonic state of the evaluation results, this matrix is largely empty. The discussion that follows highlights the apparent holes in the cost effectiveness framework for each case study.

6.1.1 INFORM

The elements of the cost effectiveness matrix for the INFORM operational test can be summarized as follows:

Savings in vehicle hours of delay: Approximately 300,000 hours of delay savings annually attributed to the VMS system.

Savings in accident costs: Analysis inconclusive.

Reduction in emissions: Not included in the analysis.

Costs reported for the INFORM project included costs associated with the entire ATMS program: communications, VMSs, ramp meters, traffic signal controls, freeway detectors, operations control center, etc.. The costs for the ATIS subsystem were not specifically broken out. Total capital costs of the project were \$35 million. Annual operating and maintenance costs are approximately \$4.5 million.

As one can summarize from these data, there is inadequate information available from INFORM to make the kind of cost effectiveness evaluation that is proposed in this thesis. Interestingly, an a priori review of the goals and objectives of the INFORM system (Table 4-1, Goals 2, 5 and 6) suggests that each of these selected MOEs are logical output of the evaluation program. The fact that results were not quantified for these areas may be attributable to a lack of data, inappropriate models, problems with the methodologies, or an inadequate evaluation budget.

The evaluation plan did present a benefit cost analysis for the entire ATMS which showed a positive B/C ratio (greater than 1) for the project.

6.1.2 Pathfinder

The elements of the cost effectiveness matrix for the Pathfinder operational test are summarized below:

Savings in vehicle hours of delay: No significant travel time savings were reported.

Savings in accident costs: Not included in the analysis.

Reduction in emissions: Not included in the analysis.

The factors that were cited for the limited quantifiable benefits of Pathfinder were: short origin-destination pairs; limited alternate routes; the lack of "severe" incidents during the test program; and the quality of the traffic information.

The cost of the Pathfinder project was \$2.4 million. This excluded the cost of the highway infrastructure because the test utilized the infrastructure constructed as part of the \$48 million Santa Monica "Smart Corridor" project.

From a cost effectiveness standpoint, Pathfinder is certainly not an appropriate model. However, this case study did make significant contributions to the state-of-the-practice of ATIS in the areas of human factors, technology development, the value of good traffic information, and institutional issues. The TravTek operational test design, implementation, and evaluation benefited from all of the hard lessons learned in the Pathfinder experiment and should be an excellent gauge of the cost effectiveness of in-vehicle technology.

6.1.3 TravTek

It is too soon to fill out the cost effectiveness matrix for the TravTek experiment. The modelling efforts and safety studies which will report on the majority of system effects are the last pieces of the evaluation plan which is scheduled by June of 1994. The prospects are good, however, that all of the MOEs in the comparative cost effectiveness framework will be quantified once the evaluation is complete (assuming the results hold true to their objectives). Presumably more detail on system costs will be available at that time, as well.

The results of the TravTek test will be an important benchmark in the development of ATIS. If its benefits to the overall transportation system are weak, there is likely to be retrenchment of public sector support and a movement towards privatization of ATIS functions.

6.1.4 SmarTraveler

The SmarTraveler evaluation program is also not far enough along to understand its benefits and cost implications. Unlike TravTek, however, the SmarTraveler evaluation plan is not scoped to address the issues of network effects on safety or congestion, and it is unclear, at this time, whether any air quality analysis will be presented. Consequently, the comparative cost effectiveness framework does not hold good prospects for the SmarTraveler operational test.

With respect to costs, the SmarTraveler project has a sizable private sector component which reduces the public sector costs. Furthermore, a privatization study and plan is part of the evaluation program. This may offer some insight into the financial feasibility of the project, but will certainly not be in a format conducive to comparisons.

6.1.5 Trafficmaster

The elements of the cost effectiveness matrix for the Trafficmaster pilot test can be summarized as follows:

Savings in vehicle hours of delay: Broadly neutral.

Savings in accident costs: Broadly neutral.

Reduction in emissions: Not included in the analysis.

While the system benefits of the Trafficmaster pilot program are not impressive, it is important to remember that the public sector costs for the project were also negligible. The private sector, in the case of Trafficmaster, is responsible for installation, operation and maintenance of the surveillance infrastructure. The only public sector involvement in this area was to establish safety guidelines for the work within the public right-of-way.

Trafficmaster will be an important project for public sector officials to monitor as it is marketed nationwide in the United Kingdom. If the Trafficmaster program achieves some success, it may become one model for privatization of ATIS in the United States.

6.2 Long-Term Planning Issues

Setting the context for the public sector planning issues associated with IVHS in his paper entitled "IVHS: Opportunities and Challenges for the Transportation Professional at the Local Level", Rowe [1991] writes:

"In the decade of the 1990's, we will see the progressive implementation of the first elements of a national Intelligent Vehicle Highway System (IVHS). This will present both great opportunities and difficult challenges to the transportation professional at the local level.

The elements of IVHS which will impinge most directly on the local level are Advanced Transportation Management Systems (ATMS), Advanced Traveler Information Systems, and Advanced Public Transportation Systems (APTS). The transportation professional at the local level will play a key role in the design, implementation, operation, and maintenance of these systems"

To achieve long-term benefits from these systems, Rowe argues that the public sector must adopt a systems engineering approach and consider issues of funding, technical expertise, multi-jurisdictional coordination and political acceptance. Rowe emphasizes that if adequate resources are not committed to operation and maintenance, the effectiveness of the system will be severely compromised.

These public sector issues were given additional credence with a recent Federal Highway Administration review of 24 traffic signal and freeway management systems which found that only two of the systems were operating efficiently. [FHWA, 1990].

Put another way, Gifford et al [1992] discuss the typical process of technology diffusion:

"...a key concept in current technological theory is that during the implementation of technologies there is "mutual adaptation" between the technology and the context in which it is being implemented. That is, while a technology is being implemented, there is a reflexive process by which both the technology changes to adapt to local circumstances, and the local organizations change to adapt to the constraints of the technology. The capability for producing or creating this mutual change or 'reflexive adaptation' is critical to the successful adoption of the technology."

Indeed, the potential demands placed on the public sector to maintain a real-time information system for an ATIS application can be daunting. The ATIS strategies currently being tested must be reviewed and compared on the basis of what long-term demands they will place on local transportation officials. These issues could

be the most critical obstacles in the future development, deployment and success of the ATIS component of the IVHS program.

6.2.1 A Comparison of Planning Issues

A general summary of the long-term planning issues to consider in ATIS deployment are summarized in Figure 6-2. A matrix which rates the relative impact of each case study against the long-term planning issues facing the public sector is provided in Figure 6-3.

In-vehicle systems such as Pathfinder or TravTek, are the most difficult ATIS undertakings from a public sector perspective. On-going operation and maintenance of the surveillance, communications and computer systems, operating in a multi-jurisdictional setting, and tackling the requirements of well planned public/private partnership agreements necessitate committed resources and a steady multi-disciplinary public sector staff.

Public sector ATIS projects, such as INFORM, also require significant technical staff and resources, but are generally less complicated from the point of institutional issues and public/private arrangements.

Staffing and resource requirements are largely reduced under the more heavily privatized concepts of SmarTraveler and Trafficmaster. SmarTraveler, because of its multi-modal nature, requires a high degree of coordination among institutions. Deployment of ATIS strategies like Trafficmaster and SmarTraveler will require a well

Figure 6-2 ATIS Long Term Planning Issues

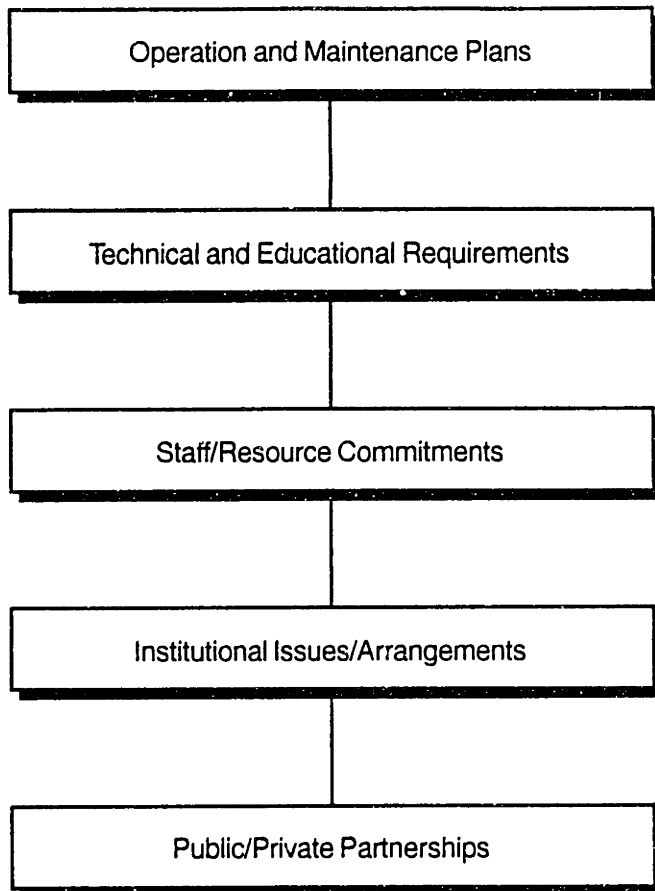


Figure 6-3
Level of Public Sector Involvement in
Key Planning Areas

	Operations and Maintenance Plans	Technical/Educational Requirements	Staff/Resource Commitment	Institutional Issues	Public/Private Agreements
INFORM	HIGH	HIGH	HIGH	MEDIUM	LOW
Pathfinder	HIGH	HIGH	HIGH	HIGH	HIGH
TravTek	HIGH	HIGH	HIGH	HIGH	HIGH
SmarTraveler	LOW	LOW	MEDIUM	HIGH	MEDIUM
Trafficmaster	N/A*	N/A	LOW	MEDIUM	MEDIUM

* N/A = Not applicable

defined policy on private participation in the provision of surface transportation services.

Public sector professionals must anticipate the level of commitment necessary to operate and maintain an ATIS. These needs are not unlike those necessary for a comprehensive incident management program, or an area traffic control or freeway management system. Planning for the future deployment of ATIS can benefit from past experiences in these areas.

7 CONCLUSIONS

This thesis examined highway-related Advanced Traveler Information System applications from a public-sector perspective, focusing on three key questions:

- Does government sponsorship of ATIS result in a better transportation system?
- Which concept among the emerging ATIS technologies has the best long-term potential?
- What long-term challenges and opportunities will ATIS technology place on state and local governments?

To gain insight on the first two questions, the research focused on case studies of current tests. The U.S. Department of Transportation (U.S.DOT) embarked on a formal program of operational tests in 1990 to evaluate the effectiveness of ATIS in "real" applications and to determine whether the benefits of these systems justify the expenditures and which systems offer the greatest returns for the least costs.

To address the second question, an analytical framework was developed and tested by which the costs and benefits of the various tests and their associated architecture can be compared.

The long-term challenges and opportunities facing the public sector as a result of the deployment of ATIS will, in large part, depend on the eventual role of government in ATIS and the technology(ies) that are pursued. Through the various public/private approaches to ATIS and the lessons learned in the case studies, some of the issues

associated with public-sector involvement in the planning, deployment and operation of advanced traveler information systems were examined.

7.1 ATIS Evaluation

The United States Department of Transportation is charged with implementation of ISTEA and, as such, leads the U.S. IVHS program. The overall goals for IVHS, as defined by the U.S. DOT's Strategic Plan [1992] are:

- Improved safety
- Reduced congestion
- Increased and higher quality mobility
- Reduced environmental impact
- Improved energy efficiency
- Improved economic productivity
- A viable U.S. IVHS industry

The U.S. DOT is responsible for the operational test program, including selection of each project, overseeing its design and testing, and evaluation of its performance.

The mandate for comprehensive evaluation of operational tests of IVHS is made clear in the ISTEA. The U.S. DOT, with the help of academia and the consulting community, has made significant progress in developing a consensus on the goals and objectives of ATIS operational tests, identifying candidate measures of effectiveness (MOEs) and discussing of appropriate methods to quantify these MOEs.

Bolczak [1992] authored guidelines for ATIS evaluations on behalf of the U.S. DOT which provide an overview of the evaluation process. The report identifies five phases of an evaluation effort:

- Operational test definition
- Evaluation definition
- Evaluation plan design
- Evaluation plan performance
- Reporting

Evaluating ATIS projects offers many challenges beyond those encountered in evaluating conventional transportation improvements. ATIS applications are intended to improve transportation system safety and efficiency by providing real-time information. Given the issues of market penetration, the various responses that the user might have to this information, and the availability of alternate routes or modes, the potential impacts of ATIS are complex. The effectiveness of any system actually depends on a wide range of factors, which may include:

- Market penetration
- Public acceptance
- Driver behavior/response
- Level of congestion
- Availability of alternatives
- Reliability of the technology
- Accuracy of the information

Bolczak simplifies these aspects into five more general evaluation goals: institutional issues; performance of the system and its impact on the transportation system; performance of the individual functional areas; costs; and user acceptance.

Although methodological gaps exist in IVHS evaluation (e.g., dynamic travel demand modelling), Underwood and Gehring write: "...that most of the evaluation questions can be addressed through the clever adaptation of the traditional methods and procedures found in areas such as human factors, social psychology, traffic engineering, transportation planning, marketing, environmental impact assessment, program evaluation, technology forecasting and assessment, and the like."¹⁴

A public sector official who is responsible for the design or review of an ATIS evaluation plan must have a clear understanding of the costs to implement and operate the system and must focus the evaluation plan on quantifying the public benefits of the ATIS to the transportation network. The three key issues of concern to the public sector transportation professional are:

- How effective is ATIS in reducing transportation system delays?
- How effective is ATIS in lowering the costs of accidents?
- How effective is ATIS in reducing mobile source emissions?

The eventual level of public sector involvement in advanced traveler information systems will be dictated by the demonstrated cost effectiveness of the early ATIS tests. If public benefits are large, the government should be expected to play a significant role in the deployment of ATIS technologies.

¹⁴ Will IVHS Transform Transportation System Effectiveness? - Draft - Benefits and Costs Committee Workshop-Proceedings. "Evaluating Intelligent Vehicle-Highway Systems: A Perspective on Methodological Development," December 1992. p B-11.

7.2 Early Results of Operational Tests

Five case studies were presented in this thesis: INFORM, Pathfinder, TravTek, SmarTraveler and Trafficmaster. The first four are U.S. operational tests, the last is from the United Kingdom. Each case study described the project, its public and private participants, the evaluation methodology used to assess its performance, the findings of the evaluation and lessons learned to date.

A range of technologies and approaches to ATIS were reviewed. Technologies included in-vehicle systems (Pathfinder, TravTek, and Trafficmaster), a variable message sign system (INFORM), and a telephone-based information system (SmarTraveler). The approaches ranged from wholly public sector ventures, like INFORM, to wholly private sector initiatives, such as Trafficmaster.

7.2.1 Test Results

The research set out to determine if government sponsorship of ATIS results in a better transportation system and which concept among the emerging ATIS technologies has the best long-term potential. The answers are still unclear.

Overall, the results of the operational tests are quite limited and somewhat disappointing. ATIS effects on the transportation system, in terms of congestion and safety benefits, have been small or insignificant, and its cost effectiveness has not been demonstrated. In most of the evaluations completed or underway, the right questions are being asked but they are not being adequately answered. Hence, no technology or system approach is emerging as the standard for ATIS.

These early findings suggest that a large public investment in ATIS, as an isolated program, would not be a cost effective transportation improvement at this point in time. However, implementing ATIS as a component of a more comprehensive advanced traffic management system, or incident management program might still be very worthwhile, depending on the project. These programs have demonstrated their value in improving transportation system operations in the past, reducing delays by as much as 35 percent [Lindley, 1989].

Furthermore, this thesis did not focus on the application of ATIS in the area of commercial vehicle operations, which is a market that is generally believed to hold much promise. The expression "time is money" is the bottom line for the trucking industry and it is expected that real time traffic information and routing advice will improve fleet efficiency, improve customer service, and enhance the working conditions for the driver [Batz, 1991]. Several operational tests are currently underway in this area.

Additional results and findings from the highway-related ATIS case studies are summarized in the following sections of this thesis.

General Lessons

In general, it was found that:

- Systems need to be flexible to adapt to new technologies and address problems in system operations and human interface as they arise.
- Ongoing traffic engineering and management commitment to the project is necessary for success.

- Maintaining communications, both technically from a hardware perspective and personally among people and agencies is crucial.
- Good quality traffic data is essential to ATIS success.
- Traffic surveillance and control on adjacent facilities is critical to the traffic management plan.
- Operations and maintenance issues should be incorporated into the design process.
- The direct benefits of ATIS programs are difficult to measure.

User Response

- Early results suggest that ATIS has the potential to redistribute travel demands across a network.
- In-vehicle systems are generally perceived as easy to use and helpful to drivers in finding their way, saving travel time, and concentrating more on their driving.
- Most drivers do not feel that these systems overly interfere with their driving tasks.
- In-vehicle systems can also save time in trip planning when compared with using a traditional paper map or telephone assistance.

System Effects

- Early results show the effect of ATIS on network congestion and safety as being slightly positive or neutral.
- As market penetration grows, system benefits are expected to increase; however, these effects are somewhat constrained by the lack of alternate routes and modes.
- Furthermore, market penetration and system traffic effects will be diluted as the ATIS market area grows geographically. As a result, the overall system effects could be broadly neutral for many years.
- Little emphasis in the operational tests have been given to pre-trip planning which could have the most positive effect on reducing system congestion.

Willingness to Pay

- The willingness of users to pay for the in-vehicle systems in the operational test studies (revealed through questionnaires and driver debriefings) ranged from "about the price of a radio" in Pathfinder to \$900 for the TravTek system. (Approximately \$400 for navigation and route guidance features, \$200 for services and attractions, and \$300 for real-time traffic information).

- In reality, motorists in the United Kingdom are paying approximately \$500 to purchase Trafficmaster, plus a mandatory \$35 per month for the information subscription.
- Perceived safety and driving benefits are important factors in predicting ATIS product acceptance/willingness to pay. Personal security may also become a factor in ATIS market development.

7.3 Comparative Evaluation Framework

As the operational test program is carried out and evaluation plans are designed and implemented, there will be increased opportunity to make comparison, or at least make judgment, on the relative merits of the various IVHS technologies. It is worthwhile at this early stage in the process to define an evaluation framework to provide some structure for the conduct of these comparisons.

The comparative evaluation framework proposed in this thesis focused on two areas: 1) cost effectiveness--what ATIS concept has the best long-term potential; and 2) what are the operational and maintenance implications for the public sector-- the long-term planning issues-- associated with the ATIS deployment.

The first component of this comparative evaluation framework concentrates on the key benefits and costs that are expected from implementation of the ATIS concept. The second piece of the framework sets forth the long-term planning implications of ATIS strategies that public sector officials should consider prior to committing to a technology.

These issues vary depending on the technology and the level of private sector involvement.

7.3.1 Cost Effectiveness

The cost effectiveness comparison focuses on three measures of benefits: savings in vehicle hours of delay; savings in accident costs; and reductions in emissions. These three measures capture the primary system benefits expected from ATIS deployment and represent the key issues of concern to the public sector transportation professional.

Applying this framework to the ATIS operational tests should demonstrate the cost effectiveness and inherent public sector responsibilities applicable to the various systems. To test the cost effectiveness evaluation framework, one would ideally like to set up a matrix with the case studies listed in the left-hand column and benefits, costs, and the benefit/cost ratio listed across the top. Then one could starkly compare the investment implications of all of the tested ATIS strategies. Unfortunately, due to the embryonic state of the evaluation results, this matrix is largely empty. Furthermore, the prospects are not good for filling in the missing pieces of data in this cost effectiveness framework any time in the near future.

Inadequate data are available from the completed evaluations of INFORM and Pathfinder to determine their cost effectiveness within the structure of the comparative framework proposed.

It is too soon to fill out the cost effectiveness matrix for the TravTek experiment; however, the prospects are good that all of the MOEs in the comparative cost effectiveness framework will be quantified once the evaluation is complete.

The SmarTraveler evaluation plan will likely not provide the information necessary to fill out the cost effectiveness matrix and, therefore, is not a good prospect for the comparative cost-effectiveness framework.

The Trafficmaster pilot program results fit fairly well into the comparative framework. However, the results are not that impressive since the system effects are largely neutral and the public sector costs for the project were also negligible.

In summary, it is unclear when definitive answers on the cost effectiveness of ATIS will be available from the operational test program.

7.3.2 Long-Term Planning Issues

As seen by the case studies, approaches to ATIS have ranged from wholly public sector initiatives, such as INFORM, to wholly private sector efforts like Trafficmaster. The level of public infrastructure required for surveillance also varied significantly, from what one might call an infrastructure "intensive" project like INFORM, to an infrastructure "light" project such as SmarTraveler. These very important factors will affect the long-term role and responsibilities of the public sector in ATIS.

The potential demands placed on the public sector to maintain a real-time information system for an ATIS application can be daunting. The ATIS strategies currently being tested were reviewed and compared on the basis of what long-term demands they will place on local transportation officials. These issues could be the most critical obstacles in the future development, deployment and success of the ATIS component of the IVHS program. Lessons can be learned from past efforts to plan,

deploy and operate incident management programs, or from the design, installation and maintenance of area traffic control systems.

In-vehicle systems such as Pathfinder or TravTek, are the most difficult ATIS undertakings from a public sector perspective. On-going operation and maintenance of the surveillance, communications and computer systems, operating in a multi-jurisdictional setting, and tackling the requirements of well planned public/private partnership agreements necessitate committed resources and a steady multi-disciplinary public sector staff.

Public sector ATIS projects, such as INFORM, also require significant technical staff and resources, but are generally less complicated from the point of institutional issues and public/private arrangements.

Staffing and resource requirements are largely reduced under the more heavily privatized concepts of SmarTraveler and Trafficmaster. SmarTraveler, because of its multi-modal nature, requires a high degree of coordination among institutions. Deployment of ATIS strategies like Trafficmaster and SmarTraveler will require a well defined policy on private participation in the provision of surface transportation services.

Public sector professionals must anticipate the level of commitment necessary to operate and maintain an ATIS. These needs are not unlike those necessary for a comprehensive incident management program, or an area traffic control or freeway management system. Planning for the future deployment of ATIS can benefit from past experiences in these areas. Again, public sector involvement in ATIS must be justified by demonstrated benefits to the overall transportation system, not just to the individual users of the technology.

7.4 Conclusions and Areas for Further Research

Quite obviously, continued work is needed in the area of quantifying the benefits and costs of ATIS operational tests. It is hoped that these future results will be the products of comprehensive evaluation programs that address the transportation system impacts from a public sector cost-effectiveness standpoint and not piecemeal evaluation exercises that are targeted solely at the specific goals of a particular operational test. This thesis identified three key areas of ATIS transportation system benefits that should be quantified in every evaluation program: reduced travel delays; savings in accident costs; and reduced emissions.

The early operational test findings suggest that a large public investment in ATIS, as an isolated program, would not be a cost effective transportation improvement at this point in time. However, implementing ATIS as a component of a more comprehensive advanced traffic management system, or incident management program might still be very worthwhile, depending on the project.

The results of the TravTek test will be an important benchmark in the development of ATIS. If its benefits to the overall transportation system are weak, there is likely to be retrenchment of public sector support and a movement towards privatization of ATIS functions.

Trafficmaster will also be an important project for public sector officials to monitor as it is marketed nationwide in the United Kingdom. If the Trafficmaster program

achieves some success, it may become a model for privatization of ATIS in the United States.

This thesis did not focus on the application of ATIS in the area of commercial vehicle operations, which is a market that is generally believed to hold much promise. Several important operational tests are currently underway in this area.

Further research is needed into the economic and technical capabilities of the public sector to carry out the vision of IVHS in the ATIS arena. The cost of a national urban network surveillance system has been estimated at \$25 billion to construct and \$1.3 billion annually to operate and maintain [Ferradyne Systems, Inc., 1992]. Can the public sector realistically assume this level of responsibility for IVHS? And, do the public benefits justify this expenditure? Alternatively, the case studies in this thesis identified several approaches to ATIS involving the private sector.

Finally, additional study is needed to determine the most cost effective means of traffic surveillance. Operational tests of ATIS, to date, have inadequately focused on this important issue.

APPENDIX A
ATIS EVALUATION OBJECTIVES

[Source: Bolczak, 1992]

APPENDIX A

SAMPLE EVALUATION OBJECTIVES

Evaluation Goal: Evaluate the effect of Institutional Issues on the operational test

Evaluation Objectives:

- Maintain a library of all contracts and agreements
- Maintain a library of all documents created for the project addressing the legal, societal, jurisdictional, and privatization opportunities
- Collect and maintain a library of quarterly progress reports from key participants describing the impact of institutional issues on project development
- Assess participants' attitudes toward appropriate applications of IVHS technologies (before, during, and after participating in the operational test)

Evaluation Goal: Evaluate the performance of the system and its potential impacts

Evaluation Objectives:

- Assess the change in queue times (measured and projected)
- Assess the change in travel time
- Assess the change in travel distance
- Assess the change in congestion level
- Assess the change in speed profiles
- Assess the change in average speed
- Assess the change in travel patterns
- Assess the change in vehicle miles traveled
- Assess the volume of traffic rerouted
- Assess the system reliability and availability
- Assess the environmental impact (modeling studies)
- Assess the safety impact of the operational test

Evaluation Goal: Evaluate the performance of the individual functional areas of the system

Evaluation Objectives:

- Assess the performance of the surveillance system
 - Assess the accuracy of reported vehicle location
 - Assess the accuracy of reported flow rates
 - Assess the accuracy of reported link travel times
 - Assess the accuracy of reported vehicle speeds

- Assess the accuracy of the reported queue lengths
- Assess the reliability of the surveillance system
- Assess the performance of the Data/Voice Communication system
 - Assess the area of coverage
 - Assess the message load supported
 - Assess the transmission delay
 - Assess the message delivery rate
 - Assess the number of vehicles supported
 - Assess the variation between design and operational performance
 - Assess the reliability of the Data/Voice Communication system
- Assess the performance of the Navigation/Guidance system
 - Assess the accuracy of the map database
 - Assess the accuracy of display of vehicle position
 - Assess the accuracy of guidance instruction
 - Assess the clarity of guidance instruction
 - Assess the reliability of the Navigation/Guidance system
- Assess the performance of the Database component
 - Document the size and structure of the database
 - Assess the response time of the database
 - Assess the performance of the database for storing and retrieving static data
 - Assess the performance of the database for storing and retrieving dynamic data
 - Assess the reliability of the Database Component
- Assess the performance of the Data Fusion component
 - Assess the relative value of the data sources
 - Assess the accuracy of predictions
 - Assess the timeliness of the predictions
 - Assess the accuracy, and reliability of the Data Fusion component
- Assess the performance of the Route Planning component
 - Assess the route quality (time, distance, qualitative measures) of the route planning component compared to user optimal routes
 - Assess the route quality (time, distance, qualitative measures) of the route planning component compared to unassisted drivers
 - Assess the accuracy of the route planning predictions

- Assess the impact of the use of real-time (dynamic) data in the route planning process
- Assess the reliability of the Route Planning component
- Assess the performance the Control Strategies component
 - Assess the change in number of vehicle stops
 - Assess the change in delay at intersections
 - Assess the change in vehicle travel time
 - Assess the reliability of the Control hardware and software
- Assess the performance of the Traffic Modeling Component
 - Assess the accuracy of the traffic volume predictions compared to field data
 - Assess the accuracy of the number of vehicle stop predictions compared to other models and test data
 - Assess the accuracy of the delay at intersection predictions compared to field data
 - Assess the accuracy in vehicle time travel predictions compared to other models and test data
 - Assess the reliability of the Traffic Modeling component
- Assess the performance of the Traffic Information Distribution component
 - Document the methods of traffic information distribution
 - Assess the accuracy and timeliness of the traffic information received by the traveler
 - Assess the completeness of the information, including alternate travel modes
 - Assess the reliability of the Traffic Information system
- Assess the performance of the Incident Detection Component
 - Assess the accuracy of the incident detection component in terms of error rate (incidents not detected) and false alarm rate
 - Assess the response time of the incident detection component
 - Assess the impact of the quality of data on the incident detection component
 - Assess the reliability of the Incident Detection component
- Assess the performance of the TIC or TMC
 - Document the design, development, and implementation (including physical layout, staffing, procedures, hardware and software, human interface issues addressed)

- Assess the effectiveness of the TIC or TMC interface with other systems (for example, radio advisories or incident response units)
- Assess the reliability of the TIC or TMC
- Assess the performance of the Human Interface
 - Assess the frequency of use
 - Assess driver preferences and impressions concerning message delivery format
 - Assess alternate route guidance delivery methods (voice, map, heads up, etc.)
 - Assess the changes in demand on driver attention

Evaluation Goal: Evaluate the costs relative to the benefits

Evaluation Objectives:

- For operational test (actual)
 - Vehicle Capital Costs (fixed/variable)
 - Vehicle Operating Costs (fixed/variable)
 - Communication System Capital Cost (fixed/variable)
 - Communication Operating Costs (fixed/variable)
 - TIC or TMC Capital Costs (fixed/variable)
 - TIC or TMC Operating Costs (fixed/variable)
 - Traffic control system Capital Costs (fixed/variable)
 - Traffic control system Operating Costs (fixed/variable)
- For deployment (projected)
 - Vehicle Capital Costs (fixed/variable)
 - Vehicle Operating Costs (fixed/variable)
 - Communication System Capital Cost (fixed/variable)
 - Communication Operating Costs (fixed/variable)
 - TIC or TMC Capital Costs (fixed/variable)
 - TIC or TMC Operating Costs (fixed/variable)
 - Traffic control system Capital Costs (fixed/variable)
 - Traffic control system Operating Costs (fixed/variable)

Evaluation Goal: Evaluate user acceptance as reflected in attitudes and frequency of use

Evaluation Objectives:

- Assess the user estimate of value
- Assess the user appraisal of worth
- Assess the user estimate of effectiveness

- **Assess the user estimate of preference**
 - **Functions**
 - **Design**
- **Assess the user willingness to purchase**

APPENDIX B

TRAVTEK MEASURES OF EFFECTIVENESS

[Source: Ferradyne Systems, Inc., 1991]

TRAVTEK OBJECTIVES, GOALS, SOURCES AND APPROACHES

TRAVTEK OBJECTIVE/EVALUATION GOAL: A. TRIP/NETWORK EFFICIENCY

A.1 CONGESTION AVOIDANCE		
HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCES OF DATA	APPROACHES
Speed variance (ride quality) deviations of one-minute speeds/trip	In-vehicle log	1,2,3,4,5
Number of stops or instances of 0-speed/trip	In-vehicle log	1,2,3,4,5
Speed (averaged over trip)	In-vehicle log TMC log (probe reports)	1,2,3,4,5,9
Number of miles/trip	In-vehicle log TMC log (?)	1,2,3,4,5,9
Number of new routes offered to drivers because of congestion/traffic incident information	In-vehicle log	1,2,3,4,5
Number of new routes accepted	same	same
Frequency of broadcast/reception of Dynamic Link Times	In-vehicle log TMC log	1,2,3,4,5,9
Incident types, start and end times, locations [see PERCEPTION OF TIME C.2]	TMC	9
A.2 TIME SAVINGS		
Trip Time (Origin/Destin.)	In-vehicle log TMC log	1,2,3,4,5,9
Total Travel Time (within a given time period)	In-vehicle log	1,2
Total Time at 0-speed [see PERCEPTION OF TIME C.2]	In-vehicle log	1,2
A.3 POLLUTION REDUCTION		
Noxious Emissions		
Derived from measures of amount of fuel consumed, miles traveled, number and time of 0-speed, etc.	Avis log (odometer, fueling) Driver Fueling logs In-vehicle log TMC log	1,2,8 9,8
A.4 REDUCED VEHICLE OPERATING COST		
Cost of Vehicle Maintenance (amount of parts and labor used)	Avis log Oldsmobile records	1,2,8
Cost of Fuel (amount of oil and gasoline used)	Avis log Driver Fueling log (?)	1,2,8

** Note the approach numbers correlate with the numbered bullets in the scope of work.

TRAVTEK OBJECTIVE/EVALUATION GOAL: B. BENEFITS TO NON-TRAVTEK USERS

HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCES OF DATA	APPROACHES
Decreased Network Congestion (traffic measures, collisions)	Traffic/police reports Control group in-vehicle logs	0,9 1,2,3,8,9
Decreased Network Travel Time	Gasoline trip time data Control group in-vehicle logs	0,9 1,2,3,4,8,9
Resulting Reductions in -Pollution -Fuel -Vehicle Operating Cost		0
Unmeasurable benefits, see LOCAL AREA IMPACT, J.5] (see SAFETY, D)		0,10

TRAVTEK OBJECTIVE/EVALUATION
 PERFORMANCE/BEHAVIOR/SATISFACTION

GOAL:

C. DRIVER

C.1 DRIVING/NAVIGATION BEHAVIOR		
HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCES OF DATA	APPROACHES
Effect on driving task performance [cross reference: SAFETY (D)] -Eyes on road vs eyes off road: -number of glances -amount of time/glance -timing of glances -speed of vehicle	Camera data In-vehicle log	5 5
-Number and type of vehicle loss of control maneuvers -steering reversals -brake applications, etc. -lane excursions, etc.	In-vehicle log Experimenter reports Lane tracker data Other camera data Special instrumentation	5
-Driver reactions to displayed messages (new route, etc.)	same	
-Stops to use 0-speed and park allowable functions	In-vehicle log Camera data Experimenter reports	1,2,4,5
Novice/Expert Shift -Improvement in performance over time (measures taken at different points in time, same driver with local use of vehicle between) [see LEARNABILITY (c.3)]	Same as above (driving task performance)	2,5
Improvement in navigation [cross reference: SAFETY (D)] -See TRIP EFFICIENCY (A.1,A.2) -See USABILITY/LEARNABILITY (C.2) -Amount of time driver spends lost -derived from driven route data -Amount of time driver spends looking for signs, distracted -Subjective measure of navigation ease/difficulty	In-vehicle log In-vehicle log Camera data Experimenter reports Debriefing/Questionnaire	1,2,3,4,5 2,3,4,5,8 1,2,3,4,5,6,7
Driver Compliance -Percentage of TravTek routes accepted/driven	In-vehicle log Debrief/Questionnaire	1,2 6,7
C.2 PERCEPTION OF CONGESTION, TIME, SAFETY		
Driver Perception of Time/Congestion	Experimental log Experimenter reports Debriefing/Questionnaire	3,4,5 1,2,3,4,5
Driver Perception of Safety	Experimenter reports Debriefing/Questionnaire	3,4,5,1,2,3,4,5

TravTek Evaluation Plan

C.3 USABILITY/LEARNABILITY		
The following are measures of Usability for Park and 0-speed functions (data entry, trip planning, initiating communications, reposition functions):		
Number and type of button presses -frequency in use of HELP key, GOBACK key, etc. -errors in performing task sequences -response time in performing task sequence	In-vehicle log Camera data Experimenter reports	1,2,3,4,5,8 5 5
In addition, the following are measures of Usability for Drive functions (navigating, receiving communications): -Also see DRIVING/NAVIGATION BEHAVIOR (C.1):		
Performance on specific route following, way finding, etc. tasks -number of errors -time to complete tasks	In-vehicle log Camera data Experimenter reports	1,2,3, 3,4,5 3,4,5
The following are measures of Usability for redrive and drive functions:		
Use of TravTek Helpline	In-vehicle log TISC log	1,2,3,4
Subjective driver measures of Usability	Questionnaire Debriefing	1,2,3,4,5 3,4,5
The following are measures of Learnability:		
Improvement in usability measures over time (learning curve) -Reduction in errors and time performing task sequences -Reduction in use of Help key, GOBACK -Reduction in use of TravTek Helpline	In-vehicle log Camera data Experimenter reports In-vehicle log TISC log	1,2,3,4,5,8 5 5 1,2,3,4
Subjective measure of Learnability Ease of Learning	Questionnaire Debriefing	1,2,3,4,5 3,4,5
Novice/Expert Shift in Driving/Navigation Behavior (See DRIVING/NAVIGATION BEHAVIOR (C.1))		
C.4 FEATURE USE		
Number of times a feature of interest is picked from menu	In-vehicle log Experimenter reports Camera data	1,2,3,4,5 5 5
C.5 USER FRIENDLINESS/DRIVER SATISFACTION		
Subjective measures of user friendliness/satisfaction General impressions of -Usefulness of information -Format of info. presentation -Timeliness info. presentation - Criticisms (e.g. confusing/intimidating)	Questionnaires Interviews/Debriefing	1,2,3,4,5,7 1,2,3,4,5
Subjective measures of user friendliness/satisfaction Specific impressions of -Features	Questionnaires Interviews/Debriefing	1,2,3,4,5,7 1,2,3,4,5
Subjective measures of user friendliness/satisfaction - Training & Orientation	Questionnaires Interviews/Debriefing	1,2,3,4,5,7 1,2,3,4,5
Subjective measures of IVHS concepts - (See Perception of Congestion, Time, Safety (C.2)) -Sense of travel security	Same as above In-vehicle log	1,2

TravTek Evaluation Plan

TRAVTEK OBJECTIVE/EVALUATION GOAL: D. SAFETY

HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCES OF DATA	APPROACHES
Effect on Driving Task Performance (cross reference: Driving/Navigation Behavior (C.1)) Improvement in Navigation Behavior (cross reference: Driving/Navigation Behavior (C.1)) Congestion Avoidance (cross reference: Trip/Network Efficiency (A.1))		
Collision Avoidance -Number and type of accidents: -reported to police, etc. -reported to, discovered by Avis	Police, etc logs Avis log	1,2,1a
-Number and type of near misses	Experimenter reports Questionnaires Debriefing, Interviews Experimental logs	3,4,5 1,1a,2,3,4,5, 1,1a,2,3,4,5 3,4,1a

TRAVTEK OBJECTIVE/EVALUATION GOAL: E. SYSTEM AND SUBSYSTEM PERFORMANCE

E.1 HARDWARE E.2 SOFTWARE E.3 DATA		
HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCES OF DATA	APPROACHES
E.1 Hardware Reliability (test and evaluation phases) -Types and frequencies of component failure -Diagnosed cause of failures Compatibility (test phase)	Vehicle maintenance log	1,2
E.2 Software Reliability (test phase) Compatibility (test phase)		
E.3 Data Accuracy (test and evaluation phases) -Map, local information databases -Real time traffic data	TISC log TMC log Police/traffic reports	1,2
Timeliness (test and evaluation phases)	In-vehicle log TMC log Questionnaires, Interview/Debriefs	1,2,4,6,7
E. 4 OPERATIONS/PROCEDURES		
a. Data collection (map, events, local information, traffic) b. Data input - TMC, TISC c. Driver recruitment, training, debriefing d. Helpline management e. Vehicle management f. Vehicle maintenance	TMC log Operator logs Operator reports Vehicle logs Interviews with operators and City staff	9

TRAVTEK OBJECTIVE/EVALUATION GOAL: F. IMAGE

HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCES OF DATA	APPROACHES
Changes in public perception of TravTek Partners, IVHS over time	Phone Interviews	6,7,10

TRAVTEK OBJECTIVE/EVALUATION GOAL: G. IMPACT FUTURE TRANSPORTATION/TRAVEL

G.1 GENERALIZABLE/TRANSPORTABLE G.2 TECHNOLOGY TRANSFER		
HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCES OF DATA	APPROACHES
G.1 Generalizable Map and Local Information Databases (in formats which can be used in other locations - geographically -physically	DOD, SAE, etc.	8,10
Transportable (portable product potential) (see Market Research Plan)	Questionnaire Interviews/Debriefs	1,2 1,2,4
G.2 Effective transfer of technology and knowledge -research reports -conference presentation -other presentations - TravTek experts work on future projects	DOT, SAE Standards Citations	10
Model Traffic Management Center	Questionnaire (traffic planners)	7,10

TRAVTEK OBJECTIVE/EVALUATION GOAL: H. FEATURE PREFERENCES

HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCES OF DATA	APPROACHES
[cross reference: DRIVER PERFORMANCE, FEATURE USE (C.4)] Frequency of use of each function and feature	In-vehicle log Camera data	1,2,5 5
Preference ratings	Questionnaires Interviews/Debrief	7, above 6, above

TRAVTEK OBJECTIVE/EVALUATION GOAL: I. PRICE/COST

HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCES OF DATA	APPROACHES
1. Willingness to buy in personal vehicle	Questionnaire Interview/Debrief	1,2,4,6,7
2. Willingness to buy in rental vehicle	same	same
3. Infrastructure (TMC, TISC)	Records of expenditures	8,10

TRAVTEK OBJECTIVE/EVALUATION GOAL: J. LOCAL AREA IMPACT

J.1 IMPROVEMENTS BEYOND TRAVTEK OPERATING PERIOD J.2 ROUTING THROUGH SENSITIVE AREAS J.3 LOCAL DRIVER USAGE J.4 LOCAL JURISDICTION, POLICY ISSUES J.5 MACROECONOMIC BENEFITS		
HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCES OF DATA	APPROACHES
J.1 Improvements Beyond Travtek Operating Period		
J.2 Routing Through Sensitive Areas Frequency and circumstances of occurrences	TMC log Police log (complaints)?	8,10
J.3 Local Driver Usage Same as tourist usage, but with local high frequency car use population, over longer period of use		1,2,3,9
(see Novica/expert shift, Driving/Navigation Behavior (c.2))		2
J.4 Local Jurisdiction, Policy Issues		10
J.5 Macroeconomic Benefits		8,10

BIBLIOGRAPHY

Batz, Thomas M. [1991]. The Utilization of Real-Time Traffic Information by the Trucking Industry. *Vehicular Technology*. Volume 40, Number 1. New York: IEEE Vehicular Technology Society.

Blumentritt, Charles W., Keith N. Balke, and Edward J. Seymour [1993]. TravTek System Architecture Evaluation: Preliminary Analysis of Selected Elements. *Proceedings of the Vehicle Navigation and Information Systems Conference*, Institute of Electrical Engineers, Ottawa, Canada, October 12-15.

Bolczak, Richard [1992]. *Guidelines for IVHS Operational Test Evaluation Plans: Advanced Traveler Information Systems and Advanced Traffic Management Systems*. Washington D.C: The MITRE Corporation

Boyce, David E., Allan M. Kirson, and Joseph L. Schofer [1992]. ADVANCE: The Illinois Dynamic Navigation and Route Guidance Demonstration Program. Forthcoming in *Advanced Technology in Transport: IVHS and ATT*. London, England.

Brand, Daniel [1993]. An IVHS Benefits Assessment Framework. Transportation Research Board, 72nd Annual Meeting, Washington, D.C., January 11-15.

Carlson, E. Dean [1993]. Federal Actions to Deliver the IVHS Program. *ITE Journal*. February. Washington D.C: Institute of Transportation Engineers.

Castle Rock Consultants [1992]. *The Minnesota Guidestar Program Final Report Volume II: Guidestar Strategic Plan*. Minnesota: Castle Rock Consultants.

Constantino, James [1993]. IVHS AMERICA Two Years Later. *ITE Journal*. February. Washington D.C: Institute of Transportation Engineers.

Federal Highway Administration [1992]. *Traffic Control Systems Operations and Maintenance--A Plan of Action*. Washington D.C: U.S. DOT.

Federal Highway Administration [1992]. *Traffic Control Systems Operations and Maintenance--Expert Panel Report*. Washington D.C: U.S. DOT.

Ferradyne Systems, Inc. and The Center for Applied Research [1991]. *TravTek Evaluation Plan -- Final*.

Ferradyne Systems, Inc. [1992]. *Economic Issues Associated with the Definition of Public/Private Roles in the Deployment of IVHS*. Rockville, MD: Ferradyne.

Fleischman, Rebecca N., Lisa A. Thelan, and Deborah Dennard [1993]. A Preliminary Account of TravTek Route Guidance Use by Rental and Local Drivers. *Proceedings of the Vehicle Navigation and Information Systems Conference*, Institute of Electrical Engineers, Ottawa, Canada, October 12-15.

Gifford, Jonathan L., Brien G. Benson, Kingsley E. Haynes and Roger R. Stough [1992]. Evaluating Institutional Effectiveness: Development of Concepts and Methods for Incorporation into Operational Field Tests (Draft). Institute of Public Policy, George Mason University.

Humphrey, Thomas F. [1992]. IVHS Operational Testing Programs: The Need for Evaluating Costs & Benefits in Order to Win Support for Development. *Will IVHS Transform Transportation System Effectiveness?*, IVHS AMERICA Benefits and Costs Committee Workshop, San Diego CA, December 1-3.

Inman, Vaughan W., Rebecca N. Fleischman, Thomas A. Dingus, and Chin H. Lee [1993]. Contribution of Controlled Field Experiments to the Evaluation of TravTek. *Proceedings of the 1993 Annual Meeting of IVHS AMERICA*, Washington D.C., April 14-17.

IVHS AMERICA [1992]. *Strategic Plan for Intelligent Vehicle - Highway Systems*. Washington D.C: IVHS AMERICA.

JHK & Associates [1993]. *Pathfinder Evaluation Report*. CA: Caltrans.

Juster, Richard [1993]. Telephone conversation. December 6, 1993.

Lindley, Jeffrey [1989]. Urban Freeway Congestion Problems and Solutions: An Update. *ITE Journal*. December. Washington D.C: Institute of Transportation Engineers.

Massachusetts Highway Department [1992]. Request For Proposals for Evaluation of the SmarTraveler Operational Test. Boston, MA: MHD.

Minnesota Department of Transportation [1993]. *Minnesota Guidestar Intelligent Vehicle Highway Systems Program*. St. Paul, MN: MN DOT.

Mobility 2000 Working Group [1990]. *Intelligent Vehicle Highway Systems- Operational Benefits*. Dallas, TX: Texas Transportation Institute.

Multisystems [1993]. *Evaluation of the Smart Traveler [sic] Advanced Traveler Information System Operational Test - A Proposal, Part II*. Cambridge, MA: Multisystems.

Perez, William A., Rebecca N. Fleischman, Gary Golembiewski, and Deborah Dennard [1993]. TravTek Field Study Results To Date. *Proceedings of the 1993 Annual Meeting of IVHS AMERICA*, Washington D.C., April 14-17.

Perez, William A., Gary Golembiewski, and Deborah Dennard [1993]. Professed Willingness to Pay for TravTek Features. *Proceedings of the Vehicle Navigation and Information Systems Conference*, Institute of Electrical Engineers, Ottawa, Canada, October 12-15.

Rillings, James H., and Mark K. Krage [1992]. *TravTek: An Operational Advanced Driver Information System*. Warren, Michigan: General Motors Research.

Royles, M.E. [1992]. *Assessment of the Trafficmaster Driver Information System: Questionnaires and Driver Logs*. Crowthorne, Berkshire: Transport and Transportation Research Laboratory.

Royles, M.E. and A. Stevens [1992]. *Assessment of the Trafficmaster Driver Information System: Network and Safety Impacts*. Crowthorne, Berkshire: Transport and Transportation Research Laboratory.

Rowe, S. Edwin [1991]. IVHS: Opportunities and Challenges for the Transportation Professional at the Local Level. *Proceedings of the Institute of Transportation Engineers Annual Meeting*, September 24.

SmartRoute Systems [1993]. *The SmarTraveler Operational Test--Early Findings October 30, 1992 to March 30, 1993*. Cambridge, MA: SmartRoute Systems.

SmarTraveler [1993]. Media Press Kit for the Launch of the SmarTraveler Project. Cambridge, MA: SmartRoute Systems.

Smith, S. [1992]. *INFORM Evaluation Volume I: Technical Report and Volume II: Executive Summary*. Washington D.C: U.S. DOT.

Stephens, Burton W. [1992]. An Overview of Evaluation Plans Intelligent Vehicle-Highway Systems Operational Tests. *Proceedings of the 1992 Annual Meeting of IVHS AMERICA*.

Stevens, A. [1992]. *Assessment of the Trafficmaster Driver Information System: Summary and Discussion of Traffic and Safety Implications*. Crowthorne, Berkshire: Transport and Transportation Research Laboratory.

Underwood, Steven E., and Frederick M. Streff [1992]. Avoiding Delay, Death and Dirty Air: Framework for Evaluation of Intelligent Vehicle-Highway Systems. *Proceedings of the 1992 Annual Meeting of IVHS AMERICA*.

Underwood, Steven E. and Stephen G. Gehring [1992]. Evaluating Intelligent Vehicle Highway Systems: A Perspective on Methodological Development. *Will IVHS Transform Transportation System Effectiveness?*, IVHS AMERICA Benefits and Costs Committee Workshop, San Diego CA, December 1-3.

United States Congress [1991]. Intermodal Surface Transportation Efficiency Act. *Congressional Record - House*. Washington, D.C., November 26.

United States Department of Transportation [1992]. *Strategic Plan for Intelligent Vehicle - Highway Systems*. Washington D.C: U.S. DOT.

Van Aerde, Michael and Mark Baker [1993]. Modelling 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.